How to Use Data to Increase Bike Use by Travelers

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Abstract The Government of the Netherlands wants to be energy neutral by 2050 (Rijksoverheid, sd). A transition towards non-fossil energy sources also affects transport, which is one of the industries significantly contributing to CO2 emission (Centraal Bureau Statistiek, 2019). Road authorities at municipalities and provinces want a shift from fossil fuel-consuming to zero emission transport choices by their inhabitants. For this the Province of Utrecht has data available. However, they struggle how to deploy data to positively influence inhabitants' mobility behavior. A problem analysis scoped the research towards data to stimulate cycling. Three interviews, desk research and a survey revealed the gap between the province's current data-item approach that is infrastructure oriented and the required approach that adopts traveler's personas to successfully stimulate cycling. For this more precisely defined captured data is needed and the focus should shift from already motivated cyclists to non-cyclers.

Keywords: zero emission, mobility behavior, transport choice, data driven mobility.

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1 Introduction

The European Government's sustainability goal to reach zero-emission by 2050 provided the trigger for this research (Rijksoverheid, n.d.). The Province of Utrecht (hence province) exists of twenty-six municipalities that together present an estimated number of 1,36 million inhabitants (Provincie Utrecht, 2019). Each municipality and the province itself perform the role of road authority. The province questioned their utilization of available mobility data as a mean to change inhabitants' behavior about their day-to-day transportation modality choices. To date, the use of available data from different external data providers has not delivered the expected results. Currently, the Netherlands hosts 22.8 million bicycles with an average of 1.3 bicycles per citizen (Fietsersbond, 2020). With annual sales reaching between the 900,000 to 1,400,000 bikes (Railvereniging, 2021) of which 50% are currently e-bikes the province wants to turn these available assets into 'zero emission' transport options. Analyzing all twenty-six mobility plans of the municipalities showed 38% the word 'bicycle' and 32% the word 'car'. All plans showed a strong interest in *how to replace the car by bike trips*. This narrowed the research scope of this study down to the bicycle as transport modality. Although the well-developed cycling infrastructure in the Netherlands helped reducing car trips in general, the road authorities want to further increase transport by bicycle. For this, available bicycle-data need to become indicators that positively influence mobility behavior. Therefore, the research question formulated is: *"Which data leads to specific information that helps road authorities to nudge travelers' mobility choice towards bicycle use?"* This main question led to three sub-questions:

1. What factors positively stimulate the traveler's decision to use a bicycle?
2. Which factors related to stimulating bicycle use can the province obtain from the twelve bicycle-data-items?
3. Which differences form the gap between the twelve bicycle-data-items of the province and that of the travelers' decision factors found at sub-question one?

This paper presents a theoretical background followed by the research approach. Subsequently, the research results, conclusions and recommendations to the province follow. The paper ends with limitations and a discussion.

2 Theoretical backgrounds

In 2005 the EU started to address sustainable mobility in the thematic strategy on urban environment (EC, 2005). In 2009, this grew into the Sustainable Urban Mobility Planning (SUMP) approach and within four years a guideline for use by municipalities of the EU countries was added (EC, 2009; EC, 2013). Different studies show that the success of adopting SUMP in EU countries depended on municipalities goals and vision that often miss climate change and social equity. However, the SUMP itself missed specific guidance and a common framework for equity evaluation to offer equal assessments among cities (Urban Mobility Observatory, 2022) as well as adequate smart climate targets that are necessary to achieve the sustainable goals (Mozos-Blanco et al., 2018). The goal of zero emission increases the importance of available mobility data at a local level, e.g., presenting numbers and volumes of types of mobilities used as well as the motivation for a mobility choice. Therefore, regardless SUMP, the mobility transition requires a data driven approach as picked up by the provence.

2.1 Literature review

Prior to understanding the data driven mobility transition challenge of the province this study first defined the terms: *Mobility and behavior, City based transport,* and *Data driven mobility*. Using Google Scholar and HUGO (the university's search engine) resulted in 390,459 hits. Adding word combinations, trend information on travelers, commuters, and bicycle usage and adopting the snowball effect on useful references resulted in thirty-two useful articles.

