Digital nudging towards public transport use

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Abstract

Addressing the detrimental effects of car use is essential because of the surge in transportation-related CO2 emissions brought on by our everyday demand for mobility. Driving is a major source of global CO2 emissions, so it is crucial to persuade drivers to opt for more environmentally friendly modes of transportation. This study focuses on the efficacy of digital nudging strategies, specifically inside the Google Maps application, in encouraging the usage of public transit for the Breda to Utrecht route in the Netherlands. This study analyses the effects of two different nudges, the feedback nudge and the default option nudge, by looking at the potential modal choice preferences of 360 participants in an online experiment. The study finds that both nudges positively influence participants' inclination towards public transport. However, the feedback nudge demonstrates a stronger impact, suggesting the effectiveness of highlighting the environmental advantages. By integrating digital nudging techniques into existing applications like Google Maps, policymakers and researchers can effectively encourage car users to adopt more sustainable transportation behaviours. It is important to acknowledge that this study focused on the Breda-Utrecht route and the results may not be fully generalizable to other locations and transportation routes. Additionally, the study examined potential modal choice rather than actual behaviour, which may introduce some limitations in predicting real-world outcomes. Further research is needed to validate and expand upon these findings, exploring the effectiveness of digital nudging in different contexts and evaluating its long-term sustainability impacts.

Keywords: Digital nudging, Google Maps, sustainable transportation, public transport, CO2 emissions, Netherlands

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Digital nudging towards public transport use

In our daily lives, the need for mobility is becoming increasingly important leading to an increasing demand. This increasing demand, however, has negative side effects, with rising CO_2 emissions being one of the most detrimental. Being the second-fastest rising source of CO_2 emissions in the world, transportation now contributes to 20% of all CO_2 emissions, just behind the power sector (Statista Research Department, 2023).

The majority of transportation emissions worldwide are produced by road vehicles. In 2020, 41% of all transportation CO_2 emissions came from only passenger cars (Statista Research Department, 2023). Yet, the automobile is the preferred form of transportation in almost all countries, including the Netherlands (Eurostat, 2021). The Netherlands specifically has the third-highest number of automobiles per person in the EU (Bakker & Witte, 2022). Moreover, no country in the EU can rival the Netherlands when automobiles are measured per square kilometre of land area (Bakker & Witte, 2022). Due to this density, certain Dutch roadways have heavy traffic, with the A27 freeway connecting Utrecht and Breda being the most congested on average (Holtermans, 2022). Traffic congestion on roads not only increases fuel consumption but consequently leads to even higher CO_2 emissions (Bharadwaj et al., 2017).

All in all, it can be concluded that car usage is a significant contributor to CO_2 emissions; consequently, encouraging individuals to stop using their cars will help tackle this issue (Anagnostopoulou et al., 2018). As a result, effective mobility plans that result in long-lasting improvements in people's modal choices are now of interest to researchers and policymakers (Hamidi & Zhao, 2020).

Better infrastructure and urban planning can be one way to alleviate this issue, but citizens must adopt sustainable behaviours. Especially in countries where the public transport infrastructure is of good quality, like the Netherlands, it is important to influence car users to make use of this more sustainable way of travelling. When information and communication technologies (ICT) are adapted for and incorporated into route-planning applications, they can help urban commuters choose environmentally responsible transportation options. The most popular navigation application in the Netherlands is Google Maps ("Best Navigation Apps", 2023), yet it fails to offer much to guide users toward more environmentally friendly modal options.

This research suggests a digital nudge for the Google Maps application. Even though Google Maps has made environmentally friendly improvements (such as showing the most fuel-efficient driving routes), this can be furthered by encouraging people to use public transportation. As trains are CO2 neutral in the Netherlands (Vrieling, 2021), this behavioural change would significantly reduce CO2 emissions. In contrast to the extensive body of research on promoting environmentally sustainable mobility choices, this study distinguishes itself by specifically examining the effectiveness of digital nudging techniques within an already existing application. Consequently, this paper aims to answer the following research question; "*How effective is digital nudging, specifically through the Google Maps application, in increasing the likelihood of car users in the Netherlands choosing public transport for the Breda to Utrecht route?"*

In this study, participants were assigned to a control group or two experimental groups exposed to different nudges. The default option nudge emphasised public transport as the default choice, while the feedback nudge highlighted the environmental benefits of public transport. Data was collected through an online survey from 360 participants. The results showed that both nudges influenced potential public transport choice, with participants more likely to indicate that they would use public transport. The feedback nudge had a stronger influence. These findings highlight the effectiveness of digital nudging in promoting sustainable transportation choices and eventually reducing CO_2 emissions.

Literature review

Modal choice

It is vital to have a deeper understanding of people's actual travel behaviour and their modal preferences to develop policy measures to induce sustainable travel behaviour (De Witte, et al., 2013). In transport literature, it is often assumed that rational decision-makers choose their modes of transportation based on rational motives, such as the shortest travel time or the lowest costs. This assumption is commonly used to explain the decision-making process behind mode choice. As a result, people's nuanced perceptions were rarely taken into account (Bahamonde-Birke et al., 2015).

In recent years, there has been a growing recognition of the importance of incorporating subjective viewpoints into transportation studies (Hamidi & Zhao, 2020). Consequently, a new mobility paradigm was developed that incorporates a wide range of factors linked to economic considerations, transport geography and social psychology (De Witte et al., 2013). This paradigm is called the motility framework.

Access, competences and appropriation are the three fundamental components of motility and they are related to the economic, social, cultural and political systems that govern mobility (De Witte et al., 2013).

1. Access refers to the range of mobility options and is limited by contextual circumstances (e.g., infrastructure, services and access to facilities and services).

2. Competences include physical and cognitive skills and special competencies (e.g., driver's licence).
3. Appropriation refers to how entities react to and perceive their access and competencies (e.g., plans, needs, values and motivations).

Entities have varying access, competencies and appropriation depending on the situation and environment, giving them a variety of alternatives for motility. It is important to remember that the three aspects of motility might change over time (Viry & Kaufmann, 2015). With this new framework in mind, which incorporates psychological factors, one particular policy technique from psychology and behavioural economics gained attention in modal choice literature, namely nudging.

Nudging

The objective of nudges is to influence individuals to make choices that, from a purely rational standpoint, would be considered better (Thaler & Sunstein, 2008). The underlying assumption is that people frequently make irrational decisions (Lehner et al., 2016). The foundation of the nudging principle lies in the dual-process theory of behavioural economics (Wason & Evans, 1974). Humans are not always optimal decision-makers; they often rely on "System 1" thinking, which is quick and automatic, or "System 2" thinking, which is slower and more effortful. Both types of decision-making can be influenced by heuristics or cognitive biases, which serve as mental shortcuts. While heuristics can facilitate faster and easier decision-making, they can also introduce errors, leading to less desirable choices.

Nudges utilise heuristics to make desired behaviours more understandable and simplify the decision-making process (Thaler & Sunstein, 2008). By making desired behaviours more appealing and effortless, nudges encourage individuals to engage in them. Importantly, under the paternalistic view of nudging, individuals retain complete autonomy over their decision-making, without any imposition from external mechanisms (Thaler & Sunstein, 2008). Consequently, nudging grants individuals the freedom to choose their preferred behaviour. Within the realm of nudging, one primary distinction can be made: pro-self versus pro-social nudging.

Pro-self vs pro-social

Pro self nudges help people avoid making irrational decisions that would harm their long-term wellbeing. pro-social nudges encourage people to act in ways that are advantageous to society or the environment, or that are in the public interest (Hagman et al., 2015).

The paternalistic approach put out by Thaler and Sunstein (2008), who contend that nudges should aim to help the individual as evaluated by themselves, theoretically fits better with pro-self nudges. So, an individual would probably accept the nudge when it encourages them to, for example, save money or eat better food—actions that are in their logical self-interest. Theoretically, this means that people are also likely to be more receptive to such nudges (Baldwin, 2014). When encouraging pro-social behaviour, where the benefits to the individual are less clear, nudging becomes more challenging.

Despite these theoretical conclusions, nudges have been proven to be effective methods for bringing about change toward environmentally sustainable behaviour (Hummel & Maedche, 2019; Trudel, 2019; White et al., 2019). This phenomenon may arise due to the positive internal feelings associated with performing acts of kindness, theoretically blurring the line between pro-social and pro-self nudges (Baldwin, 2014). Since human behaviour continues to be at the core of many complex environmental concerns, nudging can be seen as essential for encouraging people to take on urgent societal challenges.

Individual vs communal

Pro-social and pro-self nudging can be applied on an individual or group level, with the nudge being customised for each person or uniform for everyone, respectively. When opposed to a communal strategy, interventions that provide targeted information, especially on individual travel behaviour, are more successful (Ahmed, et al., 2020). Yet, creating a customised solution can be challenging. ICT can assist in this by integrating the use of technology, data processing tools and smartphone applications to encourage people to modify their travel behaviour (Sanjust di Teulada & Meloni, 2016; Sunio et al., 2018). Digitization has significantly impacted our daily lives and has shifted relevant consumers' preferences towards digital environments, implying that using ICT to nudge is becoming increasingly important. This spawned a new branch of nudging, known as digital nudging.

Digital nudging

Individual nudging has become easier to carry out as a result of ICT (Berger et al., 2022). However, nudging in digital environments is not the same as nudging in analogue environments. This can be attributed to information richness; digital environments can create choice overload, leading people to spend less time reading intently and causing them to behave differently than in an analogue environment (Weinmann et al., 2016). As a result, Weinmann et al. (2016) expanded the definition of nudging to include a digital context, defining digital nudging as "the use of user-interface design elements to guide people's choices or influence users' inputs in online decision environments" (Weinmann et al., 2016, p. 433). One key advantage is the ability to leverage online environments, which provide tools for tracking and analysing individual preferences. This enables the implementation of digital nudges in a quicker, more cost-effective and highly customised manner. One specific tool that helped make this even easier is the smartphone.

Mobile application nudging

A smartphone is a key tool that has enabled us to improve digital nudging even further. This can be attributed to an increase in smartphone users. In 2022, the Netherlands had 15.75 million smartphone users, up from 14 million in 2018 (Taylor, 2023). This represents nearly 90% of the population. Smartphones are especially interesting for influencing mobility choices because they can provide access to, for example, travel information (Gössling, 2016). Much of this data can be gathered and communicated using navigation applications. 77% of smartphone users use navigation apps regularly (Panko, 2018), implying that nudging through navigation applications reaches a large share of individuals.

