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Information collection for smart transportation nudges

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Abstract

Global climate change is becoming of increasing concern. Transportation makes up a large part of carbon gasses, which affects climate change and air quality. As transportation is a big part of carbon emissions, everybody can contribute to reducing emissions through transportation. One way for people to contribute is to start choosing greener transportation.

Nuding is a tool that can be used to get people to choose greener transportation. It's function is to help guide people's behavior. For this project, the nudging goal is to nudge people towards healthier and greener transportation options than already in use. An example of a nudge is to provide reminders of bus departure times for a trip to an event. In order to nudge people gathering information relevant for traveling is necessary.

In this thesis, relevant information for green transportation nudges is researched. Other studies on green transportation nudges are applied to discover relevant information topics and sources. Microservices architecture is proposed as the architecture for designing nudges, where the system is divided into smaller interconnected services that work together. Demonstrators of information collection microservices are designed and implemented. The demonstrators handle data for different information topics relevant to green transportation nudges. There are demonstrators for collecting weather data, routing data, public transportation data, rental bikes and scooters data, calendar data, and location data. The thesis also discusses how the data collected can be used to form transportation nudges.

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1 Introduction

1.1 Background and motivation

Global climate change has become a significant concern. There are already clear signs of climate change, and the National Aeronautics and Space Administration (NASA) shows some statistics of how the earth has been affected by it [29]. NASA claims that the sea level increases by 3.3 millimeters per year. Global temperature is increasing, and since 1880 the global temperature has increased by around one degrees Celsius [29].

A contributing factor to climate change is the trapping of heat radiating from earth towards space, which is called the greenhouse effect [30]. Humans are changing the natural greenhouse through activities like deforestation and utilizing fossil fuel. Human activities contribute to rising levels of concentration in specific gases which increase the greenhouse effect. According to NASA, there is a 95 percent probability that human-produced greenhouse gasses have affected the increase of the earth's temperature [30].

One of the gasses that increases the greenhouse effect is carbon dioxide, which can be produced by driving fossil-fueled vehicles. United States Environmental Protection Agency (EPA) claims that an average car emits 4.6 metric tons of carbon dioxide per year [1]. In the United States (U.S.), the transportation sector is responsible for about a third of the countries emissions [5]. Globally, vehicles are also responsible for 15 percent of human-made carbon dioxide [5].

The pollution from vehicles affects air quality. In cities where there are many vehicles, the air quality is terrible. World Health Organisation (WHO) claims that 92 percent of the world's population lives in places where the level of air quality exceed "WHO's Ambient Air quality guidelines" [31]. Three million deaths occur annually due to air pollution [31].

In Paris, December 2015, 195 counties agreed on a climate deal to prevent a global increase of two degrees Celsius [7]. The countries that signed the deal submitted their plans for achieving the goal. According to an analysis from "Det Norske Veritas and Germanischer Lloyd" (DNV GL), humanity will not be able to reach this goal [15]. DNV GL points to a 2.4 degrees warming of the world by the end of the century, which is considered dangerous. To reach the Paris agreement, humans need to act faster. As transportation contributes a large part of emissions, everybody can choose transportation which lessens emissions.

A tool to influence people's choice of transportation can be nudging. Nudging is a term from economics and political theory for guiding people's behavior [25]. The definition of the term nudge is "*any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives [47].*" Richard H. Thaler and Cass R. Sunstein also state that: "*To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates [47].*" Banning cars in the city does not count as a nudge, but motivational messages to utilize other transportation methods count as a nudge.

Nudging in the context of green transportation is trying to make users choose greener transportation methods than they are currently using. By nudging people to choose greener transportation, this can affect the environment and society, as there would be less congestion and pollution.

People choose travel method based on different factors like time spent, convenience, economy and health [3]. Nudging people to choose greener transportation options requires information from many different sources. In a capstone project from 2019 I did research on which factors affected peoples travelling habits on a daily or weekly routine [23]. Seven different topics was discovered [23]: *weather*, *traffic*, *public transportation*, *carpooling*, *cycle rental*, *parking* and *route planning*.

The topic of the thesis is collecting information for green transportation nudges. Relevant information sources were discovered using relevant research as inspiration. There are demonstrators designed and implemented for collecting data from the different information sources. The thesis will discuss how to use the data collected to form smart nudges for green transportation.

1.2 The Purpose

This thesis is part of a larger project whose purpose is to influence people's behavior towards utilizing greener transportation options utilizing smart nudges. Smart nudges present guidance of the user's behavior through digital nudges tailored to fit the user's situation [25]. When forming smart nudges, there is a need for information from different sources, and the information needs to be combined and analyzed to fit the intended person.

1.3 Goal

This project focuses on how multiple information sources can be combined to provide users with nudges promoting greener transportation choices. This thesis use information from relevant research to locate sources of information. Demonstrators of information collection are designed and implemented for different relevant sources. There is a discussion on how the data from the different sources can be combined to create transportation nudges. The research questions of the thesis are:

- What data is relevant for green transportation nudges?
- How can multiple information sources be combined to provide users with nudges promoting greener transportation modes?

1.4 Challenges

The number of existing cars and drivers is increasing. According to "Statistisk Sentralbyrå" (SSB), Norwegian cars were driven 44.3 billion kilometers on Norwegian and international roads in 2015, which is an increase of 1.2 percent from 2014 [41]. The alternatives to driving need to be made more attractive in order to reduce emissions from vehicles. Alternatives to driving include walking, cycling, public transportation, or carpooling.

For greener transportation nudges, the goal is to make people choose more environmentally friendly transport choices [3]. For transportation nudges, relevant information and suggestions based on the user's current situation are crucial. There is, for example, no need to provide bus schedules to somebody that walks to work.

Humans are not only influenced by the options presented, but also how options are presented [40]. The choice environment is the environment in which a user makes choices, and users are affected by the design of the environment [40]. Digital nudging is about collecting and combining the right set of information to present the user with better and more relevant information about transportation choices.

1.5 Methodology / Methods

This project progressed as a type of prototyping and development procedure and is conducted as qualitative research. Qualitative research concerns understanding opinions and meanings to reach tentative hypothesis and theories, or to develop computer systems, artifacts, and inventions [16]. This project focuses on understanding opinions and meanings to develop demonstrators of information collection for green transportation nudges.

The work presented in this thesis is based on a study of information sources for smart transportation nudges [23]. In the study, there were conducted interviews to discover what affected people's traveling habits. From the study, there are indicators of information topics and sources to support green transportation nudges. These indicators are applied to this thesis to develop demonstrators of information collection for the different information topics. The study helps to understand what information topics are relevant for nudges and what data one can extract from the information sources to use for nudges.

The research has an abductive approach. An abductive approach starts with a set of data or observations and uses it to form a conclusion [16]. This thesis proceeds from the observations made in the capstone project to determine what data is relevant and how it can be combined to form nudges. The outcome of the thesis is possible ways to combine data to form nudges.

1.6 Delimitations

This thesis bases on the capstone project were seven different information topics for greener transportation were discovered [23]. This project will limit itself to weather, public transportation, route planning, and cycle rental as information topics. There are most likely other topics that are relevant for green transportation nudges than the ones discussed in this thesis.

The project will also limit itself to collect data from Norway exclusively.

1.7 Contribution

In this project, I identify information topics and sources that are relevant for forming green transportation nudges. A structured literature review (SLR) is conducted to discover relevant research for green transportation nudging. The relevant research is used to identify information topics and sources, and as inspiration for designing a nudging system. I propose a nudging system that collects data from relevant information sources and uses the information to form nudges. I have designed and implemented demonstrators of information collection for data from different relevant information sources. It is discussed how the data from the demonstrators can form nudges for greener transportation.

1.8 Benefits, Ethics and Sustainability

1.8.1 Benefits

The nudge project will benefit both the users and the environment. The nudge system users can possibly save money from choosing a greener transportation choice as some expenses are avoided by not using a car. There are, for example, no additional expenses when walking or cycling. Through bicycling or walking, the user will also get health benefits.

By choosing greener transportation, the number of vehicles driven will decrease, which will lead to less traffic. This will in turn decrease carbon dioxide emissions, which will increase air quality and reduce pollution.

1.8.2 Ethics

When designing nudge systems, there are ethical considerations one must adhere to. The first ethical challenge is extracting information from users, as the data extracted can be used to create real-time information about the users. Users have a right to privacy, which can be violated when extracting sensitive data [44]. Another issue with nudging is that it influences the behavior of users, which can be considered unethical. These problems will be elaborated on in section 2.10.

1.8.3 Sustainability

Studies in the context of energy and water conservation have demonstrated that the behavioral changes from norm-based messages have an effect even after the messages stop [13]. Nudging can, therefore, be a cost-efficient contribution to change the mindset of people's traveling habits and to help reduce the emissions from vehicles.

1.9 Outline

- Chapter 2 presents the theoretical background. Relevant information about research into nudges and relevant technology is presented.
- Chapter 3 presents related work and how this thesis differs from other research.
- Chapter 4 presents methodologies and methods and how the methods are used in this research.
- Chapter 5 presents information topics and sources relevant for nudging, and a general architecture for designing transportation nudges.
- Chapter 6 presents how demonstrators of information collection were implemented.
- Chapter 7 discusses how the data can be integrated to form nudges.
- Chapter 8 discusses the findings of the thesis.
- Chapter 9 presents the conclusion of the thesis.