2.1.1 Mobility

This study defines mobility as the empowerment of how people or objects can move (Hazelhorst, Metz, & Schreuders, 2005). As understood from SUMP, due to climate change Mobility needs proper planning. A mobility plan supports the traffic flow and helps to manage mobility (Frank Wefering, 2014). For social relevance municipalities' traffic policy should centralize the user and focus on explicit intra-municipality knowledge sharing (Klieverik & Tutert, 2011). Therefore, for this research a mobility plan for attracting cyclist must focus on the users of the municipality's cycle lane infrastructure, whilst the plan is also designed to manage

traffic flows from e.g., safety perspective. Our daily usage of means of transport influences our commuting choices (Zeiske, Werff, & Steg, 2021). Sustainable commuting needs sustainable modality choices and due to Covid-19 the bicycle proved to be safe, sustainable, and efficient (Fenu, 2021). Travelers can be inhabitants commuting between home and work, or persons travelling with another objective. This study concerns travelers, regardless their home location and travel objective. They travel in the province and/or cross its municipalities. This study leaves out travelers' behavior of being the e.g., conscious, forced, pro-health, or lifestyle cyclists (Biernat, 2018) due to the province missing such behavior data.

2.1.3 City based transport

The European committee asked European cities to adopt sustainable transport facilities and using eight sustainable principles for this (Urban Mobility Observatory, 2021): the plan must be for the entire functional city; have a long-term vision; cooperates across institutional boundaries; addresses all transport modes in an integrated manner; with involvement of citizens and stakeholders; includes monitoring and evaluation in its design; assesses current and future performance; and assures quality. Adaptation of sustainability also requires focus on *social equity* in supporting all inhabitants with their transport needs (Arsenio, Martens & di Ciommo, 2016).

Cycling as modality can be integrated with other zero emission modalities. It requires bicycle facilities as general term for infrastructure and services to encourage bicycle usage e.g., bicycle parking, storage possibilities, and special bicycle lanes, lighting, speed ways, etc. (Connecticut ATP, 2018). Safety and parking are important facilities influencing cycling behavior of citizens.

The transformation towards sustainable road transportation results in new business models e.g., sharing modalities (Sarasini & Linder, 2018). Flexible rental bicycles at train stations did reduce car use and increased train trips, and bicycle use for non-recurrent trips (Martens, 2020). However, these improvements are insufficient to reach the 2050 sustainability goals. Personal attitudes and preferences, residence, safety, the difference between destinations, and the time it takes to travel between these determine mobility behavior (Macharis, 2018) and therefore the adoption of cycling.

2.1.4 Data driven mobility

Zhang et al. (2021) show the complexity of using data to support travelling behavior in an organized city with various parts interacting with each other where achieving sustainable urban transportation and a resilient society are trends. Therefore the road authorities require data to guide the complex transition. With data driven mobility as viewpoint, this study's main subject is data and data-items.

3 Research approach

To answer the research question an evaluative, deductive research approach using multiple research methods is followed. Starting with desk research, a survey (quantitative research) and interviews (qualitative research) followed. Triangulation was performed managing the desk research data collection as primary, and the survey and interview data as secondary data.

3.1 Research model

A gap analysis determined the difference between the data required to nudge citizens to move from their car to a bicycle as means of transportation (SOLL situation) versus the data available (IST situation) at the province. The difference found is object to improvements to achieve the desired result by eliminating the gap (Vries, 2018). The SOLL situation as answer to the first sub-question was found through the 'conceptual state analysis' (CSA), because it offers the ability to develop an unbiased opinion without effects of investment in time or money in the past. The CSA process entailed: *defining* by deploying desk research, *inferring* by analysis, exploring via brainstorm sessions with the province data team and a survey, *reasoning about* via in-depth interviews, and *revising* conceptual attributes of a new situation and their possible values via evaluations (Mordecai & Crawlet, 2021). Next, the IST (second sub-question) was described by deploying desk research and in-depth interviews with the province data team. Desk research and in-dept interviews helped finding the gap (third sub-question).