The most regularly used navigation application worldwide is Google Maps, with nearly 70% of navigation app users saying they use Google Maps most frequently (Panko, 2018). In the Netherlands specifically, Google Maps is also the most popular navigation application ("Best Navigation Apps," 2023). The extensive adoption of smartphones in the Netherlands, coupled with the prevalence of Google Maps as the foremost navigation application, presents an intriguing avenue for scholarly investigation. However, this topic remains largely unexplored in the existing literature.

Pro-social digital nudging

The increasing digitalization of decision-making processes has extended to environmentally sustainable behaviour, shifting such decisions toward digital environments (Ferrari et al., 2019). In this regard, digital nudging offers a promising approach to promoting environmentally sustainable behaviour while preserving individual freedom of choice. Research has demonstrated the effectiveness of digital nudges delivered through mobile applications in influencing individuals' behaviours toward sustainability (e.g., Ferrari et al., 2019; Reisch et al., 2021). Various types of digital nudges have been studied and employed in the context of environmentally sustainable behaviour, with default options and feedback being the most researched and effective nudges in this domain (Berger et al., 2022).

Default option

The term "default option" refers to a situation in which the preferred option has been pre-selected and will remain if the person does nothing (Thaler & Sunstein, 2008). Existing research offers three explanations for defaults power (Sunstein, 2014). For starters, no physical or mental effort is required. Second, because it is perceived as a recommended option, the default is endorsed. Third, because it has been pre-selected, the default option is perceived as a reference point in decision-making, resulting in framing the other options as gains or losses in comparison to the default.

Despite promising results when promoting environmentally sustainable behaviour in various sustainable contexts (Berger et al., 2022), default option research on influencing public transportation use is limited. The primary focus of mobility literature is on persuading people to choose an electric car over a regular car (Berger et al., 2022).

However, from a theoretical perspective, three reasons were identified to explain why using a default option may not be the optimal choice in this particular context:

1. Default options can be classified as communal nudges because they are the same for everyone. As previously stated, tailored information, particularly on individual travel behaviour, was found to be more effective when trying to promote public transport use

(Ahmed, et al., 2020). This suggests that the default options may not be the optimal way to address the issue discussed in this paper.

2. Many people are unaware of the significant difference in personal CO2 emissions when using a car versus public transport (Tjoonk, 2021). Therefore, if this is not explained, people might not understand or even notice the ranking of defaults within a navigation application.
3. With regard to mobility choice, individuals often already have strong preferences, especially if they travel someplace often (Lin et al., 2018). This might cause them to ignore the default option and automatically click on their preferred option within a navigation application. If an individual already holds a strong preference for one mode of transportation over another, it might be challenging for a default option to significantly impact their decision-making process.

Feedback

Literature on feedback has generally shown a positive significant effect on environmentally sustainable behaviour (Berger et al., 2022; Tiefenbeck et al., 2019). Feedback works best when combined with a clear goal (Agha-Hossein et al., 2014), which explains its success in the literature on environmentally sustainable behaviour.

PerCues and OPTIMUM are examples of navigation applications that have been specifically developed to include a feedback mechanism targeting environmental sustainability and they have achieved successful outcomes in promoting sustainable behaviour (Esztergár-Kiss et al., 2021). However, the integration of this technology remains scarce, as it has not been applied to already established and popular mobile applications, such as Google Maps.

However, from a theoretical perspective, three reasons were identified to support the notion that using feedback may be a more optimal choice in this specific situation:

1. Feedback is a personalised approach, which was found to be more effective in encouraging the use of public transport than a communal approach (Ahmed, et al., 2020).
2. Feedback provides information that would otherwise be unavailable to a decision-maker. In this case the difference in CO_2 emissions between driving a car and taking public transportation (Münscher et al., 2016).
3. Feedback encourages people to consider whether their behaviour is/was good or could be improved and it highlights the consequences of decisions (Cappa et al., 2020). According to Cognitive Evaluation Theory, detailed and ready-to-use information should facilitate individual cognitive evaluation of potential behavioural opportunities and, as a result, improve their attitude toward following the suggested behaviour (Münscher et al., 2016).

However, there is a drawback to consider. When we repeatedly encounter the same feedback, it can lead to reduced attention and diminish its potential to influence our behaviour (Robitaille et al., 2021).

Research question and hypotheses

Based on the conclusions made above, the following research question was formulated: "*How effective is digital nudging, specifically through the Google Maps application, in increasing the likelihood of car users in the Netherlands choosing public transport for the Breda to Utrecht route?*"

Digital nudging through the use of a default option and feedback were tested, based on the literature review. The following hypotheses were formulated:

H1. Digital default nudging via the Google Maps application will result in a greater likelihood of potential public transport use than in the absence of intervention.

H2. Digital feedback nudging via the Google Maps application will result in a greater likelihood of potential public transport than in the absence of intervention.

H3. Digital feedback nudging via the Google Maps application will lead to a greater likelihood of potential public transport use than digital default nudging.

Methodology

Experimental design

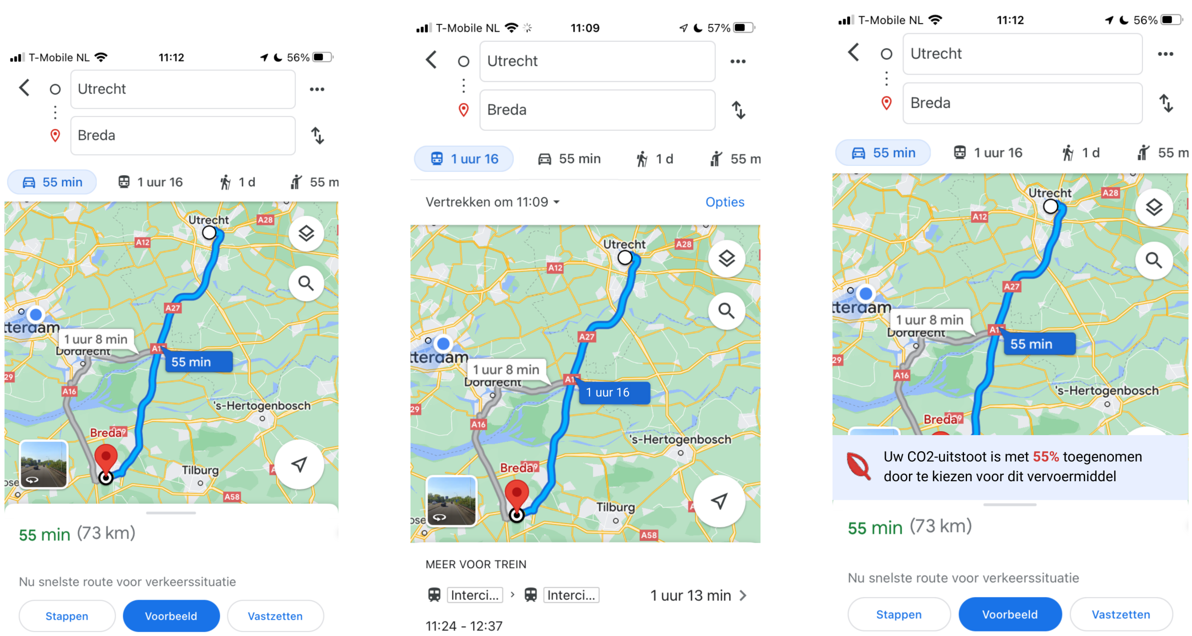
To analyse the research question, an online experiment was performed using a Qualtrics survey, with two treatment groups and a control group. A randomised controlled trial was performed, to randomly assign individuals to one of the three groups, making this a between-subjects design. A between-subject design was chosen to increase internal validity by reducing confounding variables and eliminating order effects. The Qualtrics software was programmed to automatically assign every participant either to the control group or to one of the treatment groups, making sure that they were randomly distributed. The survey obtained approval through the ethical thesis check before its distribution. The ethical test used can be found in Appendix A.

The treatments were in the form of screenshots of the Google Maps application, with different levels of nudging. The same screenshot was used as a basis for each treatment. This screenshot shows the route from Breda to Utrecht. This route was selected based on three distinct factors. Firstly, within the circles in which this survey was conducted, it is an uncommon route to travel. Consequently, personal experiences that could potentially influence one's preference for a mode of transportation were largely absent or negligible. Secondly, individuals are more inclined to consult navigation applications such as Google Maps before embarking on a journey to unfamiliar destinations. Therefore, this helped to make the situation closer to a field experiment. Lastly, as emphasised in the introduction, this route represents the most heavily congested road in the Netherlands, on average (Holtermans, 2022). Therefore, getting people to move away from car use for this particular route is of high importance.

Figure 1 displays the screenshots that were shown to the different treatment groups. Image A was shown to the control group, which is the Google Maps application in its current state. Image B was shown to the first treatment group, which is the Google Maps application with public transport as the default option. Lastly, Image C was shown to the second treatment group, which is the Google Maps application with a feedback nudge.

Figure 1

Screenshots of treatments



A - Control **B - Default option** **C - Feedback**

Variables

Independent variables

The screenshots above represent the independent variables of the experiment. Namely, the different levels of nudging (no nudge, default option and feedback).

Dependent variable

To test the validity of the nudges, potential public transport choice was measured as a binomial variable. Potential public transport choice was used as a proxy for actual public transport choice, given that it was not feasible to conduct a field experiment or modify the Google Maps application in this study. For each nudge, the potential public transport choice indicates whether the respondent would choose to use public transport or the car. Consequently, a higher proportion of respondents that choose public transport in the two treatment groups compared to the control group would suggest that the nudge is effective.

Control variables

Given the complex nature of mobility choice, control variables were chosen based on the motility framework introduced in the literature review. The specific control variables used were gathered from the well-known paper by Hamidi and Zhao (2020) that looks at shaping sustainable travel behaviour based on attitude, skills and access, i.e., the three fundamental components of motility.