2

Theoretic Background

Nudging is a term from economics and political theory for influencing people's behavior and decisions [25]. Thaler and Sunstein define the term nudge as:

> *... any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives [47].*

The choice architecture refers to the environment where individuals make choices and reflect that there are many ways to present information to the decision-maker [24]. How the choice architecture present information will influence the decision-maker, which can be influenced by, for example, the order of information presented, the order of attributes and their ease of use, and defaults [24]. There is no neutral way of presenting choices, so it is crucial to think about the design of the choice architecture, and how to present the information. Nudges try to influence people's behavior towards decisions that are beneficial for society, but also the individual [3]. When designing the nudges, it is essential to think about the choice architecture to affect the users in an intended way.

2.1 Digital Nudging

Digital nudging is a way to guide users' behavior in a digital environment without restricting the individual's freedom of choice [28]. The digital choice environment nudges people by the presentation of information or organization of workflows [40]. Understanding the digital nudge environment is critical because of digitization. People are making more and more choices in digital choice environments.

2.2 Smart Nudging

Smart nudging is digital nudging, where the nudges is tailored to be relevant to individual users based on their current situation [25]. The recommendation from smart nudges tries to guide the user's behavior in line with a nudging goal. The goal can be for users to make greener transportation choices. The smart nudges provide motivational messages and relevant information about the activity to make it easier to choose greener transportation [25].

Monitoring users is necessary to determine their normal behavior [25]. By monitoring, the system can detect the effect of the nudges and how the behavior changes over time. After nudging a user, it is crucial to evaluate if the nudge affected the user or not. If the user follows the nudge, it indicates that it is an acceptable nudge for the user. If it is a trend that the user accepts nudges for the same goal, the nudge goal could be adjusted to target greener options. If the user does not follow the nudge, it can indicate that the nudges should be adjusted. The nudges could target another activity, be designed differently, or be given at a different time [25].

2.3 Nudging for Green Transportation Choices

The goal of nudging for green transportation choices is to change people's behavior to choose transportation that is more environmentally friendly than [25]. Figure 2.1 displays the scale of the environmental friendliness of different transportation modes. It is not easy to estimate environmental friendliness because several factors can affect it. For driving cars, the number of people in the vehicle, and what engine type the car uses will affect the environmental friendliness. Vehicle transport is less environmentally friendly because the emissions from driving are contributing to the greenhouse effect.

Type	EF	Discouraging Factors	Encouraging Factors
Car		Economy (toll, parking, gas), traffic jam	Convenience
Carpool		Inconvenience, traffic jam	Economy, social
Bus		Schedule, traffic jam	Economy, priority in traffic
Bike		Time, effort, exposed to conditions	Economy, health, pleasure
Walk		Time, effort, exposed to conditions	Economy, health, pleasure

Figure 2.1: Environmentally friendliness (EF), and encouraging and discouraging factors with each transport. Larger EF means more environmentally friendliness. (From [25])

People decide how to travel based on different factors. Figure 2.1 displays encouraging and discouraging factors for different transportation modes. Traffic can discourage vehicle transportation, while beautiful weather can encourage non-vehicle transportation. Information about the encouraging and discouraging factors can be useful information for forming nudges.

2.4 Nudge composition

Personalizing nudges for a user in a given situation requires a specific design [9]. Sandor Dalecke talks about how to design personalized nudges in his master thesis [9]. A nudge consists of four to five nudge parts, and Dalecke defines five different categories of nudge parts in his thesis [9]:

- Goal: The intended behavior of the nudge. The goal is the most important part of the nudge. This classification includes nudging towards walking, cycling, other active transportation, using the bus, and using a car on a less congested route.

- Content: Providing customized information towards the user. This classification includes bus arrival times, travel routes, weather forecasts, information on road congestion, road conditions, scheduled travel plans, and time spent using a suggested mode of travel.

- Incentive: Using incentives helps to make the nudge more attractive for the user. This classification includes information on health benefits, environmental impact, monetary incentives, and places of interest.

- Effect: Can be used for specific contents or incentives. This classification includes psychological effects. Examples of psychological effects are:

  - Loss aversion assumes that the consumer values potential losses and disadvantages rather than gains and advantages [32].
  - Hyperbolic discounting assumes that the consumer values the present and near-present rather than the future [25].
  - Hedonistic framing assumes that the consumer values potential losses and disadvantages than gains and advantages[32].
- Presentation: The presentation is more of a general guideline than a classification. It includes the use of greetings, emotional messages, and stating that a process did work.

The classification is used later in the thesis for designing transportation nudges.

Dalecke also talks about how to design nudges in his thesis. Dalecke proposes seven rules on how the nudge parts have to be assembled [9]:

1. Keep the nudge short. A short nudge requires less mental energy.
2. A nudge is either generated with presentation guidelines or without it.
3. The goal is the most critical aspect for nudging towards a specific behavior. By stating the goal, it clearly states the intention and also makes the nudge transparent.
4. Only a limited number of content and incentives should be used to reduce a surplus of information.
5. A nudge cannot be generated with only one or two categories.
6. Nudges should only consist of several parts within a small margin to make the nudges more comparable. Dalecke proposes four to five parts.
7. The choice of content, incentive, and effect depends on the goal.

2.5 Internet of Things (IoT)

IoT sensors represent a wide range of data sources and can be used to provide information for smart nudges [3]. The sensors can transfer data over a network without requiring interactions from humans [35]. IoT is a sensor network of many smart devices that connect people, systems, and applications to collect and share data [35]. IoT can be used to track vehicles using location and proximity sensors, and this can provide data to update the expected arrival time of the bus [3].

2.6 Relevant information sources

In 2019, I did a capstone project that researched relevant information sources for green transportation nudges [23]. In the capstone project, five different people were interviewed about their traveling habits, their view on different transportation modes, and what could motivate them to choose greener transportation. The interviews helped to discover seven different information topics. An information source and relevant data were proposed for each of the information topics. Table 2.1 summarizes the findings from the capstone project.

Table 2.1: Information sources for green transportation nudges

Relevant information	Information source	Data to be collected
Carpool	CarpoolWorld	Nearby trips
Public transportation	Entur	Nearby stops. Planned travelling. Realtime route times
Route planning	Google cloud	Travel duration and routes for different methods of travel
Weather	Meteorologisk Institutt (MET)	Weather forecast for a location
Traffic detection	Twitter or Google cloud	Detecting congestion and closed roads
Cycle rental	Oslo bysykkel	Nearby possibility of bicycle stations
Parking	Spothero	Available parking spots

2.7 Ethics of nudging

There is an ethical problem with extracting information from users. The internet of things (IoT) devices is designed to harvest, store, and communicate a large amount of data [53]. This data can easily be used to provide real-time information about users and build user profiles. Everybody has the right to privacy, and by that has the right to keep certain things a secret [44]. The IoT devices make it difficult to use services secretly and remain unnoticed. Everybody also has the right to control the information others have on them, but this is difficult as communication between devices may trigger without the user being aware of it [44]. Other parties may want to use the collected data for totally different purposes. It is essential only to collect the data needed from the user to try to maintain their privacy.

Another ethical issue is the use of nudging as a tool. Some argue that it is unethical when policymakers use nudging to influence people's behavior [50], while others argue that nudges do not need to be unethical [39]. People argue that nudges are more inconspicuous and insidious than traditional interventions like taxes, as nudges are unsuitable to be controlled[39]. Nudges could also be argued to be manipulative, and pose a concern with individual autonomy [46].

Nudging and choice architecture is inevitable. As it is inevitable, it could be considered an ethical duty to nudge people towards positive behavior[9]. The problem with this view is that it misses an important distinction: there is a difference between intentionally shaped nudges and those that are not. Intentionally shaped nudges impose one agent's will on another and can be seen as a form of manipulation [39]. Manipulation often refers to the reduction of a person's autonomy(the right or condition of self-government), and a great way to preserve a person's autonomy is to design transparent nudges [9].

Sunstein holds that nudges should be transparent, that it should be disclosed what the intention and goal of the nudge are [39]. Some argue that nudges cannot be suitably transparent and that nudges work best in secrecy [9]. If the nudge is transparent, it could just stop working. Others argue that informing people about the use of nudges does not lower the effectiveness of the nudge [39]. Generally, nudges meet with higher acceptability than other interventionist methods [39]. A nudge system would have users acceptable to the nudges, as they could otherwise opt not to use it. While transparency could make nudging less effective, one can assume that it does not make it completely inefficient [39]. It would be better to make it transparent and accept the trade-offs.

2.8 Privacy

On the 25th of May, 2018, the general data protection regulation (GDPR) was put into effect [52]. People have the right to privacy, and GDPR is the strictest privacy and security law in the world. It imposes obligations onto organizations anywhere that target or collects data related to people in the European Union (EU). If organizations violate their privacy and security standards, the organizations will receive penalties in the form of expensive fines [52].

The GDPR have data protection principles, and if an organization process data of people in the EU, it has to be done according to seven protection and accountability principles [52]:

1. Lawfulness, fairness, and transparency: The processing of data must be lawful, fair, and transparent to the data subject.

2. Purpose limitation: Organizations must process data for the legitimate purposes specified explicitly to the data subject when collected.