3.2 Research methods

Through desk research the scope of the research narrowed down to the bicycle as means of transportation by travelers and provided insights in required data to stimulate cycling. The literature found formed the bases for the brainstorm sessions, the interviews and survey questions. The province data team supported to create a list of nineteen questions. Family, friends, relatives, and social media followers of the research team, including the members of the province formed the survey target group. They all received the survey via a Google Forms page. During the last two weeks of December 2021 the survey was placed online (LinkedIn, Instagram and WhatsApp). This resulted in 190 fully answered surveys out of 220 reactions. Sub-questions one and three used the outcome of the survey to validate the answers found through desk research.

Three in-depth interviews validated the reliability of the desk research findings. The interviewee were three different persons associated with bike use: the road authority of the Municipalities of Utrecht and of Amersfoort, and the 'bicycle mayor' of Utrecht. The data team of the province organized the interviews as digital meetings via Microsoft Teams. The interview questions were based on desk research and consultations with the research supervisor and were evaluated with the province data team. The interviews helped validating the desk research and the descriptions of the data-items.

4 Results

This section presents the findings in relation to the three sub-questions.

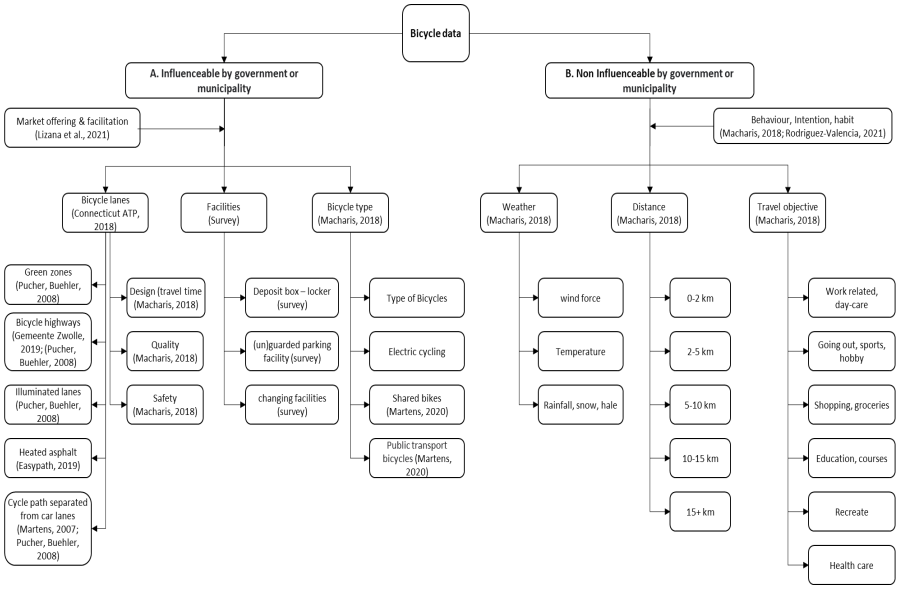
4.1 Factors that affect the choice to cycle

Based on desk research, brainstorm sessions, interviews, and subsequent analyses a framework of dimensions and underlying variables that influence the behavior of cyclists is developed (see Figure 1). Data regarding cycling has two dimensions:

(A) data that can be influenceable by the province and (B) data that cannot. Both have underlying dimensions of importance. Due to being influenceable this study focusses on Dimension (A) and its constructs: bicycle lanes, facilities, and the type

of bicycles. Next to behavior, these three constructs affect the transport modality choice of travelers. Consequently, the attractiveness of bicycle lanes depends on their quality and safety (Martens, 2007; ANWB, 2020). To improve safety on bicycle lanes solutions are available, such as bicycle highways with limited intersections and traffic lights (Gemeente Zwolle, 2019); heated bicycle lanes to prevent from freezing and improve safety while cycling in winter (Easypath, 2019); implementing LED lightning on bicycle lanes to improve safety during darkness with lights that react to movement and turn on when a cyclist passes by to help motorists notice the cyclists (Provincie Utrecht (2019).