Furthermore, an additional control variable was incorporated into the study, specifically the frequency of travel from the centre of Utrecht to the centre of Breda per month. This variable was included based on insights from the literature review, which highlighted that individuals often develop strong preferences for specific modes of transportation, particularly when they frequently travel to a particular destination (Lin et al., 2018). While the choice of the Breda to

Utrecht route was motivated by its relative uncommonness in the surveyed population, this question served as a control measure to ensure that the route was indeed infrequently travelled by the participants. A detailed overview of all control variables, along with their anticipated relationship with modal choice, can be found in Appendix B.

Procedure

Before starting the survey, participants were provided with information about the research purpose, stating that it was for a master's thesis at Erasmus University focused on Google Maps. They were informed that the survey would take approximately 3 minutes and were encouraged to share their honest opinions. Additionally, participants were advised to complete the survey on their mobile phones to enhance the experience, aiming to simulate the act of launching the Google Maps application and creating a more realistic and field-like experimental environment. For the full text, see Appendix C1. In addition, participants were required to agree to a set of rules before participating. This included rules about age and withdrawal from the survey. For the full text, see Appendix C2.

The survey had four sections: (1) the screener, (2) the experiment, (3) modal choice, (4) control questions. Figure 2 depicts a visual representation of the survey. For the full survey see Appendix G. The default language of the survey was Dutch as most people targeted to take part in this experiment were Dutch. However, it was possible to change the language to English. Similarly, the Google Maps screenshots were provided in Dutch, but due to the visual nature of the screenshots, they were easily comprehensible even for respondents who were English speakers.

The survey started with a screener that focused on the target group. Participants were asked if they were living in the Netherlands. If they answered yes, they were able to continue the survey. Additionally, respondents were asked how often they use different modes of transport per week (Car, public transport, bike and electric car) so that individuals that do not use a car frequently could be screened out.

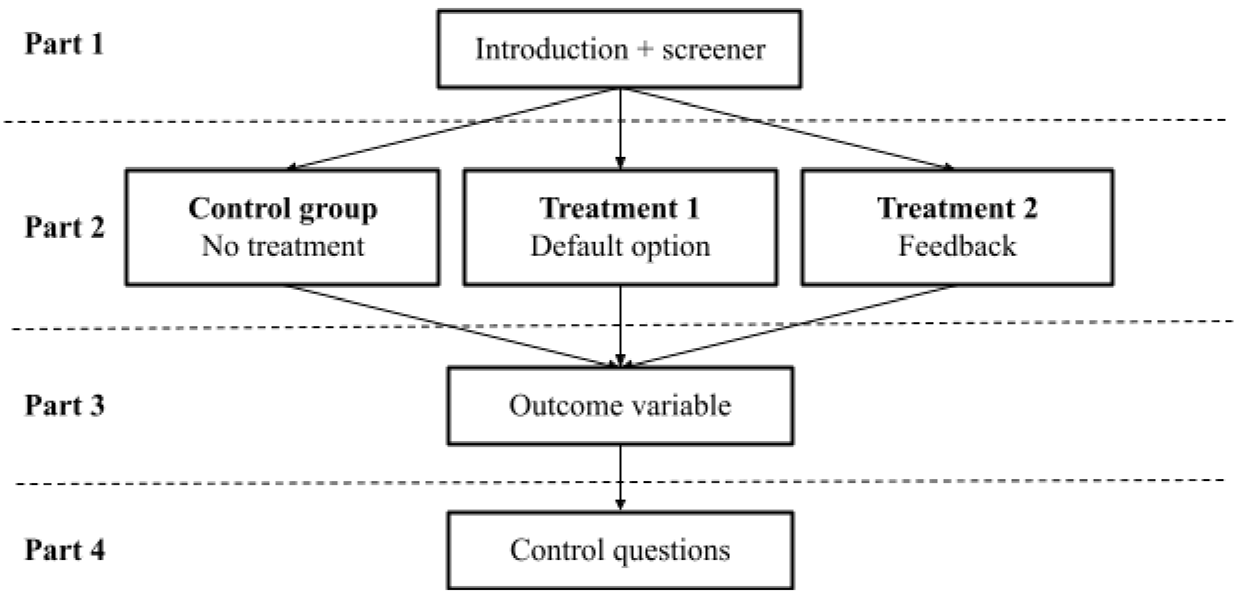
Next was the experiment, as mentioned in the experimental design section. Before showcasing these screenshots, a concise introduction was given, requesting participants to visualise themselves in the process of planning a journey from Utrecht to Breda (see Appendix C3), specifically by opening the Google Maps application on their mobile devices. This introductory step aimed to ensure participants' comprehensive understanding of the displayed content and foster their active engagement in the envisioned scenario.

After being presented with one of the three screenshots, participants were asked questions related to the outcome variables. To prevent priming effects, the question designed to measure the potential mode of transport choice after the treatment was formulated in a specific manner. Instead of asking, "Would you choose public transport?" the question asked was, "Which of the following modes of transport would you choose?" The response options provided were public transport, car, electric car and other. ‘Electric car’ and ‘other’ were included as a control for future exclusion. The rationale behind this exclusion is that individuals who already utilise electric cars tend to possess environmental considerations, which are not the primary focus of this study. By excluding these participants, the study aims to narrow its focus to individuals who rely on conventional cars for their travel choices.

Given the complex nature of mobility choice, the last section of the survey included control questions based on the motility framework introduced in the literature review to control for potential confounding factors. Additionally, respondents were asked how often they travel from the centre of Utrecht to the centre of Breda per month. After the survey, participants were provided with a debriefing statement explaining the purpose and nature of the experiment. The complete text can be found in Appendix C4.

Figure 2

Survey structure



Analysis

Preliminary analysis

All statistical tests used in this research were conducted with the statistical software Stata. For the preliminary analysis, the association between the independent and dependent variables were tested using a chi-squared test for independence. The chi-squared test for independence was chosen instead of the chi-squared goodness of fit test as the hypothesis is testing two categorical variables. The chi-square test was initially chosen as a statistical test to examine the relationship between variables and provide an incremental understanding of their association. By conducting the chi-square test first, the independence or dependence between variables was able to be assessed. This, consequently, gives insights into the relationship between them. This step was taken to analyse the data and explore any potential patterns or associations before proceeding with further analyses.

To conduct a chi-square test, there are three additional assumptions, in addition to both variables being categorical, that need to be met. These include the assumptions of independence, mutual exclusivity and expected frequencies of cells being 5 or greater. Firstly, all observations must be independent. Each individual included in the dataset was surveyed independently of every other individual. This was proven by the unique IP address of each respondent. Therefore, this assumption was met. Secondly, the cells in the contingency table should be mutually exclusive, meaning that individuals cannot belong to more than one cell. To ensure that each individual in the dataset could only participate in the survey once, a Qualtrics function was used to prevent respondents from taking the survey multiple times. This is achieved through the use of cookies, which tracks and restricts repeated participation. Lastly, the expected frequencies of the cells must be 5 or greater in at least 80% of the cells. The expected frequencies were calculated (see Table D1) and it was determined that none of the expected values of the cells were less than 5, thereby meeting this assumption.

Preparation main analysis

To account for control variables, the chi-square analysis was stratified based on the control variables. Separate chi-square test results were produced to look at the relationship between the control variables and the independent variable. If there was a significant difference in the control variable across nudge settings, the control variable was included as a covariate in the next part of the analysis.

Main analysis

For the main analysis, a binary logistic regression analysis was employed to determine the different levels of nudges' impact on the likelihood of choosing public transport when accounting for covariates. Next to general significance levels, the outcomes of binary logistic regression analyses provide odds ratios. These ratios predict the chance of an outcome of the dependent variable caused by the level or value of the independent variable – in this case, the odd ratio of whether someone chooses the public transport over the car due to the independent and control variables. A binary logistic regression is a technique used when the dependent variable is categorical with two groups. Public transport choice has two groups, therefore the dependent variable fulfils this condition. Besides the assumption that the dependent variable is categorical, various assumptions need to be met. These include independence, no multicollinearity, linearity and no extreme outliers. The assumption of independence, as stated in the chi-square assumptions, has been satisfied. None of the independent variables exhibit a correlation above 0.7, thus fulfilling the assumption of no multicollinearity (see Table D2). The linearity assumption has been met as confirmed by the Box-Tidwell test, demonstrating a linear relationship between the independent variables and the logit transformation of the dependent variable (see Table D3). The dataset was carefully examined for outliers, but no extreme outliers were identified, thereby satisfying the assumption of no extreme outliers.

Sample

An a priori power calculation was conducted using G*Power to determine the optimal sample size for the chi-square test of independence. The calculation requires input parameters such as effect size, alpha (Type 1 error level), power (1 - beta) and degrees of freedom. Typically, the minimum level for Type 1 error (alpha) is set at $p = 0.05$ and the minimum level for Type 2 error (beta) is 0.20 (Tsushima, 2022). Therefore, the minimum desired power of the test is (1 -

beta) = 0.80. Previous research has reported a median relative effect size of 0.21 for nudges (Hummel & Maedche, 2019). Since there is a control group and two treatment groups, the degrees of freedom for this study are 2. Based on these parameters, the optimal sample size for the chi-square test of independence was calculated to be 219.

The optimal sample size for a binomial logistic regression is calculated by using the formula $n = 100 + 50i$, where i refers to the number of independent variables in the final model (Bujang et al., 2018). This means that the optimal sample size for this study is 300.

To collect data, three sampling methods were employed. Convenience sampling was employed for the survey by distributing it to direct contacts through platforms such as WhatsApp and LinkedIn. Additionally, the survey was shared in relevant WhatsApp groups, Facebook, LinkedIn, Survey Swap and Survey Circle. Secondly, snowball sampling was implemented by requesting participants to share the survey link with their friends and family, thus expanding the potential participant pool.

Results

Data preparation

The survey was active from May 7, 2023 to May 29, 2023. In this period, the survey had been accessed by 360 respondents, out of which 329 completed the survey. This moderate attrition rate could be attributed to a loss of interest or lack of motivation. 9 respondents were screened out based on the grounds of not being residents of the Netherlands. A total of 81 respondents were removed on the grounds of not being car users[1]. There were no participants who were excluded based on age.

[1] Answered ‘Never’ to the question ‘On average, how often do you use a car per week?’ in the survey (see Appendix D for the survey).