3. Data minimum: Data should be collected and processed as much as it is necessary for the purpose specified.

4. Accuracy: Personal data must be kept accurate and up to date.

5. Storage limitation: Personally identifying data may only be stored for as long as necessary for the specified purpose.

6. Integrity and confidentiality: Processing must be done in a way that ensures appropriate security, integrity, and confidentiality.

7. Accountability: The data controller is responsible for demonstrating GDPR compliance with all of the principles above.

The organizations has to justify its processing of data. For a nudging system, it is important to get the user's unambiguous consent to process data. Therefore, it is essential to inform users about what personal data the system collects, why it is collected, and how the system uses the data. If a user wants to get the most out of a nudging system, they will give consent to get nudges based on their situation.

There are strict new rules for what is considered consent from users [52]:

1. The consent has to be freely given, specific, informed, and unambiguous.

2. The requests for consent must be distinguishable from other matters and presented in a clear and plain language.

3. Users can withdraw the consent whenever they want.

4. Children under 13 can only consent with permission from their parents.
5. The organization needs to keep documentary evidence of the consent.

The GDPR also gives individuals more privacy rights by giving the users more control over the data they loan to organizations [52]. It is important to understand these rights to ensure GDPR compliance. The data subjects privacy rights are [52]:

1. The right to be informed.
2. The right of access.
3. The right to rectification.
4. The right to erasure.
5. The right to restrict processing.
6. The right to data portability.
7. The right to object.
8. Rights concerning automated decision making and profiling.

When designing a system, it is crucial to have the GDPR in mind from the start. The organization must consider what data is essential, how to minimize the amount of data, and how to secure it. It is vital to secure the user's personal information, so security by design and by default is important. Encryption is one way to ensure the protection of users' data. It is also essential to have the individual's rights in mind when designing the system. It should be easy for users to retrieve, delete, or anonymize the data.

2.9 Microservice architecture

Microservice architecture describes a way of designing software applications. The idea behind microservice architecture is that the application consists of a set of smaller, interconnected services [34]. The different services typically implement a distinct feature or functionality of the system [34]. The services are running in separate processes and communicating with lightweight mechanisms, often a representational state transfer (REST) application programming interface (API) [14]. By splitting the application into several components, one gets isolation and resilience [17]. This type of architecture is also scalable, as the smaller components take up fewer resources, and the resources can be scaled to meet the demand of the individual component [17]. With a microservice architecture, one can divide the system into components that are independent of each other. When one component fails, it will not affect the entire system.

2.10 React

React is a JavaScript library created by Facebook for building user interfaces (UI) [19]. React makes it easy to create interactive interfaces and to create views for each state in the application. The components in react, which is small and isolated pieces of code, will efficiently render and update when the data changes. The components implement a "render()" method that takes input and returns Hypertext Markup Language (HTML) to be displayed. The components can also maintain internal state data. When state data changes, the component will re-render to update the state [19].

2.11 Expo

Expo is a framework and a platform for react applications [12]. It is used to develop IOS, Android, and web apps from the same javascript/typescript codebase [12]. There are two approaches to building applications with Expo, which is "managed" and "bare" workflows [12]. In the "managed" workflow, Expo tries to manage as much of the complexity of building apps, while in the "bare" workflow, the developer has control of every aspect of the native project [12].

2.12 Express.js

Express is a Node.js web application server framework that provides a set of features for web and mobile applications [45]. The core features of the express framework are [33]:

1. Express allows to set up middlewares to respond to HTTP requests.

2. Express defines a routing table that allows the program to perform different actions based on the request.

3. Express allows rendering HTML pages based on passing arguments to templates dynamically.

With a lot of HTTP utility methods and middleware at the disposal, express is well suited to create APIs.

3

Related Work

A large part of this project is to collect data from different sources relevant to transportation nudges. A structured literature review (SLR) is performed to find relevant work for green transportation nudging systems, which is useful for locating relevant sources. The SLR is described in this section, and the results from the SLR is presented. There is also relevant research from other people in the open distributed systems (ODS) group, and two of the theses are presented in this section.

3.1 Structured literature review

A structured literature review (SLR) is used to identify, study, and interpret the studies published in the literature [26]. It provides no way of finding all the relevant literature in a given area. However, it can help to map existing solutions, avoid bias in the research, and to identify gaps in knowledge [26].

The review is based on the research questions:

1. What data are relevant for green transportation nudges?

2. How can multiple information sources be combined to provide users with nudges promoting greener transportation?

A search strategy must be defined to identify relevant research. This strategy specifies which sources to search and how to search them [26]. In this structured literature review, SpringerLink and ACM Digital Library are used as the sources for literature. A search string is formed by grouping key terms based on the research questions. Each group contains terms that are either synonyms or terms that have similar or related semantic meaning [26]. The table shows the search terms.

Table 3.1: Search terms for structured literature review

	Group 1	Group 2	Group 3
Term 1	Digital nudge	Green transportation	Data source
Term 2	Persuasive system	Sustainable transportation	Information source

Implementing the search strategy can be achieved by applying "AND" between the groups, and "OR" between the terms [26]. The search string for the table above will be: ([G1, T1] OR [G1, T2]) AND ([G2, T1] OR [G2, T2]) AND ([G3, T1] OR [G3, T2]).

The search was conducted 20.04.2020 on both sources. The search on SpringerLink was refined to only include literature about computer science and excluded preview-only context. SpringerLink had 23 results for the given search string, while ACM Digital Library had two results. The results were examined through three stages to find the relevant articles. Firstly, the title and abstract were analyzed. If the article were potentially relevant to the research questions asked, it was included in the next step. Secondly, The introduction and conclusion were analyzed. If the text were relevant, it was included in the final step, which is to read the complete paper. By following these steps, two relevant articles remained.

3.1.1 GreenSense: Developing Persuasive Service Technology by Integrating Mobile Devices and Social Interaction for Sustainable and Healthy Behavior

This article proposes a mobile persuasive service [6]. The service reveals sustainable and health information to users to encourage users to utilize sustainable transportation. The service design has three elements [6]:

1. A mobile app for users to monitor their transportation behavior.

2. A visualization interface for users to see their sustainable behavioral state and performance.

3. A virtual "green credit" rewards concept to create social interactions and encourage behavioral change.

The GreenSense focuses on monitoring and recording transportation behavior, while in this thesis, the focus is on providing smart nudges to people before traveling. Context information like calendar data and position data is collected in this thesis to create nudges relevant to a user's context. In GreenSense, the users will have to monitor their behavior [6]. The GreenSens app can also be used to watch and compare the history of transportation distance, routes, calories burned, and "green credit" through the app. One can also use the GreenSense app to create a behavior strategy [6].

3.1.2 From mobility patterns to behavioral change: leveraging travel behavior and personality profiles to nudge for sustainable transportation

Anagnostopoulou presents in this paper an application that has the goal of influencing people's travel behavior through data-driven mobility and persuasive profiles [2]. The application aims to understand the traveler's behavior to generate recommendations and nudge the user towards greener transportation [2].

The nudges are embedded in a route planning application and rely on persuasive technology [2]. The application works similar to this thesis, as both provide a route with a message attached. In the application, users have to issue a request for a journey. While in this thesis, there is collected information about the user's context, like calendar and position, to create nudges relevant for the user's situation.

Anagnostopoulou system uses an external routing engine to generate routes [2]. Afterward, the persuasive intervention services process the routes. The service contains the route recommendation service and the persuasive message service. The route recommendation service filters and structures the available routes, and returns a list of recommended routes. The filtering is based on user profile information about the preferred mode and preferred travel distances for the different modes. The routes are then ranked, and the highest-ranked route is to be highlighted. The highlighted route is the targeted route for the nudge [2]. The application returns a list of recommended routes to the users. While in this thesis, the nudges contain a single suggested route.

The persuasive message service attaches a message to the highlighted route, which selects from a set of messages for three different persuasive strategies [2]:

1. Self-monitoring: Based on the user's past behavior.
2. Comparison: Based on the user's behavior compared to other users.
3. Suggestions: Based on environmental conditions and in this application, they use the weather's current status.

The messages are context-aware, so only messages that are valid for the specific trip are used. The selection of a persuasive message takes into account the user's susceptibility to different persuasive strategies, the current context, and the targeted mode of transportation [2].

Anagnostopoulou's application [2] and my master thesis have many similarities. Both have the goal of nudging people towards more environmentally friendly transportation modes than they are currently using. Anagnostopoulou's application and my thesis aim to provide information relevant to the current context of the users. Both collect information about routes, and environmental conditions to create nudges. The difference between this thesis and Anagnostopoulou's application is when to nudge. In Anagnostopoulou's application, users have to request a trip route, while in my thesis, the intention is to provide users with a nudge based on their situation.

3.2 ODS Lab

This thesis is a part of a bigger project from the Open Distributed Systems (ODS) group, where there have been several master theses written for the project. The ODS group works on a nudging project for both greener transportation and a healthier lifestyle. There is no complete nudge system implemented, but there has been work on different parts of the system. Some of the previous theses from the ODS group are: RoadAhead - Removing Uncertainty in travel, and Data Management for Nudged Green Transportation.

