Nudging residents to increase active commuting: a field experiment with Bergen City Bike

Case study context. Norway has a relatively low % bicycle share of daily trips among the Active Cities project countries: more than 5 times lower than the world's benchmark of the Netherlands, less than neighboring Denmark (almost three times) and Sweden (two times) (Harms & Kansen, 2018). At the same time, Norway is in 5th place in bikes per person (61%), behind in the ranking relative to the Netherlands (99%), Denmark (81%), Germany (75%), and Sweden (64%) (Jones, 2023). In terms of motorization rates, Norway is a little bit below the European Union average (Statista, 2023). Even though there is no explicit national cycling strategy in Norway, a similar document is in place (Colli, 2022). Combined, this provides a promising base for testing nudging as an active mobility promotion method through sharing bike services. Additionally, a recent intervention experiment giving out free E-bikes for different periods for previously inactive categories of people in three Norwegian cities (including Bergen) showed that it had a positive effect on promoting physical activity and active commuting outside of that study (Mildestvedt et al., 2020). Hopefully, this experiment, regardless of the effectiveness of nudging intervention, would also contribute to these aspects as there is evidence that active transport intervention has a positive impact on overall physical activity (Norwood et al., 2014).

Motivation and Background

Transportation is among the main contributors to climate change and accounts for almost a quarter of global greenhouse emissions worldwide (Schelte et al., 2021). However, it has significant room for improvement to become more environmentally friendly. A relatively new form of urban transportation – shared mobility – deserves more attention, considering its potential to contribute to sustainable development (Shaheen, 2020). Shared mobility can be an efficient first and last-mile solution (Shaheen & Chan, 2016), especially in the context of Bergen, where there is no vast public transportation system with only one transit line of the light rail system. In comparison, in Oslo, where there's the same bike-sharing system but a more developed transit network exists, this year's average trip length is 7:33 minutes – and the densest placement of stations that can be found is in the city center (How It Works - Oslo City Bike, 2023). This research can also help contribute to understanding behavioral transportation patterns in Bergen, which in turn can help create multi-modality hubs that will allow making the city center car-free (Mobility Hubs, 2021).

Contrary to hard measures (like regulating policies and infrastructure improvements), soft measures (i.e., information provision and marketing) prove to have a more tangible impact; however, studies demonstrate that simply providing rational reasoning in many cases is not enough (Lehner et al., 2016). Behavioral economics offers one of the solutions to promote sustainable transportation, a method that effectively works on ways to change citizens' transportation modes – nudging, which can be described as "any aspects of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein, 2009, p. 6; Metcalfe & Dolan, 2012). Its impact on stimulating more sustainable behavior has been investigated in the last decades (see i.e., S. Franses et al., 2021; Lieberoth et al., 2018). Some of the studies were particularly devoted to transportation, but active urban mobility has only lately started getting attention in this kind of research, for example, in promoting the safety of cyclists (Wallgren et al., 2020). Nonetheless, nudging does not always achieve a positive impact. A study showed that large organizations with a total amount of 68,000 employers used nudging techniques to promote carpooling among workers but did not achieve any positive effect on changing transport behavior (Kristal & Whillans, 2020). Another study involving over 14,000 individuals also failed to shift transport behavior using nudging methods in the form of social norms (Gravert & Collentine, 2021). In both studies, nudging was aimed at rational thinking rather than at intuitive everyday choices, which could be a potential weakness. Thus, it will be taken into account in the design of this proposal. In general, nudging treatments prove to be statistically significant in 62% of cases with a median effect size of 21% (Hummel & Maedche, 2019), which presents some challenges for designing future interventions.

Relevance & novelty

Sustainability concepts are becoming ordinary in the everyday reality of western countries; however, it is still debatable whether sustainable behavior itself has become a social norm (Hechter & Opp, 2001). Many recent studies provide vast evidence that social norms can play a crucial role in promoting sustainable behavior, even if that behavior is not yet a norm itself (see e.g., Cialdini & Jacobson, 2021; Yamin et al., 2019). Taking this into account, future research will use it as one of the nudging intervention instruments by framing sustainability as a descriptive social norm (Cialdini, 2007), which also corresponds with the social dimension of the EAST model (Lehner et al., 2016; BI Team, 2014). The other type of nudging – simplification – will be used via the instrument

of gamification, which matches the attractiveness and ease principle of the aforementioned model (see Figure 1). Even considering its potential, the impact of shared mobility on sustainability is still rather unclear (Santos, 2018), therefore focusing on one of its forms through this research will hopefully add some clarity. As such, *this field experiment **aims** to test the effectiveness of two nudging techniques, framing, and gamification, combined into one intervention on changing transportation behavior towards greater use of cycling as one of the most sustainable forms of active mobility* (Cycling Facts and Figures, 2017).