Further exclusions were made for respondents who indicated ‘Electric car’ as their preferred mode of transport from Breda to Utrecht. 4 participants were excluded on these grounds. Additionally, 2 participants selected ‘Other’ and entered ‘Hybrid car.’ These two responses were also excluded (for reason see procedure section). As a result, the remaining participants selected either 'Car' or 'Public transport' as their transportation option and the dependent variable was subsequently transformed into a binomial variable.

Before analysis, the dataset was cleaned and prepared. First of all, the data was manually scrutinised for outliers, which were not found. Examining the distribution of the data was not necessary as this study deals with categorical variables. Next, to check whether the respondents had filled the survey in with considerable thought, the duration of their time spent on the survey was recorded. As the creator of the survey, it took at least 2.5 minutes to fill in the survey. As such, it was determined that respondents had to take at least 2.5 minutes. Therefore, all respondents taking less time than this were removed from the dataset. This resulted in the removal of 15 respondents from the sample.

Descriptive statistics

As a result of the above data preparation, 220 valuable observations could be used for the data analysis. The demographics of the final sample are displayed in Table 1.

Table 1

Descriptive statistics of demographic variables

	Total	**Control**	**Default option**	**Feedback**	**Kruskal-Wallis test**

Statistic	N	%	N	%	N	%	N	%	p-value
Total sample	220	100%	69	31%	69	31%	82	37%	-
Age									
18-24	60	27%	16	23%	17	10%	27	33%	
24-34	28	13%	6	9%	16	23%	6	7%	
35-44	30	14%	11	16%	6	9%	13	16%	0.44
45-54	51	23%	18	26%	14	20%	19	23%	
55-64	47	22%	17	10%	16	23%	14	17%	
>65	4	2%	1	1%	0	0%	3	4%	
Gender									
Female	119	54%	35	51%	38	55%	46	56%	
Male	101	46%	34	49%	31	45%	36	44%	
Non-binary/ third gender	0	0%	0	0%	0	0%	0	0%	
Education									
WO	179	81%	53	81%	56	81%	70	85%	
HBO	36	16%	15	16%	11	16%	10	12%	

MBO	1	0%	1	0%	0	0%	0	0%	
VMBO	2	1%	0	0%	0	0%	2	2%	
Other	2	1%	0	0%	2	3%	0	0%	
Income									
Average	63	29%	20	29%	25	36%	18	22%	
Less than average	42	19%	14	20%	11	16%	17	21%	0.21
More than average	104	47%	32	46%	31	45%	41	50%	
Prefer not to say	11	5%	3	4%	2	3%	6	7%	

*Note: Table displays the absolute number and proportion of the categorical data within each demographic sub-group of the sample. The data has been displayed at the total level and has been further classified by the treatments and control. Usable observations consist of 18+ year old Dutch residents who drive a car once a week or more. The final column contains the p-value of the Kruskal Wallis test to check for significant differences between groups. To conduct this test, the age and income variables were converted to numeric variables since these are the only two variables with an ordinal relation between categories and the median score was generated. ***p-value<0.01, **p-value<0.05, *p-value<0.10, No asterisk: p-value>0.10.*

The majority of the sample consists of 18-24 year old (27%) individuals who have a university-level education (81%) and above-average income (47%). This skew could be because of the channels within which the survey was distributed. Furthermore, 54% of the sample is female and 46% is male. These measures matter to understand the sample and to better interpret external validity and other limitations.

The survey was somewhat evenly distributed among the two treatment groups. 31% of respondents were exposed to the control, 31% were exposed to the default option and the remaining 37% were exposed to the feedback nudge. As visible from the demographic data, the sample profile was similar across the three sub-groups with a similar distribution of key demographic variables. A Kruskal-Wallis test on the median values of age and income fails to reject the hypothesis that the treatment groups are significantly different from each other. This solidifies the claim that randomization was successfully achieved between the three samples.

Preliminary analysis

For the preliminary analysis, the association between different levels of nudging and public transport choice was examined without controlling for other factors. To test the hypotheses, potential mobility choice was compared between the control group, default option and the feedback nudge group to see its effect.

Table 2

Potential modal choice

	Group		
Choice	**Control**	**Default option**	**Feedback**
Car	40	25	18
Public transport	29 (42%)	44 (64%)	64 (78%)
Δ% public transport	N/A	+ 22%	+ 36%

use *(compared to control)*	

Note: The change in public transport use was calculated by subtracting the public transport use percentage of the control group from the public transport use percentage of the two nudges.

Table 2 presents the potential car and public transport use for all three groups. A chi-square analysis was conducted to compare the public transport choice between the control group and the group that received the default option nudge. For the full analysis and the cross-tabulations see Appendix E1. The results revealed a significant difference in public transport choice between car users in the default option nudge group (64%) and the control group (42%), $\chi^2(1) = 6.54,\ n = 138, p = 0.011 < 0.05$. These findings provide support for Hypothesis 1, as they indicate an association between the choice of transportation and the treatment groups (control versus default option group).

Furthermore, a chi-square analysis was conducted to compare the modal choice between the control group and the second treatment group, which received the feedback nudge. The results showed a significant difference in public transport choice between car users in feedback nudge group (78%) and the control group (42%), $\chi^2(1) = 20.55,\ n = 151, p = 0.000 < 0.05$. These findings provide evidence supporting Hypothesis 2, as they indicate an association between the choice of transportation and the treatment groups (control versus feedback group).

Finally, a chi-square analysis was conducted to compare the modal choice between the feedback nudge group and the default option nudge group. The results revealed no significant difference in public transport choice between car users in the feedback nudge group (78%) and the default option nudge group (64%), $\chi^2(1) = 3.75,\ n = 150, p = 0.053 > 0.05$.

Therefore, these findings provide support against Hypothesis 3, as they indicate no significant association between the choice of transportation and the treatment groups (default option vs feedback group).

Preparation main analysis

To investigate the influence of control variables extracted from the motility framework on different treatment groups, a chi-square analysis was conducted, stratified based on these control variables. For the full analysis and the cross-tabulations see Appendix E2. The results of each analysis are summarised below:

Age

A chi-squared analysis was performed to examine the relationship between treatment groups and age. The resulting value of the chi-squared statistic was as follows, $\chi^2(10) = 16.55,\ n = 220, p = 0.085 > 0.05$. The results indicate that the age category of respondents did not have a significant relationship with the treatment groups. Therefore, controlling for age-related effects is unnecessary.

Gender

A chi-squared test was conducted to determine the association between treatment groups and participants' gender. The results of the chi-squared test with the contingency table revealed that there was no association between the treatment groups and the participants' gender, which was verified by the values of $\chi^2(2) = 0.47,\ n = 220, p = 0.789 > 0.05$. This demonstrated that there was no significant variation in education level among the treatment groups. Therefore, controlling for age-related effects is unnecessary.

Education

The same chi-square test was performed to examine the variation in driver's licence ownership across treatment groups. The results showed a value of $\chi^2(8) = 12.37,\ n = 220, p = 0.136 > 0.05$, which indicated no significant variation in education level among the treatment groups. Therefore, controlling for education-related effects is unnecessary.

Drivers licence

For the measurement of having a driver's licence, the same test was conducted and resulted in a value of $\chi^2(2) = 2.08,\ n = 215, p = 0.353 > 0.05$. This indicated that there is no significant variation in driver’s licence ownership across treatment groups. Therefore, this effect does not need to be controlled.

Car ownership

To examine the association between car ownership and the treatment settings, the same test was conducted and the results revealed a value of $\chi^2(2) = 5.70,\ n = 220, p = 0.058 > 0.05$, designating that there is no significant variation in car ownership across treatment groups. Therefore, this effect does not need to be controlled.

Income

To examine the association between income and the treatment group settings, again, a chi-square analysis was conducted with a contingency table. The results showed a value of $\chi^2(6) = 4.97,\ n = 220, p = 0.548 > 0.05$. This indicated that there is no significant variation in income across treatment groups. Therefore, this effect does not need to be controlled.

Household size

A chi-squared analysis was conducted using cross-tabulation to examine the relationship between treatment groups and household size. The resulting value of the chi-squared statistic was as follows, $\chi^2(10) = 17.30,\ n = 220, p = 0.068 > 0.05$. This indicated that there is no significant variation in income across treatment groups. Therefore, this effect does not need to be controlled.

Time efficiency

To assess the association between considerations about time efficiency and treatment group settings, a chi-square analysis was performed. The resulting value of the chi-squared statistic was as follows, $\chi^2(6) = 4.23,\ n = 220, p = 0.593 > 0.05$. The analysis revealed no significant variation in income across treatment groups, indicating that there is no need to control for this effect.

Comfort

To examine whether the respondents' considerations about comfort when making a choice about which mode of transport to use was statistically different in each treatment group setting, a chi-square test was conducted with a contingency table. The results showed a value of $\chi^2(8) = 8.02,\ n = 220, p = 0.431 > 0.05$, which indicated that there was no significant variation in considerations about comfort in each nudge setting. Therefore, the effect does not need to be controlled.

Transporting goods

The same chi-square test was conducted to examine the variation in considerations about transporting goods across treatment groups and resulted in a value of $\chi^2(8) = 9.67,\ n = 220, p = 0.289 > 0.05$. The results suggest that there was no significant variation in considerations about transporting goods among the treatment groups. Hence, controlling for this effect is not necessary.

Relaxation

A chi-squared analysis was conducted using cross-tabulation to examine the relationship between treatment groups and considerations about relaxation when making a choice about which mode of transport to use. The resulting value of the chi-squared statistic was as follows, $\chi^2(8) = 16.67, n = 220, p = 0.034 < 0.05$. This indicated that considerations about relaxation were significantly different across nudge settings. In the next stage of analysis, the preference to relax will be utilised as a covariate to analyse the influence of the different nudge settings on mobility choice. The distribution of the respondents' considerations about relaxation based on the treatment groups is shown in Table 3 below.

Table 3

Distribution preference to relax based on treatment groups

	Group			
Safety	Control	Default option	Feedback	**Total**
Agree	20	30	20	80
Disagree	3	3	12	18
Neutral	38	30	35	103
Strongly agree	8	6	3	17
Strongly disagree	0	0	2	12
Total	69	69	82	220

Safety

To examine the association between consideration about safety when making a choice about which mode of transport to use and the treatment settings, the same test was conducted and the results revealed a value of $\chi^2(8) = 6.99,\ n = 220, p = 0.538 > 0.05$. The results indicate that there was no significant variation in considerations about safety among the treatment groups. Therefore, controlling for this effect is unnecessary.