3.2.1 RoadAhead — Removing Uncertainty in Travel

Håkon Wallann presents a data warehouse approach to environmentally friendly transportation nudges in his thesis [48]. The goal of Wallann's thesis is to nudge people towards healthier and more environmentally friendly transportation. The system created by Wallann provides information relevant for in-city traveling. The system collects data from outside sources, from people, and self-hosted solutions, and analyzes the data. Wallann created a map to present how the temperature changes in the area. The data collected from people is additional information about what is happening close to the user's location [48].

3.2.2 Data Management for Nudged Green Transportation

Cosmin Radu Crăciun presents a nudge app, a prototype application for helping people choose greener transportation options [8]. The focus of Crăciun's thesis is the data management part of the application, mainly on storing and providing data from storage or other sources. The application helps people change transportation mode by offering better options in terms of lower environmental impact.

In the application, users get a nudge when they need to go somewhere or based on the weather. Crăciun's approach stores user and nudge information for each user in a relational database that supports approximate queries for faster access. For handling external data, information is filtered and converted into a more understandable form before it is presented. Some responses from external providers are stored in the memory for a short amount of time for handling faster response time. Sources of information used are user's location, map information, user's calendar events, national events calendar, forecast, current weather conditions, traffic data, travel route information, and bus schedules [8].

My thesis differs from both theses presented from the ODS lab by focusing on information collection, and how to combine data from multiple sources to form smart transportation nudges.

4

Methodologies and Methods

The research is designed as a case study. It is an empirical study that investigates a phenomenon in a real-life context where boundaries between phenomenon and context are not evident [16]. Through the interviews made in the earlier project, I got an estimate of what information is relevant for forming nudges for green transportation. What data to use and how to use it is not defined. This study will, therefore, focus on how to use the discovered relevant sources of information, and will look at how to extract data from these sources, what data is relevant for green transportation nudges, and how to integrate the data into transportation nudges.

Good planning is crucial for the success of case studies, and a case study plan should at least contain (Robson 2002) [36]:

1. Objective: What to achieve?
2. The case: What is studied?
3. Theory: frame of reference.
4. Research questions: What to know?

5. Methods: How to collect data?

6. Selection strategy: Where to seek data?

The objective of the study concerns what to achieve [36]. This research is exploratory and will explore different information sources and generate ideas and hypotheses about what data to use and how to integrate the data for green transportation nudges.

The case can be seen as the object of the study and contains one or more units of analysis [36]. In this thesis, the case is a nudging system. From the interviews made in the capstone project, there were discovered seven topics of information that are relevant for green transportation nudges [23]. These are *weather*, *traffic*, *public transportation*, *carpooling*, *cycle rental*, *parking* and *route planning*. These information topics are the units of analysis. These sources will be analyzed to discover what sources of information one could use and what relevant data to extract from the sources.

The frame of reference is existing research, where one of the existing research papers is the capstone project. The project builds on findings from different researches and uses the existing research as inspiration to locate relevant data for transportation nudges.

The research questions are about the information sources and their data. This project's research questions are:

1. What data are relevant for green transportation nudges?

2. How can multiple information sources be combined to provide users with nudges promoting greener transportation modes?

The results of the capstone project inspire the methods for collecting data. The capstone proposed information sources and APIs for the different topics discovered. In this thesis, demonstrators are created, and the demonstrators extract data from different relevant information sources. The thesis discusses what data to extract from the sources and how to integrate the data.

In a case study, one should select the cases and units of analysis intentionally [36]. The case selected is a software development project about nudging towards greener transportation. The case is critical for the environment because it can help humans choose greener transportation options, which will reduce pollution. The analysis units bases on the capstone project's findings, as the findings presented topics that affect people when traveling.

For a case study, it is important to consider validity from the beginning of the study [36]. There are four aspect's of validity to consider [36]:

1. Construct validity: Reflect on the extent to which the operational measures are correct for the concepts studied [36]. The concept studied is a nudging system for greener transportation and the operational measures bases on existing research findings like the capstone project. In the capstone project, interviews were conducted to discover what affected people when traveling [23]. The nudging system tries to nudge people towards greener transportation, so measures based on people's traveling habits are relevant for the concept.

2. Internal validity: Is of concern when examining casual relationships, so it is not relevant in this study.

3. External validity: This type is concerned with the extent to which it is possible to generalize the findings of the study and to what extent the findings are relevant for other people outside of the investigated case [36]. The findings from this research can be relevant for other people outside the investigated case, as people worldwide use transportation to get from one place to another. This study will focus on Norway and data relevant to Norway. However, these research findings can be relevant to other countries as people are affected by similar things when planning a travel. The discoveries from this research can also help other researchers studying nudging in other domains, or nudging in general.

4. Reliability: This aspect is concerned with the study being dependent on the specific researchers, and if it could be replicated by another researcher and get the same results [36]. The methods are well-documented in this research, so another researcher could do the same research and get the same results.

5

Information and Sources

In this chapter you are presented with information and sources that are relevant for green transportation nudges. The chapter is divided into general architecture and information collection. A general architecture for designing nudges is proposed and described. Then information topics and sources that are relevant for green transportation nudges are presented, and discussed what data is relevant to collect from the sources.

5.1 General Architecture

When creating a nudging system, there needs to be collected data from different information sources. For green transportation data, it is essential to collect environmental data, both current and historical, and transportation data. The system needs to personalize the nudges for the users, so data needs to be collected based on the user's context.

In this thesis, microservices architecture is proposed as the architecture to design nudges. A microservices architecture divides the application into smaller, interconnected services that work together. The services run as autonomous processes and communicate through APIs [42]. Because the services run as autonomous processes, problems with a microservice will not affect the entire system, and failures of an individual service can be compensated quickly. A benefit of microservices is that it is flexible and can be scaled horizontally and independently [51]. The architecture is presented in 5.1. The application is divided into nudge design, information collection, public transportation, user profile, routing, weather, context/situation, and rental.

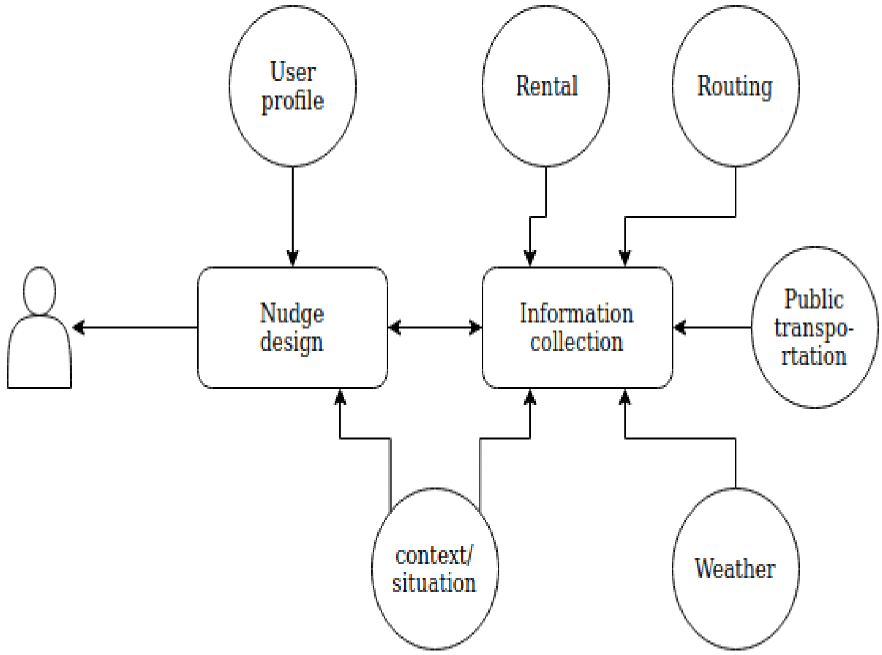

Figure 5.1: Nudge architecture

In the capstone project, I discovered seven different information topics [23]. The topics discovered were: *carpool, public transportation, route planning, weather, traffic detection, cycle rental, and parking*. This thesis will focus on public transportation, route planning, weather, and cycle rental as information topics. There are discovered sources that provide information about the topics, and demonstrators of information collection from the sources are designed and implemented.

The context/situation service is collecting data about the user's context/situation. The context/situation data is used in other services to collect information so that it is relevant for the user. The service collects data from user's devices about the location of the user and data from the calendar. The calendar provides data about the time and place for planned events.

The routing service, public transportation service, rental, and weather service collects and handles information from external providers. The routing service collects information about bicycle and pedestrian trips. The public transportation service collects information related to traveling with public transportation. The rental service collects information about available scooters for rent and bike rental stations. The weather service collects weather data, both current and historical. The different services collecting information in the nudging system use external APIs to collect data. The data received are of different formats, so the services convert into a JSON format. Then the data is stripped from unnecessary information.

The nudge design service creates personalized nudges that try to encourage users to select environmentally-friendly transportation choices. The service provides information that is useful for selecting the suggested activity with motivational messages. The nudge design service works by sending a request with a data template to the information collection service. The template is based on data in the user profile. The data returned from the information collection service is then analyzed to decide on a nudge goal, and a nudge is formed from the data returned. The result is a smart nudge.

The information collection service is the entry point into the information collection. The service gets a template with data to collect. First, the context/situation data is collected. The context/situation data is essential in the services collecting data, as it is needed to get data relevant to the user's situation. The information collection service then uses the template to collect information from the relevant services, combining the data, and processing it to produce the right set according to the template. Afterward, the set of information is passed forward to the nudge design service.

