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# A Preliminary Study

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**Short Paper Submission**

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# The Influence of the Route Environment on the Route Choice of Bicyclists: A Preliminary Study

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## Abstract

As bicycling as a mode of transport for everyday mobility gains increasing interest from both the public and from policy makers in Germany (Abt. 3 Verkehrsplanung, Referat für Stadtplanung und Bauordnung, Landeshauptstadt München, 2015) (Senatsverwaltung für Umwelt, Verkehr und Klimaschutz, n.d.) (Tomik, 2018), the need to include bicycling in the transport models that support policy evaluation procedures becomes pressing. This study used an online stated preference survey and discrete choice modelling to investigate the effects of route environment attributes on bicyclists' route choice in Berlin, Germany. Included among the attributes were two urban design characteristics, complexity and streetscape design. Both multinomial logit models with interaction parameters and mixed logit models with random coefficients were estimated. The results of these models show that both urban design characteristics have a significant effect on the route choice of bicyclists. The results also confirmed many hypotheses concerting the effects of route environment attributes, including several related to pavement types, motorized traffic volumes, and bicycle type used by the bicyclist. The results are also suitable to use as input for traffic modelling programs such as MATSim (Horni, Nagel, & Axhausen, 2016).

## Keywords

route choice; bicycle; route environment; urban design characteristics

# 1 Introduction

As bicycling as a mode of transport for everyday mobility gains increasing interest from both the public and from policy makers in Germany (Abt. 3 Verkehrsplanung, Referat für Stadtplanung und Bauordnung, Landeshauptstadt München, 2015) (Senatsverwaltung für Umwelt, Verkehr und Klimaschutz, n.d.) (Tomik, 2018), the need to include bicycling in the transport models that support policy evaluation procedures becomes pressing. The primary goal of this research project, which was performed in cooperation with a research project at the Institute of Transport Research of the German Aerospace Center (DLR), was to provide high quality data for discrete choice modeling and agent based transport models that would improve the ability of said models to reflect the choices of bicyclists: in particular, to explore which attributes of the route environment affect the route choice of bicyclists.

This study also expands upon the work of (Ewing & Clemente, 2013) (Ewing, et al., 2014), in which urban design qualities that affect pedestrian traffic volumes were identified, quantified, and tested for significance with respect to predicting pedestrian counts. In this study, one of the quantifiable urban design attributes defined by (Ewing & Clemente, 2013), "complexity", and another from (Ewing, et al., 2014), "streetscape design", were included as route environment variables in order to test the hypothesis that bicyclists' route choice is affected by the aesthetic urban design qualities of the route environment. This study is unique in that it uses discrete choice modeling to test if aesthetic urban design qualities have an effect on bicycle route choice, and as such contributes significantly to the growing effort to identify and quantify the effect of urban design on pedestrian and bicycle traffic and demand.

In this short paper, the study design and survey execution will be summarized. Next, the models that have been estimated thus far will be described. Afterwards selected results will be presented and further work will be discussed.

# 2 Study Desgin

The study design was adopted from the cooperating DLR project, namely the doctoral work of Ilil Beyer Bartana (Beyer Bartana, not yet published), which focuses on the surrounding route environment as a predictor for bicycle travel demand and for which this study served as a pre-test.

The attributes were chosen based on the outcomes of problem-oriented interviews with bicyclists in Berlin (Beyer Bartana, not yet published).

Each of the choice situations had two route alternatives that differed only with respect to differences in the levels of the aforementioned attributes, and as such were analyzed as unlabeled alternatives. Two "non-purchase" alternatives were provided to prevent participants who find both route choices to be unacceptable from biasing the results. These "non-purchase" alternatives were the option to choose a different bicycle route with a distinctly longer travel time (how much longer was left undefined) or to choose to not use the bicycle at all and instead to complete the trip via a different mode. The route alternatives were presented to the participants both visually, using carefully designed drawings, and in written form via short, supplemental written descriptions. The "non-purchase" alternatives were only described with written descriptions, since these "non-purchase" alternatives were not assigned attribute levels and thus needed to be analyzed as labeled alternatives. Two choice sets of seven choice situations each were developed. Each participant was randomly assigned one choice set.