Environment

A chi-squared analysis was conducted using cross-tabulation to examine the relationship between treatment groups and the considerations about the environment when making a choice about which mode of transport to use. The resulting value of the chi-squared statistic was as follows, $\chi^2(8) = 17.54,\ n = 220, p = 0.025 < 0.05$. This indicates that considerations about the environment significantly differed across nudge settings. In the next stage of analysis, the preference to consider the environment will be utilised as a covariate to analyse the influence of different nudge settings on mobility choice. The distribution of respondents' considerations about the environment based on the treatment groups is presented in Table 4.

Table 4

Distribution preference to consider the environment based on treatment groups

	Group			
Environment	Control	Default option	Feedback	**Total**
Agree	13	18	29	60
Disagree	15	14	3	32
Neutral	35	31	40	106

Strongly agree	2	4	3	9
Strongly disagree	4	2	7	13
Total	69	69	82	220

Reliability

A chi-squared analysis was conducted using cross-tabulation to examine the relationship between treatment groups and considerations about reliability when making a choice about which mode of transport to use. The resulting value of the chi-squared statistic was as follows, $\chi^2(8) = 16.66,\ n = 220, p = 0.034 < 0.05$. This indicates that considerations about reliability significantly differed across nudge settings. In the next stage of analysis, the preference for reliability will be utilised as a covariate to analyse the influence of different nudge settings on mobility choice. The distribution of respondents' considerations about reliability based on the treatment groups is presented in Table 5.

Table 5

Distribution preference for reliability based on treatment groups

	Group			
Reliability	Control	Default option	Feedback	**Total**
Agree	49	38	47	134
Disagree	2	4	1	7

Neutral	3	15	11	29
Strongly agree	15	12	21	48
Strongly disagree	0	0	2	2
Total	69	69	82	220

Social status

The same chi-square test was conducted to examine the variation in considerations about social status across treatment groups and resulted in a value of $\chi^2(8) = 7.91,\ n = 220, p = 0.442 > 0.05$. The results indicate that there was no significant variation in considerations about social status among the treatment groups. Therefore, controlling for this effect is unnecessary.

Cost

The results of the chi-square test revealed no association between the treatment groups and participants' considerations about cost. The chi-square test resulted in the following; $\chi^2(8) = 3.68,\ n = 215, p = 0.885 > 0.05$. The results demonstrate that considerations about costs did not significantly vary among the treatment groups. As a result, there is no need to control for this effect.

Frequent travel from Utrecht to Breda

Similarly, the chi-square test was conducted to examine the association between the treatment groups and the frequency of travel from the centre of Utrecht to the centre of Breda. The test yielded a chi-squared statistic of $\chi^2(8) = 4.15,\ n = 220, p = 0.386 > 0.05$. The findings indicate that there was no significant variation in travel frequency among the treatment groups. Therefore, there is no need to control for this effect.

Main analysis

Based on the previous analysis, it is evident that considerations for relaxation, the environment and reliability should be included as covariates. To account for their potential influence, a binary logistic regression was conducted, incorporating these variables. The complete logistic regression table can be found in Appendix F1.

The addition of the covariates in the model demonstrated a significant improvement in model fit compared to the null model without control variables. This was verified by the likelihood ratio chi-square test $LR\chi^2(12) = 45.24,\ n = 218, p = 0.885 > 0.05$. Therefore, the inclusion of the control variables significantly contributes to explaining the variation in public transport use. The Pseudo R-squared value of 0.1562 indicates that the predictor variables in the binary logistic regression model explain approximately 15.62% of the variation in public transport use versus car use. This suggests a moderate level of explanatory power, indicating that the included predictor variables collectively contribute to explaining a substantial portion of the variation in the dependent variable.

Looking at the individual nudges, the effect of the default option nudge significantly increased the likelihood of choosing public transport compared to the control group, $Exp(B) = 2.32$, 95% $[0.133;\ 1.552]$, $p < 0.05$ ($p = 0.020$). An odd ratio of 2.32 indicates that car users exposed to the default option were 2.32 times more likely to choose public transport as their mode of transport when travelling from Breda to Utrecht compared to the control group. This provided evidence for Hypothesis 1.

The effect of the feedback nudge significantly increased the likelihood of choosing public transport compared to the control group, $Exp(B) = 5.06,\ 95\% \ [0.881; 2.362],\ p < 0.05\ (p = 0.000)$. An odd ratio of 5.06 indicates that car users exposed to the default option were 5.06 times more likely to choose public transport as their mode of transport when travelling from Breda to Utrecht compared to the control group. This provided evidence for Hypothesis 2.

The effect of the feedback nudge significantly increases the likelihood of choosing public transport compared to the default option nudge (Hypothesis 3), $Exp(B) = 2.45,\ 95\% \ [0.117; 1.674],\ p < 0.05\ (p = 0.024)$. An odds ratio of 2.45 indicates that car users exposed to the feedback nudge were 2.45 times more likely to choose public transport as their mode of transport when travelling from Breda to Utrecht compared to the default option nudge. This suggests an economically meaningful and substantial increase in the likelihood of choosing public transport. Along with being statistically significant, these results are economically significant as This provides evidence for Hypothesis 3.

Focusing on the control variables or covariates, only one variable significantly influenced the likelihood of choosing public transport when travelling from Breda to Utrecht. The measure for environmental consideration was found to be significant, $Exp(B) = 1.718,\ 95\% \ [0.195; 0.888],\ p < 0.05\ (p = 0.002)$. Based on these findings, car users who have a higher level of consideration for the environment (rated on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree) were 1.72 times more likely to choose public transport when travelling from Breda to Utrecht compared to those who have a lower level of environmental consideration. In other words, car users who place a higher emphasis on the environment are more likely to choose public transport in this situation.

In terms of insignificant control variables, neither reliability ($Exp(B) = 0.634,\ 95\% [-0.927; 0.016],\ p > 0.05\ (p = 0.058)$) nor relaxation ($Exp(B) = 1.384,\ 95\% [-0.099; 0.748],\ p > 0.05\ (p = 0.133)$) were found to significantly influence the likelihood of choosing public transport.

Discussion

The increasing demand for mobility has led to rising CO2 emissions, with transportation now accounting for 20% of global emissions. Globally and specifically in the Netherlands with its high concentration of automobiles, passenger cars are the primary contributors to transportation emissions. Encouraging individuals to reduce car usage is important and digital nudging through the Google Maps application could promote sustainable choices like public transport. This research aims to assess the effectiveness of digital nudging in influencing car users to switch to public transport in the Netherlands by answering the following research question, *"How effective is digital nudging, specifically through the Google Maps application, in increasing the likelihood of car users in the Netherlands choosing public transport for the Breda to Utrecht route?"*

Main findings

This study provides strong evidence that digital nudging can effectively influence car users to choose public transport, thus supporting the research hypotheses. Hypothesis 1 posited that the implementation of a default option as a nudge for car users would result in a higher likelihood of choosing public transport when compared to the control group (for the route Breda-Utrecht). This hypothesis received empirical support from the results of both the chi-square analysis and the binomial logistic regression. These results are in line with the three justifications offered in the literature for the success of default settings. First off, choosing the default selection is effortless because it doesn't involve any mental or physical effort. Second, it is frequently regarded as the suggested or favoured choice. Last but not least, the default selection acts as a benchmark against which other choices are evaluated (Sunstein, 2014).

According to Hypothesis 2, car users who receive feedback would be more likely to choose public transport than those in the control group (for the route Breda-Utrecht). This hypothesis was validated by the results of the chi-square analysis and binomial logistic regression, which were in line with the three justifications listed in the literature study for expecting feedback to be successful in this particular situation. These include the individualised nature of feedback (Ahmed et al., 2020), the ability of feedback to give decision-makers access to information that was previously unavailable (Munscher et al., 2016) and the capacity of feedback to encourage people to assess the goodness or badness of their behaviour, which is supported by cognitive evaluation theory (Cappa et al., 2020; Munscher et al., 2016).

These results support the work of Hummel and Maedche (2019), Trudel (2019) and White et al. (2019), who discovered that pro-social nudges work despite initial theoretical predictions. The pro-social nudges' success can be linked to the good feelings produced by deeds of kindness, which theoretically blurs the line between pro-social and pro-self nudges (Baldwin, 2014).

Hypothesis 3 proposed that nudging car users through the use of feedback would result in a higher likelihood of selecting public transport when compared to employing a default option as the nudge (for the route Breda-Utrecht). This hypothesis was solely supported by the results of the binomial logistic regression analysis and not the chi-square analysis. The discrepancy in results suggests that the effect of the feedback nudge on the likelihood of selecting public transport is dependent on the individual's perceptions and preferences related to the environment, reliability and relaxation. The inclusion of these variables in the logistic regression model allowed for a more nuanced understanding of the relationship between nudging techniques and modal choice.

The study's findings provide compelling evidence in favour of the theoretical limitations of using a default option in this situation, as mentioned in the literature review. Additionally, they argue that putting in place a feedback nudge can provide a possible solution to deal with these limitations. Table 6 presents a comparison of feedback and default options, with the feedback characteristics serving as answers to the problems indicated in the default option row.

Table 6

Comparison nudge types

Default option	Feedback
Communal	Individual
Lack of awareness	Provision of previously unavailable information
Strong preferences	Encourage individuals to evaluate the goodness or badness of their behaviour

According to Ahmed et al. (2020), communal nudges, such as default options, were found to be less effective in promoting public transport usage. Therefore, since feedback is an individual nudge, it offers a solution in this situation. Furthermore, Tjoonk (2021) emphasises that a lot of people are not aware of the considerable difference in personal CO_2 emissions between driving a car and taking public transportation. People might not comprehend or even notice the ranking of defaults in a navigation application without enough explanation. Feedback resolves this problem by making information previously unavailable available. Lastly, Lin et al. (2018) point out that people frequently have strong preferences for their mobility choices, which are difficult to be changed by default options. To tackle this, feedback encourages individuals to reflect on whether their behaviour is good or could be improved while highlighting the consequences of their decisions (Cappa et al., 2020), therefore, providing a solution.