The user profile is where information about a user is stored. The user profile describes and represents the user, and it can contain information about:

- Preferred transportation mode.
- Available modes.
- Maximum time and distance for the different modes.
- Reaction to past nudges, so that the nudges can adapt to the user.
- Age.

The information from a user profile is used to personalize the nudge in the nudge design.

This thesis focuses on the information collection of a nudging system. A complete nudging system would be bigger and have more services than the architecture proposed. In the architecture proposed, the context/situation service is used to trigger nudges. In a complete architecture, it could be an own service for triggering nudges, that includes other data than calendar data and location data. In a complete nudging system, there would also be data storing and updating for specific services.

New services can be added to the system as there is information about other parts of traveling that are relevant to include in transportation nudges. The advantage of using a microservice architecture, unlike a monolithic architecture, is that it is easier to develop and deploy services independently. The services can be deployed by itself. The only problem is that dependent services also need to be updated. The architecture will further be discussed in the discussion chapter and compared with other architectural solutions.

5.2 Information Collection

The information sources discovered are inspired by the findings from the capstone project and other relevant research on green transportation nudges. The capstone discovered seven different topics that people found relevant for planning travels, and that could help motivate more environmentally friendly traveling. The information topics discovered in the capstone project was *carpooling, weather, public transportation, route planning, cycle rental, traffic, and parking*. Green transportation nudges need to collect information about transportation, the environment, and the user.

It is essential to collect information about transportation as it is a significant part of green transportation nudge. The goal of the nudges is to motivate people to use greener transportation options than they are currently using. Therefore, it is essential to collect information about different transportation modes. From the information topics discovered in the capstone carpooling, public transportation, route planning, cycle rental, and parking provides information about different transportation modes and how to get from one location to another. Carpooling, public transportation, walking, and cycling are all greener options than driving a car, as one either shares a vehicle with others or does not use vehicular transportation. One reduces the amount of emission per traveler by sharing a vehicle, and there is no emission of traveling by non-vehicular transportation.

Environmental information provides information about the conditions for traveling. This information can be both a barrier and a motivational factor. From the seven topics discovered in the capstone, traffic and weather provide information about the environment. By providing information about the traffic and weather, it can motivate the use of greener transportation. People are more willing to opt for active traveling in beautiful weather, or when it can save time and money. Traffic can lead to an increase in travel time and can be used as motivation for the use of active traveling.

Information about the user and the user's situation is vital for planning travels. For transportation nudges, there is a need for information about the user's location, and a user's plan for traveling. This information is essential for collecting information about the different topics to get relevant information for the user's context. Information about the user's location and the user's planned events can be collected from their smartphones.

Information about the different topics is collected through external APIs. A demonstrator for collecting calendar data and a demonstrator that collects location data is implemented. Demonstrators are designed and implemented for the weather service, public transportation service, rental service, and routing service. These topics were chosen as they are most relevant for the beginning of a nudging system. There is information about active transportation, vehicular transportation, and weather. The weather data can be used to motivate users and detect road conditions. The demonstrators of the information collection services use context/situation data with external APIs to collect information relevant to the user. The output of the services is a JSON object.

5.2.1 Weather

Weather is an important factor for green transportation nudges as most people use the weather for planning trips. The weather can be both a barrier and a motivational factor. Adverse weather makes people want to use vehicular transportation as there is less exposure to weather conditions. Pleasant weather can motivate people to use active transportation. The weather from yesterday, today, and the rest of the day are affecting the travel, and it is, therefore, essential to collect data about the weather.

Meteorologisk Institutt (MET) is used by the weather service to collect weather data. MET provides many different APIs with various data about the weather in Norway [22]. The architecture of the weather service is presented in figure 5.2. Met is used to collect both historical data (Frost API) and current data ("locationforecast" API).

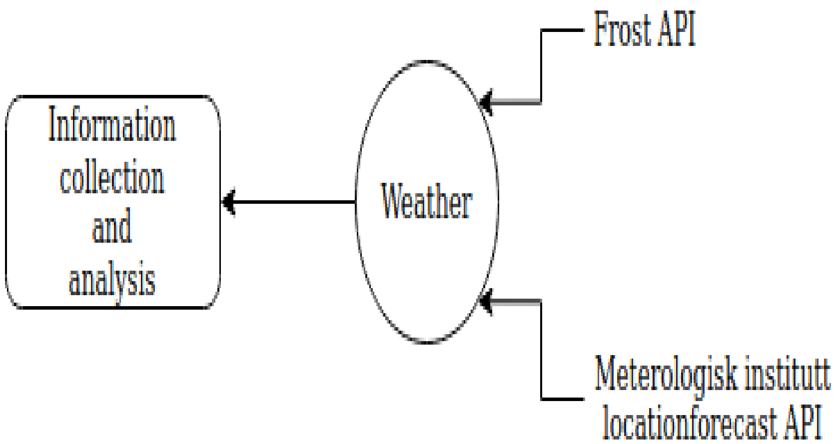

Figure 5.2: Weather service

One of MET's APIs is their "locationforcast", which provides weather information about a specific location for nine days [22]. The weather service uses "locationforecast" to get the weather at a specific time for a specific location. The "locationforecast" provides much information, but the most useful information is temperature, wind speed, downpour, and cloudiness. When there is a lot of wind, downpour, clouds, or low temperature, it could be a barrier to outside travel. People could then be motivated to use public transportation, as there is less exposure to the weather. People could be motivated for outside traveling when there is pleasant weather conditions.

The other API from MET that the weather service uses is MET's Frost API. This API provides historical weather data from MET Norway's archive of historical data [21]. Frost API allows users to locate stations nearby to extract data from [21]. The stations provide historical data about their location. The weather service collects historical data about precipitation and temperature. This data can be used to detect road conditions that would affect peoples choices in transportation. Warnings about the road conditions could help people prepare for their travel, and help them reach their destination on time.

5.2.2 Public transportation

Information about public transportation is essential as it is a greener option for vehicular transportation. Entur operates the national registry for all public transportation in Norway [11]. The public transportation service uses their APIs and software development kit (SDK) to plan a trip with public transportation. The SDK simplifies the use of their APIs. There is collected information about the departure location, the arrival location, the time of departure, arrival time, the duration of the trip, any connections on the trip, and the estimated start time of the travel. This information can help make it easier to travel using public transportation.

5.2.3 Routing

Walking and cycling are active transportation methods that are both healthy and environmentally friendly. If the circumstances are right with pleasant weather and the destination is not too far away, people can be willing to opt for walking or cycling. The routing service uses "here.com" [1] to calculate routes for walking and cycling. HERE provide precise instructions to a destination for various transportation modes through their routing API [18]. The routing API is used to create routes and to provide an approximate of the travel time and distance. Information about time and distance can motivate people to use active transportation. The "here.com" routing API allows specifying if one wants the shortest route, fastest route, or a mix between the two in the request. The routing service uses a balance between the two.

5.2.4 Rental

The rental service collects information about bicycle stations and scooters. This information is relevant for green transportation nudges as it can be combined with routing for a more efficient route than walking. Entur has APIs that provides data about bicycle rental station and scooters [10]. Entur's bicycle rental API collects information about where to find bicycle rental stations and if there are any available bicycles at the stations. The API for scooters provides information about where to find available scooters, what operator it is, and how much battery the scooter has.

1. https://developer.here.com/documentation/routing/dev_guide/topics/request-a-simple-route.html

5.2.5 Context/situation

Location

Users can provide relevant data about them selves. Information about their calendar events and their location can help form nudges. Accessing the calendar and the location is done in the front-end with the expo framework. Expo allows access to the device's capabilities, and through the framework, one gets access to the location of the device [12]. The location can help in the other services as one can use the coordinates when accessing the different APIs to get data relevant to the user's situation.

Calendar

The expo framework also provides access to the calendar events stored on the device. The calendar holds information about the time and place of the event. This information is useful for the public transportation service and the routing service, as they both need a time of arrival and travel destination. The calendar and location information can help plan a return trip, as the calendar contains information about the end of the event, and the location before traveling can be seen as the return address.

5.3 Integration of new topics

A complete nudging system would include other topics in addition to the topics discussed in this thesis. New templates could be created to include data about the new topics. The information collection service would need an update to know what to request from where, and the nudge design would need an update to be able to use data from the new topic when forming a nudge. The new service must output a JSON object to make it easy to combine the data in the information collection service.

6

Implementation

In this chapter, the data collection methods and design choices will be described in more detail. There are implemented demonstrators of the weather service, routing service, public transportation service, and rental service. Demonstrators that show location data and calendar data are also implemented. These demonstrators are presented and explained. The information collection service, nudge design service, and user profile are not implemented.

The weather service, route planning service, public transportation service, and rental service are built using Node.js. The services use the Express web framework for its myriad of HTTP utility methods and middleware at disposal. The location demonstrator and calendar demonstrator uses expo to collect information from the smartphones about the user's position and calendar events. Expo is a framework and platform for react applications [12]. Most of the programming was done in JavaScript programming language.

6.1 Weather

For transportation nudges, it is essential to collect data that are relevant for outdoor traveling, and weather data will affect people's willingness for outdoor travel. The weather will most likely affect their choice of travel mode. Therefore, the weather data collected is concentrated around the time of departure and the previous 12 hours.