These choice sets of Beyer Bartana were modified to accommodate the addition of the attribute "complexity" and in the process of doing so, the definition of "complexity" had to be adjusted. In particular, this meant omitting the following elements of complexity: the presence or lack of outdoor dining and the number of people present on the street (Ewing, et al., 2005). Both of these elements had been indicated as possible attributes during the problem-oriented interviews (Beyer Bartana, not yet published), and it had been decided to exclude these attributes from this particular study (Beyer Bartana, not yet published). After evaluating the feasibility of communicating this adjusted concept of "complexity" in the context of an online survey, it was decided to represent the concept with a contrast between historical Berlin neighborhoods built during the industrial revolution, colloquially known as "Altbaugebiete" in Berlin, and neighborhoods built in the decades following World War II. This choice was made because the historical neighborhoods display all aspects of complexity (many colors, public art - here in the form of building decorations -, and smaller building size (Ewing, et al., 2005)) and thus have higher complexity scores than the post-war neighborhoods, which often have larger buildings with fewer colors and fewer decorations or other forms of public art. Admittedly, this means that this study technically investigated the effect of historical buildings on route choice, but limitations in visualization skills prevented an investigation of complexity separate from building epoch. This simplification had a useful side effect, though: "Streetscape Design" could thus be defined during the analysis as a composite variable of "complexity" and the "actively used" level of the attribute "street environment", because streetscape design is, in the most simple terms, present when historical buildings are used actively (Ewing, et al., 2014).

The selection of relevant socio-economic and trip-specific attributes to be gathered via questions accompanying the choice sets was oriented towards identifying taste variations that could be modeled in MATSim (Horni, et al., 2016), an agent based transport model being developed by the TU Berlin and the Swiss Federal Institute of Technology in Zurich (ETH Zürich). The questions used to gather the socio-economic and trip-specific attributes were, when possible, based upon similar questions used in the 2008 Mobilität in Deutschland (Follmer, et al., 2010) study. The Mobilität in Deutschland (MiD) study is a re-occurring, nation-wide mobility survey, which, in various forms, has been conducted for the various incarnations of the German federal ministry of transportation since the mid-1970s (Follmer, et al., 2010).

# 3 Survey Excecution

The resulting stated preference survey was performed online using the survey software LamaPoll. In order to increase the likelihood that all participants had similar experiences with respect to those route attributes that were not specified and might have an impact on evaluating the choice situations, such as the prevalence of aggressive driving styles or the maintenance level of the infrastructure, or those attributes that were difficult to define succinctly for the general public, such as “complexity”, it was attempted to recruit only participants who had experience cycling in Berlin, Germany. Participants were recruited using e-mail lists from a Berlin-specific collegiate music organization, the recipients of Berlin-specific scholarships, an employee-to-employee email list of the Streetcar Division of the Berliner Verkehrsbetriebe, at an open-house at the DLR campus in Berlin, and through personal and professional contacts who were cyclists in Berlin. All participants were asked to forward the survey link to their contacts who were also cyclists in Berlin in order to further enlarge and diversify the recruitment pool. The only groups that were avoided were transportation researches and planners with expertise in bicycle traffic and members of bicycling advocacy groups, since members of these groups were likely to perceive the choice sets and make choices in a manner not representative of the general public. A chance to win gift certificates to local Berlin restaurants was offered as an incentive to complete the survey and to insure further that only those who regularly spend time in Berlin would participate. The resulting pool of potential participants numbered in the thousands, across all age, income, and educational brackets, although persons with university degrees were overrepresented. Over the course of three weeks, 454 complete responses to the survey were received, 425 of which were useable for the analysis, resulting in 2,975 useable observations due to the seven decisions each respondent made during the survey.

# 4 Modeling

A series of discrete choice models was estimated for the data. These models included multinomial logit (MNL) with interaction parameters and mixed logit (ML) models. The ML models utilized normally distributed random coefficients for selected route environment variables in order to capture panel effects.

In the following discussion, the socio-demographic and trip-specific variables shall be called framing variables and the route environment variables shall be called base variables. The selection of which interaction parameters to include in the models was not trivial, since questionnaire provided for 10 base variables and 22 framing variables (not taking into account the increase due to the coding of the nominal variables as dummy variables). It was decided to first test the interactions of the base variables with the framing variables of gender, education level, income, age, trip purpose, and bicycle type. Next, a methodical selection process was applied in which both taste variations for which there were well-defined hypotheses and for which there were no well-defined hypotheses were selected and tested for significance by estimating a series of MNL models. The consideration of taste variations for which there were no well-defined hypotheses was motivated by the desire to "let the data speak"; in other words, to explore the data to see if there were significant taste variations that had not been predicted, as long as those taste variations were reasonable.