Q1 Does the proposed nudging treatment lead to changes in average time spent on bike per user?

Q2 Does the proposed nudging treatment influence the intention to commute by bike?

Research design and methodology

Sustainability framing. Contrary to game theory, the design of this research is not aimed at testing the rational intentions and strategies of the users of Bergen's city bike service under certain potential payoffs (Camerer, 2011), but rather puts two groups in an apparent similar situation that they all have free access to bikes for a month. Tools used for the experiment group will reframe information about users' sustainable impact from their rides in a simplified and intuitive design presented as behavioral feedback (Lieberoth et al., 2018), which aims to influence fast-thinking System 1 with the added deliberative elements for the slow-thinking System 2 (Kacheman, 2011). One field experiment in Rotterdam testing intervention in public transportation showed a positive effect from incorporating messages that positively label passengers as sustainable travelers in their communication strategies (S. Franses et al., 2021). Nevertheless, as previously mentioned, a soft strategy centered on the rational reasoning of the passengers being environmentally friendly not always proves to be enough on its own for changing established transport behaviors. Thus, the framing technique will be enhanced through gamification elements aiming to increase commuting in the experiment group.

Potential aspects for sustainability framing: CO2 emissions saved per trip (compared to different modes of transportation), energy savings, reduced air and noise pollution.

Gamification. It has been studied that mobile applications can encourage greener travel choices (see i.e., Froehlich et al., 2009; Rahman et al., 2012). A controlled field experiment in Denmark studying selective psychological effects of nudging, gamification, and rational information in converting commuters from cars to buses showed that though no big difference was identified between them, the most feasible psychological impact came from the gamification technique, which deserves future research implications (Lieberoth et al., 2018). This type of nudging instrument also showed effectiveness in promoting walking in Vienna (Wernbacher et al., 2020). Mobile technologies prove to be an efficient instrument to apply behavioral changes, including nudging (see i.e., Zhao & Baird, 2014; Baird, 2014). Furthermore, user interface design can directly influence people's choices (Schneider et al., 2018).

In the intervention, gamification will be presented as a reinforcement tool for sustainability framing. Taken together, they can be called a *gamified sustainability framing* and act as the treatment for future intervention.

Correspondence of nudging with the EAST model. Emphasis will be placed on the *social dimension* of the EAST model. Firstly, messages that will show that sustainable behavior is socially acceptable and valuable will be incorporated into the app, framing it as a descriptive social norm; secondly, the app would act as a kind of social network, where people can observe who performed most of the rides, etc., which will encourage participants to make commitments – both for themselves and other riders (BI Team, 2014). In its turn, the gamification design will focus on the principles of *attractiveness and ease*: it will simplify sustainability messages with the help of visualisation and use elements to attract attention, such as virtual badges, rewards, and other incentive programs (see Figure 1) (BI Team, 2014).

Methodological framework: quasi-experiment. **Method:** case-control study

The null hypothesis (H0) is that nudging intervention will not stimulate Bergen's city bikes usage (the difference between the two groups' means will be zero). The alternative hypothesis (H1) is that nudging intervention will stimulate the use of Bergen's city bikes (the difference between the two groups' means will be not equal to zero).

Future research would use both quantitative and qualitative types of information, as it would help improve internal validity and provide insights into treatment effects (i.e., during post-intervention surveying and observations) as was proven effective in the evaluation of a program promoting active mobility (Crawford & Garrard, 2013).

Recruiting participants. The whole experiment will be performed under the **condition** of free access of participants to the bike-sharing service of Bergen, meaning that control group (G1) and experiment group (G2) both will be given free monthly passes to ride city bikes (currently, the subscription with the limit of a free hour ride costs around seven euros). This will allow focusing on the nudging treatment, omitting economic incentives. The minimal desirable number of participants for each group is around 200, considering that the working population of Bergen is over 100.000 people and the precision level (sampling error) would be ±5% (Israel, 1992). Selection could be classified as non-probability sampling, but it will aim to be as representative as possible to tackle research biases and include a wider group of the population than the existing users of the city bike app who would be targeted during the pre-intervention stage. Especially it can focus on those who do not yet use the city bike service. Also, through social awareness campaigns, the experiment could specifically target parents, as they can most benefit from cycling popularization. Already registered but inactive users can be additionally motivated.