The weather service uses express, which is a web framework for node.js [45]. Express makes it easy to create APIs, as it has a myriad of HTTP utility methods and middleware at disposal [45]. The weather service collects information from Meteorologisk Institutt (MET). Depending on what data the information collection service requests, the weather service either collects historical data from Frost or forecast data from the "locationforecast".

The weather service collects data from the last twelve hours through Frost API from MET. Frost provides access to MET's archive of historical weather and climate data [21]. The weather service firstly has to locate nearby sources where one can extract data. The nearby sources are located using the Frost sources API. The available source, a reference time, and what elements to retrieve is then specified in a request to Frost observations API [21]. The weather service collects data about precipitation and temperature. The object returned from Frost is then filtered to remove unwanted data before returning it to the information collection service. The object returned is previewed below.

```
{
    {
        "timestamp": "",
        "data": {
            "air_temperature": {
                "unit": "",
                "value": null
            }
        }
    },
    {
        "timestamp": "",
        "data": {
            "air_temperature": {
                "unit": "",
                "value": null
            },
            "sum(precipitation_amount P1D)": {
                "unit": "",
                "value": null
            }
        }
    },
...
}
```

The weather service returns an object containing observations from the last

12 hours, with temperatures for each of the last 12 hours. The precipitation previews the amount of precipitation from the last day from 06.00 UTC to 06.00 UTC. This data is collected as it can provide information about road conditions. The change in temperature and precipitation can be analyzed to detect different road conditions. Information about road conditions can help people plan their travels, and choose different modes or routes to avoid problems.

For traveling, there is a need for information about the current weather. MET has a "locationforecast" API that is used to collect forecast weather for a specific location, and it provides data for nine days [22]. The "locationforecast" returns an XML object. This object is converted into a JSON object. The object is then filtered to remove unnecessary information. The JSON object returned to the information collection is previewed below.


```
{
    "temperature": {
        "_attributes": {
            "id": "",
            "unit": "",
            "value": ""
        }
    },
    "windSpeed": {
        "_attributes": {
            "id": "",
            "mps": "",
            "beaufort": "",
            "name": ""
        }
    },
    "precipitation": {
        "_attributes": {
            "unit": "",
            "value": "",
            "minvalue": "",
            "maxvalue": ""
        }
    },
    "symbol": {
        "_attributes": {
            "id": "",
            "number": ""
        }
```

```
    },
    "minTemperature": {
        "_attributes": {
            "id": "",
            "unit": "",
            "value": ""
        }
    },
    "maxTemperature": {
        "_attributes": {
            "id": "",
            "unit": "",
            "value": ""
        }
    },
    "cloudiness": {
        "_attributes": {
            "id": "",
            "percent": ""
        }
    }
}
```


The object returned from the weather service contains temperature, wind speed, precipitation, cloudiness, min and max temperature, and a symbol with a short message about the weather. This information is highly useful when traveling. If there is much wind, precipitation, or cold outside, it is more comfortable to use vehicular transportation as one is less exposed to the weather conditions. People could, on the other side, be motivated to travel outside when there is reasonable weather conditions.

6.2 Public transportation

The public transportation service is implemented using the express framework for Node.js. This service offers an API, where one requests a route, and then the public transportation service will use Entur's APIs and software development kit (SDK) to find a route. Entur operates the national registry for public transportation in Norway and provides access to the registry [11].

It is essential to find the nearest bus stop for the start and endpoint when planning a journey. Entur provides an API for reverse geocoding that takes the coordinates as input and returns the street name. The reverse geocoding is used to find the street name for both the start coordinates and the end coordinates. Entur also provides a software development kit (SDK) where one of the functions is used to find traveling patterns. The coordinates and street names for the start and endpoint is used to find a journey at a specified time. The information returned from Entur contains essential information about the travel. The retrieved JSON object from Entur is filtered in the service, as not all the information is relevant for nudges. The JSON object returned to the information collection service contains information about the proposed journey and the different modes used in the journey. The below object is returned to the information collection service.


```
{
    "startTime": "",
    "endTime": "",
    "duration": null,
    "legs": [
        {
            "mode": "foot",
            "expectedStartTime": "",
            "expectedEndTime": "",
            "distance": null,
            "duration": null,
            "fromPlace": {
                "name": "",
                "latitude": null,
                "longitude": null
            },
            "toPlace": {
                "name": "",
                "latitude": null,
                "longitude": null
            }
        },
        {
            "mode": "bus",
            "expectedStartTime": "",
            "expectedEndTime": "",
            "distance": null,
            "duration": null,
            "fromPlace": {
                "name": "",
                "latitude": null,
                "longitude": null
```

```
            },
            "toPlace": {
                "name": "",
                "latitude": null,
                "longitude": null
            },
            "line": {
                "publicCode": "",
                "name": "",
                "transportMode": ""
            },
            "stop": {
                "stopPlace": "",
                "aimedArrivalTime": ""
            }
        }
    ]
}
```

The object contains information about factors like duration, start time, end time, and information about the modes. The start time and end time are crucial for planning the travel. It is also crucial to provide information about the different modes so that one uses the right modes to reach the destination on time. There is different information for different modes. As displayed above, traveling by foot and by public transportation requires different information. Both have information about start time, end time, start location, and end location. Additional information about the modes are the number on the mode, name on the mode, type of mode, and stop name. This information makes it more convenient to use public transportation.

6.3 Route planning

The route planning service uses express to create an API that the service offers. The routing service uses the routing API from "here.com" [1]. This routing API calculates routes between locations for different transportation modes [18]. It is, therefore, used by the routing service to collect information about both bicycle trips and pedestrian trips. The service filters the response from the routing API from "here.com." The information that is returned to the information collection service is displayed below.

1. https://developer.here.com/documentation/routing/dev_guide/topics/request-a-simple-route.html

```
{
    "summary": "",
    "info": [
        {
            "startAddress": "",
            "startCoordinates": {
                "latitude": null,
                "longitude": null
            },
            "stopAddress": "",
            "stopCoordinates": {
                "latitude": null,
                "longitude": null
            },
            "length": null,
            "travelTime": null
        }
    ]
}
```


The object returned contains information about the departure location, destination, length of the travel, the duration, and a summary of the trip. The length and duration of travel can motivate users to use active traveling. Users can be provided with nudges to walk or cycle when the destination does not exceed user selected distances.

6.4 Rental

The rental service collects information about bike rental stations and scooters near a user's location though Entur. This information is valuable when combining with route planning information. The service works similarly for collecting data about bike rental stations and scooters. The Entur SDK is used to collect information about bike stations, and one of the Entur APIs is used to collect information about scooters. The information collection service requests either nearby scooters or bike rental availability, and information about the five closest results is returned. The object returned is displayed below.


```
{
    "bikeStations": [
        {
            "id": "",
            "name": "",
```

```
            "bikesAvailable": null,
            "spacesAvailable": null,
            "longitude": null,
            "latitude": null
        },
        ...
    ]
}
```


The object returned with information about bicycle rental stations contain information about bikes available, spaces available, name of the place, and coordinates. This information helps to find nearby stations and to see if there are anything available. Information about bicycle rental stations can be combined with routing information as it is a faster way of traveling compared to walking.

The rental service also collects information about nearby scooters from Entur through one of their APIs. The API returns information about the location, operator, code, and battery percentage. This transportation mode is a faster way of traveling than walking, and it requires less effort than cycling. It can be combined with routing information to find a more efficient way of traveling.

6.5 Position

The position of a user is accessed with the use of Expo framework. Expo gives access to the user's device capabilities. The location of a user is collected by accessing the user's geolocation on the smart-phone. The demonstrator displays the location data as viewed in 6.1. The position data is crucial as it is needed by other services to collect relevant information for the user's situation.

Figure 6.1: Location data

6.6 Calendar

The demonstrator that collects calendar information uses Expo to access calendar information from the user's smart-phone. The demonstrator displays the information from the calendar as viewed in 6.2. The demonstrator collects information about the start time, end time, title, and location of the first event from the calendar. This information is useful for planning when to nudge people, but it is also crucial for information collection in other services. The start time of an event is useful for planning so that the users arrive on time.

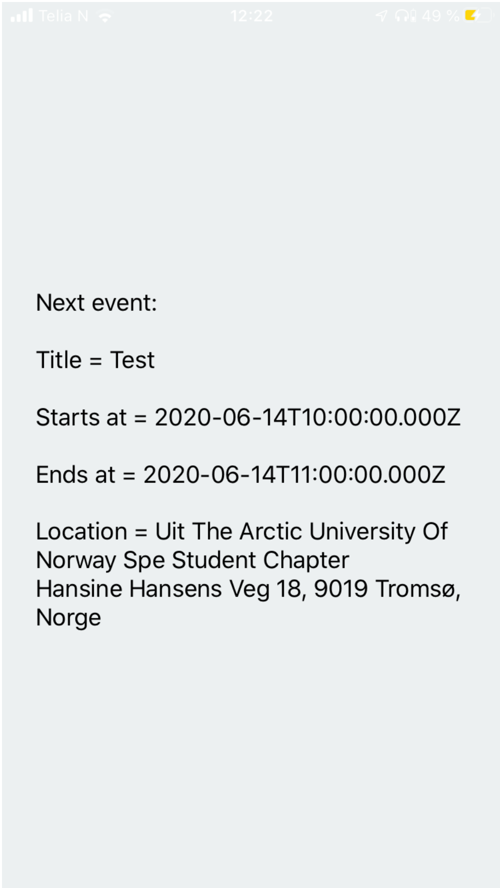

Figure 6.2: Calendar data

7 Nudge design

The last chapter described the demonstrators implemented. This section includes a discussion on how the data from the demonstrators can be used to form nudges for greener transportation. The data collected using the demonstrators include weather, public transportation, routing, rental, calendar, and location data.