Figure 1: Dimensions, variables and factors affecting cycling behavior



Facilities include amenities and accessories that cyclists require to make their travel more comfortable. A survey of January 2021 (BIM University of Applied Sciences Utrecht, 2021) shows that more than 50% of travelers find 'facilities' an essential decision factor for cycling. The survey of January 2022 zooms in at types of facilities at the arrival location that may influence the decision to go by bike. These are Secured bicycle parking 68.5%; Unsecured bicycle parking 35.5%; Bicycle province mp12.7%; Changing facilities 7.6%; Lockers 6.1%; Shower 5.6%. The secured bicycle parking makes a true difference in the modality choice.

4.2 Bicycle data province

The twelve available data-items and their priority according to the province does not fit the priority seen from a cyclist. The province rates data-items: *Bicycle parking (capacity and occupation); Travel behavior and motives; Insight demands and experiences bicycle;* and *Personal characteristics cyclist* as 'Low important' whilst desk research identifies these items as required to influence cycling. 'Medium' ranked data-items are: *Digital main grid; Type of bicycle (ownership and usage);* and *Supply and availability bike sharing* mainly because it is relatively easy to get these data-items. 'High' ranked are *Origin-Destination pattern, routes, speeds; Information bicycle infra characteristics; Use of cycling network;* and *Road safety*. This ranking is understandable, due to the influence the province has on these data-items.

Like *Travel behavior and motives,* it is important to identify the needs and the persona of cyclists because not every population group is equally willing to take the bicycle (Bakker, 2021; CBS, 2019). Also, the survey proved that people who cycle more, reduce their car movements. Understanding which groups can successfully be stimulated in behavior, will result in an increase in car replacements. However, the province priorities are with data related to infrastructure and traffic flow. Interviews show that opinions on the data-items vary from 'too much data, which leads to complexity' (Tiemens, 2021) to "there is never enough data, if you know what to do with it" (Hepp, 2021). Analyzing the twelve data-items shows ambiguousness and overlap e.g.: '*Use of cycling network*' and '*Origin-Destination pattern, routes, speeds*' both include the same routes, which questions the data structuring method (Hepp, 2021).

4.3 Data item similarities and differences

Table 1 shows similarities and differences in bicycle data between the SOLL (research) and the IST (currently available). The white cells in the table present a direct link between the IST and the SOLL which means that the described data-items of the province corresponded exactly with that of desk research. Next, the black cells present that a direct link is missing. '*Facilities'* and '*Weather*' are least noticed by the province as important factors that help to increase the number of active cyclers because of the impact these factors have on bicycle usage (Leunga & Linh Le, 2019). The province's focus is on infrastructure and facilities. The infrastructure is for 19.8% of the survey respondents not a trigger, because they

always cycle; 10% prefers lighted lanes at dark; and 16% likes separated lanes from cars.

Table 1: GAP between bicycle data model of researchers SOLL and province IST

Research based cycling construct: The 12 Bicycle modality data-items:	*Bicycle lanes*	*Facilities*	*Bicycle type*	*Weather*	*Distance*	*Travel motive*	*No. missing*
Using the bike network		■	■	■		■	4
Origin-Destination (OD) pattern, routes, speed		■	■	■			3
Digital basic network		■	■	■		■	4
Information Bike Infrastructure characteristics		■		■	■	■	4
Bicycle parking (capacity and occupation)	■		■	■	■	■	**5**
Translocation behavior and motives	■	■	■	■			4
Insight in wishes and experiences cyclist			■		■		2
Flow optimization traffic crossings		■	■	■	■	■	**5**
Bike sharing offering and availability	■	■		■	■	■	**5**
Personal characteristics cyclist	■	■		■			3
Bicycle type (owned and used)	■	■		■			3
Traffic safety			■		■	■	3
No. missing	5	**9**	8	**10**	6	7	

5 Conclusion

In this section we discuss the findings of each sub-question to subsequently provide an overall conclusion.