Overall, the findings support the effectiveness of digital nudging in influencing car users to choose public transport via the Google Maps application for the route Breda-Utrecht. The feedback nudge was found to have a greater impact than the default option nudge, demonstrating that emphasising the environmental advantages of public transportation can be particularly effective in persuading people to choose environmentally friendly modes of transportation. These results also lend support to Viry and Kaufmann's (2015) theoretical claim that the three components of motility may change over time. Specifically, the study provides evidence that environmental factors can have an increasing effect on individuals' motility.

Control variables

Based on the motility framework, the study also investigated the impact of other factors influencing the likelihood to choose public transport when travelling from Breda to Utrecht. Findings showed that respondents who agreed more with the statement "When I choose a mode of transportation, I take the environment into account" were more likely to use public transportation, which confirmed the hypothesis (see Appendix B). This indicates that those who are more concerned about the environment are more likely to prioritise sustainable transportation options. These findings highlight the significance of encouraging environmental consciousness and sustainability in the planning of transport systems.

The study also sought to examine how other aspects, such as reliability and relaxation, may affect the mode of transportation chosen. According to the literature (see Appendix B), it was initially assumed that disagreeing more with the statement "When I choose a mode of transportation, I take reliability into account" would lead to a higher likelihood of choosing public transport. The findings, however, showed that the decision to use public transit was not significantly influenced by reliability. This could be attributed to the fact that the reliability of travel time is closely tied to day-to-day fluctuations, which may not be relevant for individuals who do not frequently travel the specific route between Utrecht and Breda (Ghader et al., 2019).

Similarly, the literature suggested that disagreeing more with the statement "When I choose a mode of transportation, I take relaxation into account" would lead to a higher likelihood of choosing public transport. However, the results did not show that relaxing had a substantial impact on the choice of public transportation. This might be the result of the limited research into the relationship between relaxation and modes of transportation (Legrain et al., 2015), which therefore prevented an accurate forecast. The motility framework outlined in the literature study is called into question by these findings.

Policy implications

To encourage people to choose environmentally friendly transport, policymakers can use digital platforms and apps. Policymakers could promote the use of public transport as the preferred option and give people individualised information about its environmental advantages by including default options and feedback mechanisms.

The results also show that people who prioritise the environment are more likely to take public transportation. Therefore, policymakers ought to concentrate on encouraging environmental consciousness in the selection of transportation options. This can be accomplished by running educational campaigns, spreading knowledge on the environmental effects of various modes of transportation and aiding initiatives that emphasise how public transportation helps to cut CO_2 emissions.

The study emphasises how crucial it is to take into account various factors when influencing modal choice. Although not important in the context of the particular route under study, factors like reliability and relaxation might be more important in other transportation scenarios. The specific characteristics that affect modal choice in various settings should be better understood by policymakers in order to better tailor initiatives.

Limitations and recommendations

Sample

An online survey and several sampling techniques, including social media and snowball sampling, were employed to collect the sample for this study. Due to sampling bias, the results may not be as broadly applicable to the overall population. The findings might be more relevant to people who, for instance, use social media frequently or have access to internet resources. The findings also indicate that the majority of respondents hold a university degree. Modal choice was predicted to be influenced by educational level (see Appendix B), which can impact the generalizability of the results. Furthermore, the study's subjects voluntarily chose to take part, which could lead to self-selection bias. People that participated voluntarily can differ from non-participants in terms of traits or motivations. The findings' external validity may be impacted by this.

To reduce sampling bias and improve the generalizability of findings, more varied sampling techniques should be used in future investigations. A more representative sample might be obtained by combining online surveys with other recruitment techniques like random sampling or stratified sampling.

Chosen route

When evaluating the results, it is crucial to take into account that the study concentrated on a particular route, namely the one from Breda to Utrecht. It is important to understand that the findings from this study might not immediately apply to different routes or transportation scenarios. The Breda to Utrecht route, for example, has the highest traffic density in the Netherlands, on average. This element is not typical to other routes or areas.

Future research may examine several routes or carry out comparable studies in various regions to create more reliable generalisations. This would give a more thorough grasp of the diversity of transportation decision-making and provide a more comprehensive understanding of the effectiveness of nudging techniques across various contexts.

Online experiment

The experiment is carried out in a simulated online environment, which may not accurately represent the complexity and nuances of decision-making in the actual world. Screenshots from Google Maps were used as stimulus. A static image may not accurately depict the complexity of real-world transportation decision-making. Therefore, it's possible that these findings won't directly apply to different decision settings.

In addition, hypothetical responses from participants were employed in place of real-world behaviours. Potential modal choice can offer insights, but it may not always represent participants' actual choices or actions. Additionally, the potential modal option was self-reported, which is susceptible to participant recall bias and interpretation difference. These restrictions may have an impact on the precision and dependability of responses pertaining to modal choice. Participants may also give a response that they believe to be in line with the study's objectives or to be socially desirable. The accuracy of self-reported measurements like modal choice may be impacted by this bias. For instance, participants could exaggerate how much they favour taking public transit.

Future research could profit from setting up field tests where the Google Maps app is altered and evaluated, enabling data collecting on actual behaviour. Alternatively, conducting follow-up surveys to cross-validate participants' reported choices with their observed transportation behaviour would be an improvement. Additionally, researchers need to be aware of the possibilities of socially acceptable responses from subjects. Techniques like implicit measurements or adding more indirect measures of modal choice could be used to reduce the effect of social desirability bias on self-reported data.

Control variables

Although control variables were included to account for potential confounding factors, they may not fully reflect all relevant factors impacting mobility decisions as they were chosen based on current literature. The connection between the independent variables and the dependent variable may still be influenced by other unmeasured variables. Future studies ought to think about integrating a larger range of potential confounding elements that can affect modal preference.

Statistical analysis

A larger sample size (n = 300) is often needed for binomial logistic regression in order to generate accurate estimates and sufficient statistical power. The sample size was minimal due to time restrictions, which could indicate that the estimates are unstable and the inference is inaccurate. Larger and more diversified sample sizes should be sought after for future research. Future studies might also investigate more sophisticated statistical methods to evaluate the direction and strength of correlations. Regression models with multiple variables may offer more subtle insights into the complicated dynamics of modal choice.

Timeframe

Since participants only received the nudges once, it's critical to recognise that behaviour may change over time. According to the literature review, exposure to the same feedback repeatedly can result in lower attention and diminished effectiveness in affecting behaviour (Robitaille et al., 2021). Future research might therefore take into account using a longitudinal design or including numerous exposures to the nudges in order to evaluate their long-term effects. In order to promote behaviour change, this would give a more thorough understanding of the long-term effects of digital nudging interventions.

Design of the feedback nudge

In this experiment, negative feedback was used as the feedback nudge. The generalizability of the findings may be constrained by the possibility that negative feedback may have distinct effects from positive feedback. To understand the distinctions between positive and negative feedback nudges and how they affect the use of public transport, future study might examine these topics. To maximise its impact, it would also be intriguing to investigate how to improve the feedback nudge's overall design and user experience. To increase the efficiency and usability of the nudging intervention, this might be done by conducting user testing and obtaining feedback.

Conclusion

In conclusion, this study investigated the impact of digital nudging through the Google Maps application on individuals' modal choices when travelling between Breda and Utrecht in the Netherlands. The results showed that both the feedback nudge and the default option nudge were successful in persuading people to select public transport over private vehicles. The feedback nudge—which included information on the environmental advantages of public transportation—proved to be especially effective. This implies that raising people's understanding of the beneficial environmental effects of using public transport can have a big impact on how they make decisions. Furthermore, the inclusion of the environmental consideration variable revealed that car users with a higher level of environmental concern were more likely to choose public transport. This highlights the importance of promoting environmental awareness and sustainability in transportation decision-making processes.

Overall, the results show that using digital nudging to encourage sustainable mobility and lower CO2 emissions from transportation systems can be a successful tactic. Policymakers and transport providers can persuade people to choose environmentally friendly transport by exploiting digital platforms and adopting targeted nudging.Further investigation is required to support and build upon these findings, explore the efficacy of digital nudging in other situations and assess its sustainability impacts over the long term. This will increase the generalizability of the findings. Nevertheless, this study sheds important light on the potential of digital nudging as a tool for promoting sustainable mobility behaviour.

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Appendix A

Ethical checklist

1. Does your research target vulnerable groups? Examples of vulnerable groups include the under-aged, the elderly, members of any minority and/or underprivileged groups and people with sickness.
2. Does your research involve unusually high payment to subjects? (> €30 per hour and/or the maximum possible payment per participant exceeds €200?)
3. Does your total research budget exceed €100? (MSc thesis question)
4. Do subjects participate without verbal or written 'informed consent' whereby subjects agree to take part in your study?
5. Do you need to ask consent from someone (e.g., a parent or legal guardian) on behalf of the research subject(s) who is not legally competent to give consent (e.g., a minor (<16 years old); someone deemed legally incapable)? Please note that for children under age 12, both parents must give consent. For children between age 12 and 16, one parent and the subject must give consent.
6. Will subjects participate without being sufficiently informed about the nature of the experimental tasks they will be asked to perform?
7. Will subjects participate without being debriefed at the end?
8. Do you use some form of deception? This concerns, in particular, providing untrue information (to participants).
9. Does your research involve direct manipulation of physiological variables? This can, for instance, involve the administration of bodily hormones to your participants (e.g., testosterone, oxytocin) or administration of drugs (e.g., pain killers, nicotine, alcohol).

Small quantities of such substances that may be contained in foods (e.g., a candy bar) or drinks (e.g., a can of coke) do not qualify as direct manipulations of physiological variables.

10. Does your research involve manipulations or measures that affect physiological variables in a significant way? For instance, the use of endurance tests may affect heart rate, breathing rhythm etc.
11. Does your research include biological variables?
12. Is there a possibility that participation in your research has nontrivial positive or negative consequences for subjects' physiological functioning or physical health?
13. Does your research potentially influence the wellbeing, mental health, or the legal or economic situation of your participants in significant ways? For instance, do your manipulations significantly affect participants' long term self-esteem or mood? Experiences that people would encounter during their normal course of daily life do not qualify.
14. Could the research induce nontrivial psychological stress or anxiety, or cause non trivial harm or negative psychological consequences for the subjects?
15. Is it realistically possible that this research has nontrivial negative consequences for the subjects other than described in the preceding questions?
16. Could the research induce nontrivial psychological stress or anxiety, or cause non trivial harm or negative consequences for the researcher(s)?
17. Does (part of) the research take place outside the Netherlands? If yes: Please realise that local ethics approval may be needed. Discuss with your supervisor.
18. Could the situation at the place where the research is conducted put the subjects at risk?