7.1 Combination of data

The classifications defined in Dalecke's thesis is used for designing nudges [9]. Section 2.5 presents the classifications defined by Dalecke. There are five different classifications: goal, content, incentives, effect, and presentation. Most of the data can be classified as content data, but some of the data collected can be used as incentives. A nudge consists of four to five parts from different classifications.

Firstly when creating a nudge, information is collected. The nudge design decides on a data template with the use of the user profile. The template is sent to the information collection service. This service use the template and data from context/situation to collect relevant data for the user. The data from the different services are then combined into an object by the information collection service. The information collection service then sends the object containing the data from the different services to the nudge design service.

The nudge design service analyses the information to decide on the goal of the nudge and the context of the nudge. The nudge design service first decides the nudge's goal, then creates a nudge using nudge parts from the other classifications.

The weather and distance are two motivational factors that are relevant for deciding on method of travel. The nudge goal can be decided by analyzing these two factors. During adverse weather or when historical weather indicates difficult road conditions, the system can nudge people towards public transportation. During pleasant weather and when the destination is nearby, the system can nudge the user towards walking or cycling.

7.1.1 Adverse weather

Adverse weather conditions like precipitation, wind, or low temperature can lead to a nudge goal of using public transportation. When utilizing vehicular transportation, users are less exposed to the weather. The system could use data from the calendar and the location of the user to plan a trip. The nudge could then provide relevant information for the users journey. Below is an example of a nudge using data collected by the demonstrators.

Example nudge one

Goal: public transportation.
Content: Weather: Raining outside.
Content: Bus route: 20 "Stakkevollan via UNN" at 15.15 from Fr. Langes gate F4
Incentive: Environmental impact.
Effect: loss aversion.
The presented nudge: *The weather is poor and it is a lot of rain, so why not use the bus. You can take bus nr. 20 "Stakkevollan via UNN" at 15.15 from Fr. Langes gate F4. Taking the bus helps to preserve the climate for future generations. You'll lose 10 minutes if you use the car.*

7.1.2 Pleasant weather

Pleasant weather can lead to a nudge goal of using active transportation like walking or cycling. The weather can motivate active travel for shorter distances. The weather information could be combined with information about cycling routes or pedestrian routes. The nudge can point out a scooter or a bicycle station with available bikes for the user. Data from the calendar and the location of the user can be used to plan a journey, and remind the user about the departure. The nudge can then provide the location of the bike rental station, the duration of the travel, and the weather. Below are two examples of nudges using data from demonstrators.

Example nudge one

Goal: Walking
Content: Calendar: Meeting at 10:00.
Content: Weather: The weather is sunny and it is warm outside.
Content: Route: It is 2.1 kilometers and would take 30 minutes.
Effect: Commitment: fits right into your travel plan.
The presented nudge: *Get on time to your meeting at 10:00 by walking. It is warm and sunny outside, why not walk. The trip takes 30 minutes. Walking helps fulfilling your goal.*

Example nudge two

Goal: Cycling
Content: Calendar: Meeting at 12:00
Content: travel route with rental station: bikecycle rental station at Lakkegata
Content: Route: It is 2.0 kilometers and would take 8 minutes using a bike.
Incentive: Health benefits: Cycling can increasing your energy.
The presented nudge: *Get on time to your meeting at 10:00 by cycling. There is a bike rental station at Lakkegata. Cycling to the destination would take 8 minutes. cycling reduces the risk of heart diseases.*

7.2 Combination of data

For combining the data from the different services, the system can use data templates. Templates can contain data about two different transportation modes, one vehicular and one active transportation. This is because of the nudging goal is dependent on the environmental conditions. The nudge design service uses data from the user profile to pick a template that is relevant to the user. A template using bicycle rental stations is not relevant for a person owning a bike. Therefore, it is unnecessary to collect data from the rental service. The nudge design service sends the template to the information collection service. The template informs the service of what data to collect and send in return. The information collection service analyses the data template to locate needed services. The information collection service then requests data from the different services needed. The output of every data collection service is JSON, so that it is easy to integrate the data. The information collection service uses the data from the different services to fill the data template with data. After integrating the data into the template, it is returned to the nudge design service. The nudge design service analyzes the data in the template to decide the nudge goal. A smart nudge is then formed and sent to the user before the trip.

8

Discussion

This section will discuss the essential elements of this thesis. Starting with a discussion about the data collected to form nudges. Then privacy and ethics of nudging are discussed. The architecture is discussed and compared with other architectural styles. Lastly, the research questions are answered.

8.1 Information collection

In this project, demonstrators of information collection services are designed and implemented. These demonstrators are collecting data from different relevant information sources for green transportation nudges. Data is collected about the weather, rental stations, routing information, public transportation, user location, and calendar events. The thesis has looked at what data is relevant from the different topics.

Weather data is collected from MET as it provides data that is relevant for choosing mode of travel. Rain, temperature, wind, and cloudiness are all factors people consider before traveling. When weather conditions are right, the data could motivate users to use non-vehicle transportation.

Historical weather can also provide useful information for nudges. Information about precipitation and temperature from the past 24 hours is collected, and it can, when analyzed, help to detect muddy, icy, or snowy roads. The road conditions can cause difficulty for different modes or cause traffic. The historical data helps people plan and prepare for the trip.

Rental stations provide information about bicycle stations or the location of available scooters. Not everybody owns a bicycle, and cycling and taking a scooter are a more efficient way to travel than walking, as it can potentially save time and energy. The combination of rental information and route generation can provide routes that utilize the rental services. The combination can be useful when the event exceeds the maximum travel distance of walking, and it is more convenient than taking the bus or driving.

Routing information is vital for green transportation as it provides information about possible routes for walking and cycling. The information collected is the duration of the trip and the length of the trip. This information can be used to motivate users to active transportation.

Public transportation data is essential as it provides data about a greener transportation option than driving. The information collected is used to help make traveling with public transportation more manageable for the user. Information about duration, arrival time, and departure time helps to plan the trip. There is also collected information about the transportation mode like the number on the mode, type of mode, name on the mode, start place, stop place, and mode switches.

Calendar data and location data are essential for collecting information that is relevant to the user's situation. The data collected from the calendar and location is used in other services to collect data. This data can also provide information about when to trigger nudges.

8.2 Other relevant data

There are most likely other topics that are relevant for green transportation nudges than the ones presented in this thesis. The capstone project discovered seven topics that are relevant for transportation nudges [23]. In this project, demonstrators collect information about four of the seven topics. The remaining topics are carpooling, parking, and traffic. The topics from the capstone project bases on interviews from five different people. By interviewing more people, other topics could be discovered.

Carpooling could be used to suggest driving together. There could be collected information about posted journeys by nearby users heading in the same direction. The system could nudge with the driver's posted journey and contact information. If the user is willing to share the ride and the expenses, they could make contact.

Traffic data about congestion, road work, and traffic are relevant for transportation nudges. It is useful for people utilizing vehicular transport. When there is traffic, the system can nudge users towards a different route or a different mode to save time.

Transportation nudges could provide data about available parking spots at the destination. Information about parking can reduce the time finding a parking spot, as the users know where to park.

There are other modes of transport than discussed in this thesis that is relevant to nudges. One example is cross skiing. The nudging system could provide users with information about relevant routes and duration of journeys utilizing cross skiing.

8.2.1 Frost

The different sources in Frost contain information about different observations [21]. Not all the sources in Frost collect the data requested from the weather service demonstrator. The weather service does not check the available data before requesting it, which can cause missing data in the returned object. A solution for this problem is to use "Observations/AvailableTimeSeries" to find what weather elements and time ranges are available at the source before requesting data from it. This approach would cause more API calls and make the service slower. Another solution is to use another weather data source.

8.2.2 MET

The "locationforecast" API used in the weather service has a functional capacity, but it is not unlimited [20]. The "locationforecast" generates a forecast for nine days, with data for each hour. The XML returned by MET is therefore relatively large, and if the nudge system generates many requests, it could cause a problem. MET states that one should not ask too often, and requests should not be scheduled every hour [20]. Since the data returned from MET contain a weather forecast for nine days, it could be reasonable to cache it to save MET for some traffic. By caching, the weather service would avoid handling the data from MET at every request.

As said for Frost, another solution is to use another information source. The service only uses the data at the time of travel and discards the other forecast data. Another API that provides data for a given time would be a better fit.

8.3 Privacy

Section 2.8 talks about GDPR and what companies have to consider when collecting personal data from people. In this thesis, there is collected information about location and calendar. This information can be used to provide real-time information about users. When creating a system, it is essential to consider what data to collect from users. The location and calendar information is vital in a nudging system for providing relevant nudges and for triggering the nudges.