Preparing intervention. A set of respondents will be asked to fill in the categorical questionnaire before enrolling in the experiment about their age, gender, family status, income, education obtained, distance to work, and district of residence (Survey 0). Only three of these indicators (gender, age, and residence) will be used to mix participants on the principle of randomization to assign them into two roughly similar groups (control and treatment) to achieve homogeneity of variance, minimize standard deviations and differences in means between two groups. After the distribution, they will be given unique IDs so that half of them can receive nudging treatment. Before the intervention as a part of the pretest, both groups will be also surveyed to find out their current travel behavior, especially whether they use a bike as a way of transportation (Survey 1). G1 will be then blindly tested for one month with the use of two nudging techniques – gamification and sustainability framing – combined into one.

Dependent variable: *bike rides*. The dependent variable in this research is the average time on a bike spent by each user, which will be either automatically calculated by the app or manually in the analysis by dividing the total number of rides by the total time per user. It should act as a main indicator for testing the effectiveness of the intervention on continuous data.

Secondary dependent variable: *intention to commute by bike*. The secondary dependent variable will be based on ordinal data from the survey. The influence of the intervention on responses to a question asking about the likelihood to choose a bike as a way of commuting will be evaluated. To see if there were any changes and differences post-intervention (posttest) surveying will be conducted, where participants will be asked the same questions as before, plus some additional ones (Survey 2).

Independent variable: *nudging*. Two nudging techniques are combined into one predictor variable to see how intervention can affect the average time of bike usage and intention to commute by bike.

(For more information see: the operationalization table (Table 1) and schemes (Figure 1,2,3) in the Appendix)

Citizen engagement to improve the research design

Focus groups. Primarily, focus groups will center on understanding travel behavior and mode selection, considering bikes and city bikes in particular. This will help to develop a more accurate questionnaire for pre- and post-intervention surveying. Another important aspect to be evaluated during focus groups is people's perception of sustainability: how they react to different messages and what can potentially influence their travel choice the most. Based on that, more case-related sustainability framing could be performed. Ideally, different focus groups can be formed on the principle of the segmentation approach (Markvica et al., 2020) to better understand variances between different categories of citizens.

Focus groups can be strengthened with the method of **deliberative polling** (Fishkin, 2003). Essentially, participants' opinions on the matters of active mobility and sustainability would be measured before and after the process of deliberation through surveying and/or interview (main patterns can be later identified with the help of Atlas.ti software), as the presented dialogue space will aim to create informed opinions among them (O'Doherty, 2017). These measures of the influence of informing will help to assess the potential impact and possible effects of future intervention. But even more importantly, a more targeted and comprehensive social awareness campaign for one month of free city bike passes can be created. In theory, if focus groups would also identify explicit groups

of bike users, the questionnaire might be modified so that more than one treatment group would be included in the intervention. For example, a recent study showed that a high level of life satisfaction and environmental friendliness have a positive impact on cycling frequencies, so these (or any other) categories can potentially act as a division principle for different treatment groups (Barbour & Mannering, 2023). That being said, deliberative polling during focus groups can have a strong positive impact on the improvement of the final research design.

The whole research project could benefit from using the **citizens' science practices** (Bonney et al., 2014). In the preintervention stage, volunteers could be involved in the awareness campaigns which could allow to include in the experiment those categories of citizens who are currently not using city bikes or even cycling as a way of transportation. Along all stages volunteers could be involved in observations next to bike-sharing stations: during the pre-intervention stage, it could significantly improve research design (i.e., could lead to a new independent variable as bikes' conditions in different locations) as there are likely to be some local issues and patterns (i.e., due to differences in their conditions, people can frequently change rented bikes in certain places). The aforementioned practices can also contribute to establishing tactical urbanism elements (Lydon & Garcia, 2015).

Testing the intervention

The open-source data is available at Bergen City Bike (*Historical Data - Bergen City Bike*, 2023) in CSV format and presumably additional data from the experiment will be shared from the Bergen City Bike, which can be processed and analyzed through software programs such as STATA, R or even Python (if needed).

Preliminary analysis

To start, the *K-sample Anderson-Darling test* can be conducted to prove or deny that collected observations from two groups are coming from a similar population, which was tried to be reached in the pre-intervention randomized distribution. After that, a *2-sample t-test* can be performed to see if the conducted treatment shows any statistical significance between the two groups ($P<0.05$). T-test can be reinforced with *Cohen's d* analysis to see the effect size of the treatment measured in the difference between the two groups' means. Optionally, *Bonferroni analysis* can be done to avoid false positives (Type 1 error).