19. Could the situation at the place where the research is conducted put the researchers at risk?
20. Do you store any highly private and sensitive personal information about your participants in such a way that this information could be linked to individual participants? Examples are information about their national/ethnic background, sexual orientation, health status, financial situation or political/religious beliefs.
21. Do you advertise your study as an Erasmus study (e.g., by using the Erasmus behavioural Lab template of Qualtrics) or use the Erasmus university/school logo in any way? Please note that it is allowed to mention you collect this data as part of your MSc thesis project at the Erasmus University, but it is not allowed to use any logos.
22. Is there any other reason why you think you should have a discussion with your supervisor about the ethical aspect of your study? For example, in relation to external stakeholders who are involved; potential conflict of interest; potential misuse of research results.

Appendix B

List of variables obtained from the survey

Variable	**Question type**	**Motility framework**	**Expected relationship with public transport choice**	**Source(s)**
Age	Categorical	Skills	(-)	(Schmöcker et al., 2008; Buehler, 2011)
Gender	Categorical	Skills	Female (+), male (-)	(Pourhashem et al., 2022; Goel et al., 2022)
Education	Categorical	Skills	(-)	(Buehler, 2011; Kizony et al., 2020)
Income	Categorical	Access	(-)	(Buehler, 2011; Kizony et al., 2020; Clark, 2015)
Driver's licence	Binary	Skills	(-)	N/A
Car ownership	Binary	Access	(-)	(Albalate & Gragera, 2020;

				Masoumi et al., 2022)
Household size	Ordinal	Access	(-)	(Clark, Chatterjee, & Melia, 2016; Masoumi et al., 2022)
Preference for:				
Time efficiency	Ordinal	Attitudes	(-)	(Özgün et al., 2021)
Comfort	Ordinal	Attitudes	(-)	(Mayo & Taboada, 2020; Masoumi et al., 2022)
Transport of goods	Ordinal	Attitudes	(-)	(Budd & Ison, 2020)
Relaxation	Ordinal	Attitudes	(-)	(Eluru & El-Geneidy, 2015; Rezapour & Richard

				Ferraro, 2021)
Safety	Ordinal	Attitudes	(-)	(Fu & Juan, 2017)
Environment	Ordinal	Attitudes	(+)	(Chen & Li., 2017; Budd & Ison, 2020)
Reliability	Ordinal	Attitudes	(-)	(Dixit et al., 2019; Alonso-Gonzalez et al., 2020)
Social status	Ordinal	Attitudes	(-)	(Saif et al., 2018; Abdulla et al., 2020)
Cost	Ordinal	Attitudes	(-)	(Ulahannan & Birell, 2022; Hamadneh & Esztergar-Kiss, 2021)
Frequency per month route	Categorical	N/A	N/A	N/A

Breda > Utrecht

Appendix C

Survey texts

Appendix C1: Information sheet

Hello! Currently, I am conducting research on the use of Google Maps for my master's thesis at Erasmus University Rotterdam. I kindly request 3 minutes of your time to complete this survey. Please feel free to provide your honest opinion. The type of data to be collected involves multiple choice and likert scale questions.

If you would like to learn more about this research and its results, please contact me at this email address: maximeessaadi@gmail.com

For the best experience, it is recommended to complete this survey on your mobile phone.

Appendix C2: Informed consent

If you agree with the following statements, please click on Continue:

1. I am 18 years of age or older.
2. I understand that I can ask questions about the survey at any time (questions can be directed to maximeessaadi@gmail.com).
3. I understand that I can withdraw from participating in this survey at any time without any consequences.
4. I understand that the results will be presented only at a group level and cannot be traced back to an individual.
5. I understand that the data from this survey will be stored anonymously with password protection for a maximum of 5 years after publication.

Appendix C3: Introductory text

I will now present a hypothetical scenario:

Imagine that you are planning to travel from the centre of Utrecht to the centre of Breda. You are using the Google Maps mobile application to check your travel time and you experience the following:

Appendix C4: Debriefing

Thank you for participating in our survey on nudging towards public transport use through Google Maps. We appreciate your time and valuable input.

In this study, I investigated the effectiveness of two nudges: feedback and default option. Feedback highlighted the environmental impact of choosing to use a car over public transport, while the default option pre-selected public transportation in Google Maps.

Your responses provided insights into the effectiveness of these nudges in influencing modal choice. The findings will contribute to knowledge on sustainable transportation practices and inform policymakers.

We sincerely appreciate your participation. For any questions or complaints, please contact me at this email address: maximeessaadi@gmail.com. If you are interested in receiving the results of this investigation, feel free to email as well.

Appendix D

Statistical test assumptions

Appendix D1: Chi-square test of independence assumptions

Table D1. Expected frequency table

	Default option	Feedback	Control	Total
Car	25 26,03	18 30,94	40 26,03	83
Public transport	44 42,97	64 51,06	29 42,97	137
Total	69	82	69	220

Note: Observed frequency is above, expected frequency is below.

Appendix D2: Binomial logistic regression assumptions

Table D2. Spearman correlation

Independent variable	Group	Reliability	Relaxation	Environment
Group	1.000			
Reliability	-0.085	1.000		
Relaxation	0.119	-0.047	1.000	
Environment	0.051	-0.104	0.123	1.000

Note: Variables are highly correlated if the correlation is above 0.7.

Table C3. Box-Tidwell test

	Coefficient	Std. error	z	Nonlin. dev.	P-value
Reliability	-0.376	3.336	-1.65	0.732	0.392
p1	-0.847	2.133			
Relax	0.119	0.200	0.60	0.002	0.969
p1	0.119	6.615			
Environment	0.589	0.175	3.37	2.713	0.100
p1	3.336	2.056			

Appendix E

Chi-square analysis

Appendix E1: Chi-square analysis main effect

Table E1. Default option and control group

	Default option	Control	Total
Car	25	40	65
Public transport	44	29	73
Total	69	69	138

Pearson chi2(1) = 6.5437 Pr = 0.01

Table E2. Feedback and control group

	Feedback	Control	Total
Car	18	40	58
Public transport	64	29	93
Total	82	69	151

Pearson chi2(1) = 20.5500 Pr = 0.000

Table E3. Default option and feedback group

	Default option	Feedback	Total
Car	25	18	43

Public transport	44	64	108
Total	69	82	151

Pearson chi2(1) = 3.7518 Pr = 0.053

Appendix E2: Chi-square analysis control variables

Table E4. Treatment group and age

	Default option	Feedback	Control	Total
18-24	17	27	16	60
24-34	16	6	6	28
34-44	6	13	11	30
45-54	14	19	18	51
55-64	16	14	17	47
>65	0	3	1	4
Total	69	82	69	220

Pearson chi2(10) = 16.5529 Pr = 0.085

Table E5. Treatment group and gender

	Default option	Feedback	Control	Total
Female	38	46	35	119
Male	31	36	34	101

Total	69	82	69	220

Pearson chi2(2) = 0.4746 Pr = 0.789

Table E6. Treatment group and education

	Default option	Feedback	Control	Total
WO	56	70	53	179
HBO	11	10	15	36
MBO	0	0	1	1
VMBO	2	0	0	2
Other	0	2	0	2
Total	69	82	69	220

Pearson chi2(8) = 12.3653 Pr = 0.136

Table E7. Treatment group and driver's licence

	Default option	Feedback	Control	Total
No	6	3	3	12
Yes	63	79	66	208
Total	69	82	69	220

Pearson chi2(2) = 2.0823 Pr = 0.353

Table E8. Treatment group and car ownership

	Default option	Feedback	Control	Total
No	9	23	12	44
Yes	60	59	57	176
Total	69	82	69	220

Pearson chi2(2) = 5.7006 Pr = 0.058

Table E9. Treatment group and income

	Default option	Feedback	Control	Total
Average	25	18	20	62
Less than average	11	17	14	42
More than average	31	41	32	104
Prefer not to say	2	6	3	11
Total	69	82	69	220

Pearson chi2(6) = 4.9683 Pr = 0.548

Table E10. Treatment group and household size

	Default option	Feedback	Control	Total
1	6	8	8	22
2	19	20	22	61

3	11	7	19	37
4	23	29	11	63
5	5	11	5	21
>5	5	7	4	16
Total	69	82	69	220

Pearson chi2(10) = 17.2945 Pr = 0.068

Table E11. Treatment group and time efficiency

	Default option	Feedback	Control	Total
Strongly disagree	0	1	2	3
Neutral	2	2	2	6
Agree	43	45	33	121
Strongly agree	24	33	32	89
Total	69	82	69	220

Pearson chi2(6) = 4.6227 Pr = 0.593

Table E12. Treatment group and comfort

	Default option	Feedback	Control	Total
Strongly disagree	0	1	0	1

Disagree	1	0	0	1
Neutral	7	12	6	25
Agree	49	55	43	147
Strongly agree	12	14	19	45
Total	69	82	69	220

Pearson chi2(8) = 8.0207 Pr = 0.431

Table E13. Treatment groups and goods

	Default option	Feedback	Control	Total
Strongly disagree	0	1	0	1
Disagree	6	7	2	15
Neutral	28	36	26	90
Agree	27	26	23	76
Strongly agree	8	12	18	38
Total	69	82	69	220

Pearson chi2(8) = 9.6694 Pr = 0.289

Table E14. Treatment groups and relaxation

	Default option	Feedback	Control	Total

Strongly disagree	0	2	0	2
Disagree	3	12	3	18
Neutral	30	35	38	103
Agree	30	30	20	80
Strongly agree	6	3	8	17
Total	69	82	69	220

Pearson chi2(8) = 16.6559 Pr = 0.034

Table E14. Treatment groups and safety

	Default option	Feedback	Control	Total
Strongly disagree	3	7	2	12
Disagree	13	18	10	41
Neutral	11	11	16	38
Agree	33	38	30	101
Strongly agree	9	8	11	28
Total	69	82	69	220