A nudging system should be implemented with privacy and security by default [27]. For the implementation made in this paper, there is no data storage, but data in a microservices architecture are in transit between different services. The data should be applied suitable encryption to avoid information leaking [38]. Other factors that could be used to protect the data in transit from the APIs are: avoid exposing URLs, consider timestamps in requests, and avoid exposing API keys [38].

Transparency is a crucial point of GDPR [38]. Users should be able to uncover what data is collected, the purpose, who accessed the data, and how long the data lives in the system [38]. Users should also be able to verify, correct, export, move, and erase their data easily. The data collected in the demonstrators are not stored, but in a nudging system, there would potentially be data stored. The user should be informed about the intentions of the nudging system, and consent to information collection before the system collects data.

8.4 Ethics of nudging

There are ethical issues with nudging to consider when forming a nudging system. The ethics of nudging is presented in 2.10. Transparency is one solution to ethical issues. The system should be optional to download so that the users that want exposure to nudges for greener transportation can download it on free will. The system itself should also be transparent with the goal and intention clearly stated. There is no manipulation if users download and use the system on free will.

8.5 Architecture

The architecture chosen in this thesis is microservice architecture. In this section, the nudge design architecture will be discussed and compared with other possible architectures.

8.5.1 Microservices Architecture versus Monolithic Architecture

A microservices application consists of a set of smaller, interconnected services. In comparison, a monolithic application is a single, autonomous unit. There are benefits and drawbacks to both monolithic architecture and microservices architecture.

One limitation for the monolithic architecture is the habit of growing over time, eventually becoming an enormous code base [34]. With a large, complex monolithic application, it is hard for developers to understand the code base fully. It, therefore, becomes time-consuming to implement new features and to fix bugs [34]. Since the microservices architecture decomposes the application into services, it can be easier for developers to understand the application and modify it.

Since monolithic applications are a single unit, changes would affect the entire system [43]. A modification can require building and deploying a new version of the software, and for larger applications, redeploying can be time-consuming. Microservices architecture allows different services to deploy independently [34]. So for modifying and redeploying a microservice, only the related services need modifications and redeployment, instead of the entire system as in a monolithic application.

With a monolithic application, for scaling a specific function the entire system needs to be scaled [43]. Microservices architecture enables the services to be scaled independently [34]. The demand for different services can vary. For example, there may be a higher demand for weather service than the rental service. The microservices makes it easy to scale the services to meet the demands.

The Microservice system can utilize different programming languages and data storing techniques since the services can be independently developed [43]. With a monolithic application, it is challenging to adopt new frameworks and languages, as it is one large, complex system [34].

The microservices need to communicate, and the services communicate over a network often via APIs. The communication can be a downside, as it requires expensive remote calls and coarser-grained remote APIs [43]. The monolithic application has in-process calls that are faster than remote calls.

Since microservices are running in different processes, a bug affecting one service does not affect the entire system [43]. If an information collection service fails, the application could continue to work without it. The application can use other information to create a nudge. In a monolithic application, all modules are running within the same process, so a bug would potentially affect the entire system [34].

A significant drawback with microservices comes from the fact that it is a distributed system [34]. Partial failure is of concern for microservices as the services might be slow or unavailable. The network latency, a variety of message formats, and load balancing are other problems that arise in a microservices architecture.

Another challenge with microservices architecture is making changes that span over different services. The changes needs to be planned and coordinated for the different services, while in a monolithic architecture, one could change the modules, integrate the changes, and deploy the changes in one go [34]. In the architecture proposed, it can be challenging to make changes, as adding a service or changing services can lead to changes in other services as well. When adding new information collection services, the information collection service and the nudge design service needs an update.

Deploying the application is more difficult for a microservice-based application than a monolithic based application. The monolithic application is deployed on a set of identical services with a load balancer [34]. In a microservices-based architecture, the services will have multiple runtime instances [34]. The moving parts need to be configured, deployed, scaled, and monitored [34].

8.5.2 Microservices Architecture versus Service Oriented Architecture

Another type of architecture is service oriented architecture (SOA). Both SOA and microservices architecture rely on services as the main component.

One of the differences between microservices architecture and SOA are service granularity. In a microservices architecture, the service components are single-purpose services that handle one thing, while in SOA, the service components can range in size [37]. The services in SOA usually include more business functionality and are often implemented as subsystems [49]. There are four different services defined for SOA[49]:

- Business services: Defines core business operations.
- Enterprise services: Implements the functionality defined by business services.
- Application services: Are bound to a specific application context.
- Infrastructure services: Implements non-functional tasks such as authentication, security, and logging

Microservices support two different services, functional services, and infrastructure services [49]. The functional services are a combination of business service, enterprise service, and application service.

The communication between services differs from microservices architecture to SOA. The services in SOA communicates through an enterprise service bus (ESB), while microservices communicates through Representational state transfer (REST) [4]. For SOA, ESB is another point of failure. Since all the services are communicating through the ESB, if one service fails or slows down, the other services could be affected. In microservices, the system could continue without a slow service.

SOA and microservices differ in interoperability as SOA promotes the use of multiple heterogeneous protocols, while microservices try to reduce the number of choices for integration [4]. If the services could be accessed using the same remote access protocol, microservices are a good fit. For the nudge design architecture promoted in this paper, the different services can be accessed through RESTful APIs.

SOA is better suited for large, complex business applications, and microservices architecture is better suited for smaller applications [37]. The nudge design system is not a large and complex business application and is easy to partition. It also allows new services to be added easily. Microservices are, therefore, a good fit for the nudge design system.

8.6 Research questions

The research questions of the thesis are:

- What data is relevant for green transportation nudges?

- How can multiple information sources be combined to provide users with nudges promoting greener transportation modes?

8.6.1 Relevant data

First, relevant topics and sources for transportation nudges was discovered. A structured literature review was conducted to discover relevant research on green transportation nudges. The discovered research is used to identify information topics and sources for transportation nudges. Demonstrators that use the sources to collect data are designed and implemented. There are collected historical weather data, weather forecast data, public transportation data, rental bike station data, scooter data, routing data for cycling and walking, user's location data, and calendar data. The data collected is used to form example nudges, and by that proven to be relevant data for transportation nudges.

8.6.2 Combination of data

Data can be combined using templates. These templates contain what data to collect and combine. The nudge design service uses data from the user profile to decide on a template, and it is sent to the information collection service. This service uses the template to collect data from the corresponding services. The output of every service is a JSON object to make it easy to combine the data. The template is then filled with data and returned to the nudge design service. The nudge design service analyses the data to decide on a nudge goal. The nudge design service could analyze the current and historical weather to locate the travel conditions and decide on a goal. The travel conditions are a factor most people consider before choosing the travel mode. After deciding the goal, a nudge is formed using the data collected.

9 Conclusion

The main objective of this thesis was to gather information from different relevant sources for greener transportation and integrate the data to form nudges. There were implemented demonstrators of data collection from different information topics discovered in the capstone project [23], and topics discovered using other relevant research. There was collected information about weather, routes, public transportation, rental stations, user's geolocation, and calendar information. Microservices architecture is proposed for the nudge system. The information gathered was used to create example nudges using the five different nudge part categories defined in Dalecke's thesis [9].

Microservices architecture was chosen as the architecture of the nudge system. The architecture splits the application into smaller interconnected services, and the services implement different functionalities. It would be a good fit for information collection as the different services collecting information interact with different external APIs. The benefits of microservices are isolation, resilience, and scalability. The different services can be independently scaled to meet the demands of a nudging system.

Weather data was collected from Meterologisk Institutt (MET) through their provided API's. MET offers both current data through the "locationforecast", and historical data through Frost API. Information about the weather is essential for planning trips. If the weather is reasonable, it can be used to motivate cycling or to walk. The weather from the past 12 hours can be analyzed to predict road conditions.

Transportation data is essential for nudges. There is collected data from Here.com and Entur. Data about public transportation, walking- and cycling routes, and rental stations are collected. This data can be used in a nudge to provide information about a possible route for a journey, making it easier for users to choose the intended mode.

User data is critical to collect as it provides information about the user's context and situation. User data are collected from the smartphones through Expo framework. There are collected calendar and location information. This data is used in other microservices to collect information that is relevant to the user. This data can be useful for triggering nudges.

Nudges were formed using Dalecke's categories of nudge parts and generation rules [9]. There are five different classifications of nudge parts: goal, content, incentives, effects, and presentation. In this thesis, the data collected falls under the content class. Four example nudges are formed using the data collected in the demonstrators.

9.1 Future Work

Implementation of a full smart nudge system requires more than just information gathering. Smart nudges need to monitor the users to detect the effect of the nudge and adapt the nudges. To be able to form a smart nudge system, additional microservices are needed.

Of the microservices in the proposed architecture, demonstrators are created for the different services collecting information. The nudge design, information collection service, and user profile are not implemented. These need to be implemented to create a nudging system.

As the nudge project launches on a bigger scale, other countries and information sources need to be included. The data sources used provide data about topics for Norway. For other countries, other data sources are needed. There are also potentially other topics that are relevant to other countries.

9.1.1 Remaining data sources

This thesis utilizes the capstone project, and there are designed and implemented demonstrators for four out of seven topics [23]. The three remaining data topics are parking, carpooling, and traffic. These topics can be useful for forming future nudges.

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