Primary analysis

Regression analysis. Provided that the P-value is <0.05 in the t-test, linear regression analysis / Ordinary least squares regression (OLS) can be conducted using STATA or R. *Dummy coding* is needed as the independent variable (χ) is categorical data: treatment will be coded as 1, and its absence as 0.

$$\gamma_i = \beta_0 + \beta_1 \chi_1 + \varepsilon_i$$

Where: γ_i – bike rides (dependent variable)
β_0 – the intercept; β_1 – the gradient

Minimal parameters reflecting the strength of the regression model of treatment (independent variable) and time spent on a bike (dependent variable) in the regression model:

- Rejecting the null hypothesis: t-statistic should be greater than the t-critical
- T value: > +/-2 (higher magnitude higher evidence against H0)
- Standard error of the coefficient: observations fall into +/-1.96 standard error of the regression (accuracy of the model, estimates 95% prediction interval)
- R squared: >0.7 (how much of the variance (%) in time spent on a bike can be explained by intervention – *can act as a main indicator for the effect size*) (Kelley & Preacher, 2012).

If all of them are met, then it can be stated that this kind of intervention was effective. Some of the parameters may not fall into the provided intervals – in that case, it would still be possible to adjust the model. For example, new independent variables can be added from Survey 0, such as family status, income, education obtained, and distance to work to see if there is any explanatory power of them for the dependent variable. Furthermore, adding these parameters to the model can additionally mitigate the risk of omitted variable bias.

Alternative tools:

- If not create dummy variables, then a *one-way analysis of variance (ANOVA)* test is required, as there is only one categorical predictor variable in this research. If for some reason we assume that data from bike rides don't fall under normal (Gaussian) distribution then a *Kruskal-Wallis Test* can be done instead.
- If more treatment groups would appear (i.e., distributed based on different levels of nudging treatment) after conducting focus groups or due to other factors, then a *two-way analysis of variance (ANOVA)* test would be an appropriate measure of the effectiveness of an intervention.

- If more independent variables (>3) would be introduced during the design improvement, then *multiple regression analysis* would be the most suitable tool.

Secondary analysis

In the current version of the research design, the most applicable testing method for the secondary dependable variable would be *ordinal logistic regression*, which will allow seeing changes in intention to commute by bike compared to pre- and post-intervention between two groups, using three levels: if they decreased, stayed the same, or increased. For a better understanding of surveying data, it is also reasonable to conduct a measure of frequency for different parameters: for example, to better understand variances in answers based on gender.

Additional analysis:

1) Look for changes in the dynamics of bike usage per day between two groups to see on a graph if there was any intervention influence over time.
2) Evaluate participants' engagement by comparing the average time spent on the app per user between two groups. If this kind of data will be available from the city bike app, then the same linear regression analysis can be conducted as in the primary analysis. Even if no significant difference between controls and treatments would be found in terms of bike rides, this indicator can show if there is any psychological effect of sustainability framing using the gamification technique. Besides, testing users' engagement can help to improve the app regardless of the intervention, so developers can be suggested to do A/B testing from their side (Kohavi & Longbotham, 2016)
3) Look for a correlation between patterns of travel behavior (what type of activity the bike is used for), and the likelihood of taking a bike as a way of transportation (presented as ordinal data from the surveying). These questions will be asked in pre- and post-intervention stages, so the differences in correlation between the two groups can be observed.
4) Compare differences between the two groups in intention to renew the subscription to city bike service (from post-surveying) – can act as an additional indicator for evaluation of intervention effectiveness.
5) Try to identify potential spillover effects from the intervention (Francetic et al., 2022). For instance, treatment could lead to changes beyond the transportation behavior patterns, or the whole condition of free access to city bikes could create too much load on certain parts of public infrastructure and increase levels of unsafety. This information can be collected through open optional questions in the post-intervention survey or random selection interviews, and further coded in Atlas.ti software. Finally, observations of volunteers next to city bike stations could point out possible spillover effects as well.

Additional information for the proposed study

It's preferable to conduct intervention not in the summer months as during them a lot of city bike rides can be done for leisure activities and there is a feasible effect from touristic inflow, while the focus of this study is to mainly look at the use of the bicycle as a mean of transportation.

Limitations

The sample of the study is likely to be not true representative of the general population. Other variables apart from nudging are not taken into account which can potentially lead to omitted variable bias in the analysis and conformation bias in the results. To tackle these challenges, close cooperation with Bergen's citizens and municipality is needed to conduct a proper social campaign and engage a wide category of participants during the pre-intervention stage. Furthermore, in the real world, city bikes are not free, thus, theoretically, economic incentives can prevent their use but that seems unlikely as now their price is lower than public transportation. Finally, this field experiment would not be able to include children under 16 and people without smartphones.