The resulting MNL model had 42 parameters. This was the MNL model upon with the following ML models were based, and will be referred to as MNL-42. The decision to use a fairly lax significance level of 10% as the inclusion criteria for parameters during the interaction parameter selection process leading to the MNL-42 model was motivated by the fact that the significance of a parameter is influenced by which other parameters are also estimated in a model, and at this point in the process it was desirable to avoid dropping a variable that could prove significant in later steps. The log likelihood ratio test was applied during the selection process to ensure any addition of parameters improved model fit, and that any elimination of parameters did not decrease model fit. An excerpt from the MNL-42 model follows:

Equation 1: Excerpt from the model MNL-42

$$U_{in} = \ldots \beta_{cobblestone} * cobblestone_i + \beta_{\text{cobblestone\_roadbike}} * cobblestone_i * roadbike_n \ldots$$

Faced with the large number of significant interactions, it was decided to estimate panel effects only for the base variables present in the MNL-42 model (several levels of several attributes had proved insignificant). First, the random coefficients for the base parameters, which were assumed to have normal distributions, were added to the model, resulting in a model with 54 parameters. Subsequently, a winnowing process was performed, first for the random coefficients, then for all parameters. These intermediary ML models were estimated with 200 draws. During the last iteration of estimation and parameter elimination, a more stringent significance level of 5% was applied to all parameters, resulting in a model with 43 parameters that was estimated with 400 draws. The results of this 43-parameter ML model are discussed in the following section, "Results". An excerpt from the 43-parameter ML model follows:

Equation 2: Excerpt from the 43-Parameter ML model

$$U_{int} = \ldots \beta_{cobblestone} * cobblestone_i * (1 + \sigma_{cobblestone} * \eta_{cobblestone\ ,n}) + \beta_{\text{cobblestone\_ageGroup2}} * cobblestone_i * ageGroup2_n + \beta_{\text{cobblestone\_roadbike,n}} * cobblestone_i * roadbike_n \ldots$$

# 5 Results

The results of the aforementioned 43-parameter ML model support several important hypotheses concerning route environment attributes, such as that bicyclists strongly avoid cobblestone pavement ($\beta_{\text{cobblestone}}$ = -1.72, t-test = -9.72) and strongly prefer routes with no motorized traffic ($\beta_{\text{noTraffic}}$ = 2.05, t-test = 9.99). The relative magnitudes and signs of the parameters also conformed to the hypotheses.

The "complexity" of the route surroundings was also shown to be a significant factor in the route choice of bicyclists ($\beta_{\text{highComplexity}}$ = 0.28, t-test = 2.36), as was "streetscape design" ($\beta_{\text{highStreetscapeDesign}}$ = -0.61, t-test = -3.95). The sign of $\beta_{\text{highComplexity}}$ confirmed the hypothesis that complex buildings, or in this case, historical buildings, have a positive effect on route choice. The negative sign of $\beta_{\text{highStreetscapeDesign}}$ was initial surprising, but is plausible. (Ewing, Hajrasouliha, Neckerman, Purciel-Hill, & Greene, 2014) showed that a high value of streetscape design predicts high pedestrian counts. In the problem oriented interviews conducted by (Beyer Bartana, not yet published), there were indications that bicyclists in Berlin avoid routes with high pedestrian traffic. The negative sign of $\beta_{\text{highStreetscapeDesign}}$ could indicate that the survey participants perceived those routes with a high streetscape design as likely to have high pedestrian traffic, and thus avoided them in their decisions. As this study purposefully did not include the volume of pedestrian traffic as an attribute (Beyer Bartana, not yet published), it is not possible to tease apart the effects of streetscape design and the volume of pedestrian traffic on bicyclists' route choice, but this could be an interesting task for a future study.

Many taste variations related to both sociodemographic and trip-specific attributes were also shown to be significant, including several that confirmed hypotheses, such as that bicyclists that use road bikes avoid pavements other than asphalt more strongly than bicyclists using other bike types ($\beta_{cobblestone\_roadbike} = -1.56$, t-test = -2.88, $\beta_{flagstones\_roadbike} = -0.74$, t-test = -7.58), and several unexpectedly significant taste variations, such as that women are slightly more likely than men to choose the route with fewer traffic lights ($\beta_{Women\_\#TrafficLights} = -0.14$, t-test = -4.70).

These results provide a promising empirical basis with unusually well differentiated taste variations. They can, for instance, serve as input to enrich route choice models in transport models for bicycle traffic as they are e. g. developed in the context of the agent-based traffic simulation framework MATSim (Ziemke, Metzler, & Nagel, 2018). This study is also one of few to investigate the effect of urban design aesthetics on bicyclists' route choice using discrete choice models: a relationship that in the past has largely been investigated qualitatively. The results of these models provide quantitative evidence that urban design aesthetics do indeed affect bicyclists' decisions as well as providing parameters that can be used in agent-based transport models to model these decisions.

# 6 Further Work

There is further work is planned to improve the analysis and thus increase the confidence that can be placed in the accuracy of these results. Overfitting tests will be performed to verify that the data can indeed support such a highly differentiated analysis of taste variations. Furthermore, the skewed yet varied nature of the sociodemographic groups of the participants suggest that weighting the interactions using the demographic reference of the MiD studies as well as estimating the scale parameters of these different groups would be useful in improving the models and thus the results. It is the intention of the authors to complete these tests and estimations and to report their results at the conference in September.

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