Pearson chi2(8) = 6.9873 Pr = 0.538

Table E14. Treatment groups and environment

	Default option	Feedback	Control	Total
Strongly disagree	2	7	4	13
Disagree	14	3	15	32
Neutral	31	40	35	106
Agree	18	29	13	60
Strongly agree	4	3	2	9
Total	69	82	69	220

Pearson chi2(8) = 17.5422 Pr = 0.025

Table E14. Treatment groups and reliability

	Default option	Feedback	Control	Total
Strongly disagree	49	38	47	134
Disagree	2	4	1	7
Neutral	3	15	11	29
Agree	15	12	21	48
Strongly agree	0	0	2	2
Total	69	69	82	220

Pearson chi2(8) = 16.6570 Pr = 0.034

Table E15. Treatment groups and social status

	Default option	Feedback	Control	Total
Strongly disagree	31	44	31	106
Disagree	24	25	19	68
Neutral	11	9	13	33
Agree	1	4	5	10
Strongly agree	2	0	1	3
Total	69	69	82	220

Pearson chi2(8) = 7.9086 Pr = 0.442

Table E15. Treatment groups and cost

	Default option	Feedback	Control	Total
Strongly disagree	1	2	0	3
Disagree	2	4	4	10
Neutral	13	17	15	45
Agree	43	43	38	124
Strongly agree	10	16	12	38
Total	69	69	82	220

Pearson chi2(8) = 3.6822 Pr = 0.885

Appendix F

Binomial logistic regression

Table F1. Binomial logistic regression table

Log likelihood = -122.22463	Number of obs = 218 LR chi2(12) = 45.24 Prob > chi2 = 0.0000 Pseudo R2 = 0.1562

Variable	**Coefficient**	**Std. err.**	**z**	**P>z**	**[95% conf. interval]**
Nudge					
Default	0.630	.382	1.65	0.099	[-0.118;1.379]
Feedback	1.640	.412	3.98	0.000	[0.832; 2.448]
Reliability					
Disagree	0.438	0.964	0.45	0.649	[-1.452; 2.328]
Neutral	1.346	0.619	2.17	0.030	[0.132; 2.559]
Strongly agree	-0.133	0.438	-0.30	0.762	[-0.991; 0.726]
Strongly disagree	0	(empty)			

Relaxation					
Disagree	-0.659	0.622	-1.06	0.289	[-1.878; 0.560]
Neutral	0.0373	0.382	0.10	0.922	[-0.712; 0.787]
Strongly agree	0.279	0.636	0.44	0.662	[-0.969; 1.526]
Strongly disagree	0	(empty)			
Environment					
Disagree	-0.898	0.534	-1.68	0.093	[-1.945; 0.149]
Neutral	-1.301	0.428	-3.04	0.002	[-2.141; -0.462]
Strongly agree	0.345	1.163	0.30	0.767	[-1.934; 2.624]
Strongly disagree	-1.969	0.718	-2.74	0.006	[-3.376; -0.562]
Constant	0.561	0.480	1.17	0.243	[-0.380; 1.502]

*Note: ***p-value<0.01, **p-value<0.05, *p-value<0.10, No asterisk: p-value>0.10.*

Appendix G

Survey

Introduction

Hello! Currently, I am conducting research on the use of Google Maps for my master's thesis at Erasmus University Rotterdam. I kindly request 3 minutes of your time to complete this survey. Please feel free to provide your honest opinion.

If you would like to learn more about this research and its results, please contact me at this email address: maximeessaadi@gmail.com

For the best experience, it is recommended to complete this survey on your mobile phone.

If you agree with the following statements, please click on Continue:

1. I am 18 years of age or older.
2. I understand that I can ask questions about the survey at any time (questions can be directed to maximeessaadi@gmail.com).
3. I understand that I can withdraw from participating in this survey at any time without any consequences.
4. I understand that the results will be presented only at a group level and cannot be traced back to an individual.
5. I understand that the data from this survey will be stored anonymously with password protection for a maximum of 5 years after publication.

Screener

Do you currently reside in the Netherlands?

Yes

No

How often do you use the following modes of transportation on average per week?

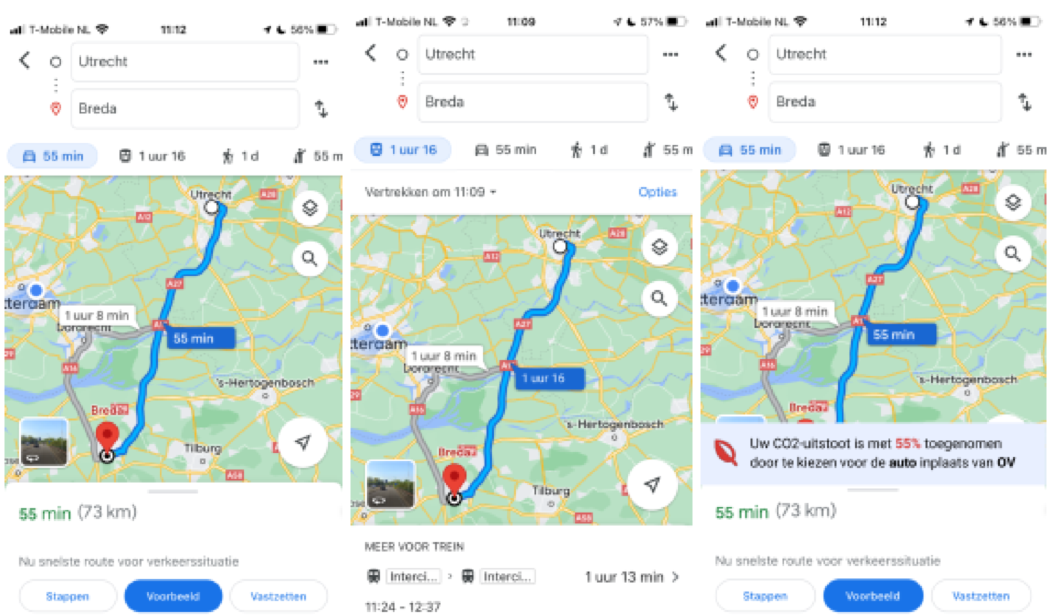
	Never	1-2 times per week	3-4 times per week	>4 times per week

Car	Car Never	Car 1-2 times per week	Car 3-4 times per week	Car >4 times per week
Public transport	Public transport Never	Public transport 1-2 times per week	Public transport 3-4 times per week	Public transport >4 times per week
Bike	Bike Never	Bike 1-2 times per week	Bike 3-4 times per week	Bike >4 times per week
Electrical car	Electrical car Never	Electrical car 1-2 times per week	Electrical car 3-4 times per week	Electrical car >4 times per week

I will now present a hypothetical scenario:

Imagine that you are planning to travel from the centre of Utrecht to the centre of Breda. You are using the Google Maps mobile application to check your travel time and you experience the following:

Experiment



Questionnaire

Which of the following modes of transportation would you choose to travel from the centre of Breda to the centre of Utrecht?

Car

Public transport

Electrical car

Other

Which of the following modes of transportation would you choose to travel from the centre of Breda to the centre of Utrecht?

Car

Public transport

Electrical car

Other

Which of the following modes of transportation would you choose to travel from the centre of Breda to the centre of Utrecht?

Car

Public transport

Electrical car

Other

How often do you travel from the centre of Utrecht to the centre of Breda per month?

Never

Once

More than once

How often do you travel from the centre of Utrecht to the centre of Breda per month?

Never

Once

More than once

How often do you travel from the centre of Utrecht to the centre of Breda per month?

Never

Once

More than once

Motility framework - Attitudes

In the following section, please indicate to what extent you consider the mentioned factors when choosing your mode of transportation.

When choosing a mode of transportation, I consider the following factors:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Time efficiency	Time efficiency Strongly disagree	Time efficiency Disagree	Time efficiency Neutral	Time efficiency Agree	Time efficiency Strongly agree
Comfort	Comfort Strongly disagree	Comfort Disagree	Comfort Neutral	Comfort Agree	Comfort Strongly agree
Whether I can transport goods.	Whether I can transport goods.	Whether I can transport	Whether I can transport	Whether I can transport	Whether I can transport goods.

	Strongly disagree	goods. Disagree	goods. Neutral	goods. Agree	Strongly agree
Relaxation	Relaxation Strongly disagree	Relaxation Disagree	Relaxation Neutral	Relaxation Agree	Relaxation Strongly agree
Safety	Safety Strongly disagree	Safety Disagree	Safety Neutral	Safety Agree	Safety Strongly agree
Environmentally friendly	Environmentally friendly Strongly disagree	Environmentally friendly Disagree	Environmentally friendly Neutral	Environmentally friendly Agree	Environmentally friendly Strongly agree
Reliability	Reliability Strongly disagree	Reliability Disagree	Reliability Neutral	Reliability Agree	Reliability Strongly agree
Social status	Social status Strongly disagree	Social status Disagree	Social status Neutral	Social status Agree	Social status Strongly agree
What other do around me	What other do around me Strongly disagree	What other do around me Disagree	What other do around me Neutral	What other do around me Agree	What other do around me Strongly agree

Cost	Cost Strongly disagree	Cost Disagree	Cost Neutral	Cost Agree	Cost Strongly agree

Motility framework - Skills

Please select your age

18-24

24-34

35-44

45-54

55-64

>65

Prefer not to say.

Please select your gender.

Male

Female

Non-binary / Third gender

Prefer not to say

Please select your level of education.

Primary education

Secondary education (vmbo, havo, vwo)

Intermediate vocational education (mbo)

Higher vocational education (hbo)

Higher education/University education (wo)

Other (specify)

Do you have your driver's licence?

Yes

No

Motility framework -

Access

Do you have a car?

Yes

No

What is your yearly income?

Less than average.

Average.

More than average.

Prefer not to say.

What is the size of your household?

1

2

3

4

5

more than 5

Thank you for taking the time to participate in this survey.
This survey was about promoting the use of public transport through Google Maps. In this study, I examined the effectiveness of two influencing techniques: feedback and the default option. Feedback highlighted the environmental impact of choosing the car over public transport, while the default option preselected public transport in Google Maps.

Your responses have provided insights into the effectiveness of these influencing techniques in influencing mode choice. The findings will contribute to knowledge on sustainable transportation practices and inform policymakers.

We genuinely appreciate your participation. If you have any further questions, please feel free to contact me at maximeessaadi@gmail.com.

Your response has been recorded.