Other involved parties

Essentially, this study would be impossible without Bergen Bysekkel's active participation. Additionally, experts from the biggest Norwegian environmental certification scheme Miljofyrtarn could contribute to sustainability framing methodology and various UX/UI designers could help improve gamification techniques.

Future implications

If proven effective, sustainable framing with elements of gamification can be used in future versions of the Bergen Bysykkle app for all users, as well as in the cities of Oslo and Kristiansand (as their city bike rental systems are also a part of Urban Infrastructure Partner company) to promote cycling. Beyond city bike rental these methods can be studied further and applied in a wide range of other forms to popularize active mobility and sustainable behavior, which will hopefully create a platform for livable cities with zero-carbon multimodality. Regardless of the results, this study hopes to contribute to the development of co-creation schemes that could help promote active mobility more effectively (Agusti et al., 2014).

Appendix:

Table 1. Operationalization table

Type	Variable	Indicator	Data type	Source
Dependent variable	Bike rides	Average time on bike spent by each user (sum of time of every ride divided by the number of rides)	Continuous	(Open) data for all rides from Bergen Bysekkel with the connection to users' IDs
Secondary dependent variable	Intension to commute by bike	Changes in desire to choose a bike as a means of transportation	Categorical (discrete)	Pre- and post-intervention surveying/interviewing
Experimental independent variable	Nudging	Gamified sustainability framing	Categorical (Binary)	Control vs. experiment group

Figure 1. **Nudging context**

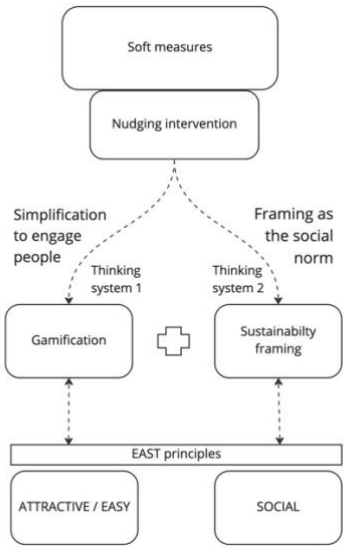


Figure 2. **Variables relations**

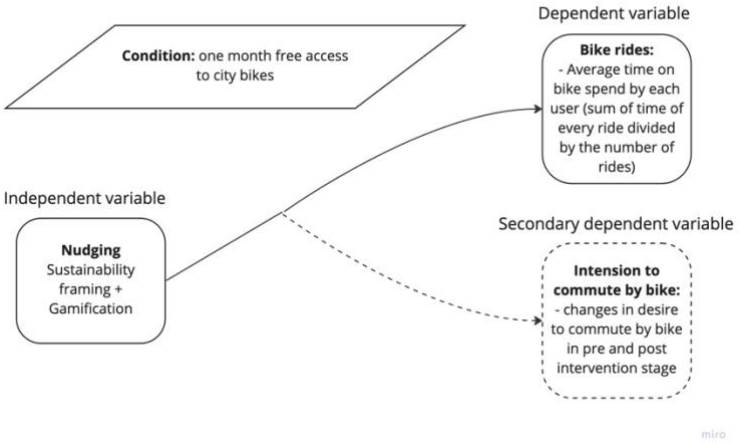
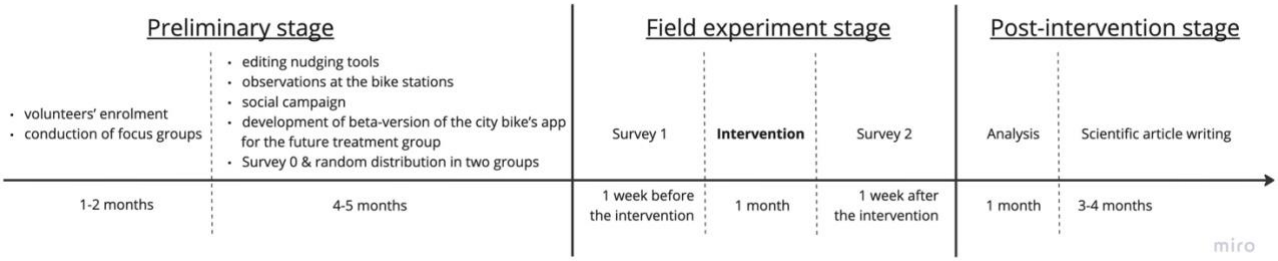


Figure 3. Timeline (*total time: around 1 year*)



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