5.1 Sub-question 1

The first sub-question to answer is: *What factors positively stimulate the traveler's decision to use a bicycle?* As figure 1 shows there are 29 factors that influence the cyclist decision. With the interconnection at the level of the six constructs this data model

shows options to discover how to motivate cyclists to increase their numbers of trips by bike. For example, the fact that it is freezing in the Netherlands is uninfluenceable (variable weather), however, slippery frozen bicycle lanes can be improved by equipping these lanes with heating elements (variable bicycle lanes). The same factors will also improve the motivation of non-cyclers to support zero emission travelling and start cycling.

5.2 Sub-question 2

The second sub-question to answer is: *Which factors related to stimulating bicycle use can the province obtain from the twelve bicycle-data-items?* The twelve data-items used by the province are available from external sources and miss a detailed description of what each item presents. The province has no influence in how these data-items presents themselves and how and why (purpose) their partners capture the data. Therefore, the dataset the province uses, can be seen as an ad random set that exists through coincidence. Consequently, the users misinterpreted the data-items in practice. Also, among the twelve data-items overlap appears: The item *(OD) pattern, routes, speed* coincides with the item *Using the bike network*. Also, *Digital basic network* partly overlaps with *Information Bike Infrastructure characteristics*. Additionally, it is difficult to determine which data-item includes data about bicycles and cycling. The province ranked the four most valuable data-items found through this study as 'low' priority, whilst the survey showed a 68% on parking as motivator. Therefore, the province misses capturing and understanding the opinions and desires of the cyclist to nudge more cycling.

5.3 Sub-question 3

The third sub-question to answer is: Which differences form the gap between the twelve bicycle-data-items of the province and that of the travelers' decision factors found at sub-question one? The gap analysis shows that the IST has little emphasis on the constructs 'Weather' and 'Facilities' regardless the fact that both do have a major impact on cycling behavior and therefore directly impact the travelers' mobility choice (eleven out of the twelve data-items focus on the cyclist). Data item 2 Travel behavior and motives (Table 1) has a broader focus then the cyclist only. Through this item interest in defining persona's is possible. So far, the province

provided her service around the available data-items, instead of firstly defining data driven mobility management as service to the road authorities.

5.4 Overall conclusion

The most important conclusions concern the viewpoint by the province and the unstructured data-item approach. The current focus is what the cyclist does (once the cycler is on the road). However, to stimulate more inhabitants to become frequent cyclers demands focus on factors that influence bicycle use and the needs of the non-cyclists. The data-items *What distance the cyclist travels* and *What routes they use to reach their destination* indicate the strong focus on infrastructure. Therefore, the province misses stimulating non-cyclers. Unfortunately, the focus on the twelve data-items only, also limits the province in utilizing a broader range of information sources.

6 Recommendation, limitations and discussion

The province should upgrade the four data-items that link directly to the cyclist with grade 'high' to nudge travelers to (more) cycling and to improve the data-items description including their source and method of capturing. Only then the province can analyze data-items regarding their value as cycling motivating factor for their road authorities. Also, the province should adopt a data driven mobility management approach as a service. Adopting the newest tools of SUMP will be useful. On data itself a structured approach in which the cyclist is present as a persona, will help better understand the data-items needed.

The survey result is indicative. Next to a limited number the division of respondents misses accuracy because handing the survey out to friends and family members of the researchers. As a result, the respondents do not present the age, profession, and travel objective build-up of the Province of Utrecht.

Follow-up research will define and validate personas to better understand the (non-)cyclist; to adopt differences at city levels matter (Mitra et al., 2021); and to add findings from all twenty-six road authorities. Extension in developing the motivation factors found at Figure 1 will deepen the insights in how to reduce more emission by having the car replaced by bike trips.

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