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Observational Method and Coding Framework for Analyzing the Functionality of Unprotected Bicycle Lanes

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Abstract

This research evaluates how well unprotected bicycle lanes function as dedicated travel lanes for bicyclists. Two types of bicycle lanes are included in this study, including on-street bicycle lanes demarcated with painted lines on the vehicular roadway and bicycle lanes at-grade with, and immediately adjacent to, the pedestrian sidewalk. Specifically, the research is focused on how people behave and interact on street segments with these facilities in place. To assess how, and how well, these types of bicycle lanes function for the bicyclists using them, an observational method is deployed to record, document, and analyze people’s behavior and interactions. A three-step Straussian grounded theory coding procedure is used to systematically discover the categories of actions people engage in on street segments with unprotected bicycle lanes to determine what consequences these actions have for the infrastructure’s intended function. Based on a pilot study used to develop this coding procedure, this article presents a coding framework which will be validated and refined through a subsequent observational study.

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1. Introduction

Bicycle infrastructure is a required component of a sustainable transportation network. This is evidenced by policies set at all levels of government requiring or recommending the development of bicycle infrastructure as a tactic to curtail the demand for driving and increase the modal split of bicycling to meet greenhouse gas emission reduction targets. These sustainable transportation goals are coupled with municipal and federal goals for roadway safety. The
City of Munich, for example, aims to reduce the overall number of bicyclist fatalities and serious injuries as the volume of bicycle traffic increases over time (Landeshauptstadt München 2010, 20). To operationalize these interconnected, long-term policy goals, roadway engineering standards, design guidelines, and traffic laws are developed as blueprints for constructing bicycle infrastructure and regulating people’s behavior to create transportation networks that accommodate safe bicycle mobility. Germany’s National Cycling Plan strives to inform such technical guidelines by pushing forward principles for designing roads for bicycling which place roadway safety as a driving force behind infrastructure design (BMVBS 2013, 24).

The aim of this study is to examine the intent of transportation goals and policies, review the implemented manifestation of technical regulations at given locations, and evaluate how well performance measures for the bicycle lanes are met based on the observed behavioral interactions of people using the roadway. This article focuses on the development of the research methods and coding framework established to conduct an observational study of the functionality of unprotected bicycle lanes on urban street segments.

In the City of Munich, forty-percent of the bicycle network is built up as dedicated unprotected bicycle lanes along vehicular roadways (von Sassen 2013, 22). This study focuses on the two variations of unprotected bicycle lanes provided in this network, including:

- On-Street Bicycle Lanes – facilities on the vehicular roadway demarcated by dashed or solid painted lines; and
- Bicycle Lanes on the Sidewalk – facilities on the sidewalk separated from the pedestrian path with an at-grade curb or painted line.

The observational study specifically looks at road users’ behavior along street segments where unprotected bicycle lanes are in place, excluding an analysis of intersections where this type of bicycle infrastructure begins or ends. Intersections are excluded from this study as intersection behavior is assumed to be fundamentally distinct from the behavior road users engage in while traveling along street segments.

Three primary research questions are explored through this study:

- How well do unprotected bicycle lanes function as safe, dedicated travel lanes for bicyclists traveling along street segments?
- Under what circumstances do road users stay in their lane when traveling along street segments with unprotected bicycle lanes? And, under what circumstances do bicyclists experience interactions and/or conflicts with other people or objects on or adjacent to unprotected bicycle lanes?
- What design and policy recommendations can be supported to improve the safety of unprotected bicycle lanes using empirical evidence of road users’ travel behavior, conflicts with other road users, and compliance to traffic regulations?

This paper presents the observational methods developed to answer these research questions. Section 2 introduces the relevant research and grounded theory approach used to frame this study. Section 3 addresses the research design and conceptual model used for this research and the research methods for the observational study are presented in Section 4. TheStraussian grounded theory-driven coding framework is introduced in Section 5 and initial results describing categories of intersection events are introduced in Section 6. The paper then concludes in Section 7 with a discussion of the current findings, limitations, and next steps of this research.

2. Background

2.1 Relevant literature

This study contributes to literature about how people behave and interact on street segments where unprotected bicycle lanes are in place on vehicular roadways and sidewalks. Existing research on unprotected bicycle lanes, and bicycle infrastructure in general, is largely informed by road user surveys and interviews, naturalistic cycling studies
using instrumented bicycles, and reported traffic safety data. Surveys and interviews help to frame people’s preferences for bicycle infrastructure typologies as well as characterize people’s reported behavior and perceptions of safety. These methods of research, are, nevertheless, limited in their ability to reveal objective truths about human behavior as they rely on an assumption that responses are truthful and respondents accurately recall their previous actions or experiences. Naturalistic studies are able to accurately document drivers’ speed and lateral positioning when passing bicyclists. A limitation to these studies, however, is that, rather than riding as they normally might, bicyclists riding the instrumented bicycles are often directed where to ride on a particular portion of the roadway and to travel at a particular speed (Shackel and Parkin 2014). Analyses of traffic crash and injury statistics provide valuable insights into a street segment’s objective safety, yet such datasets are limited by the underreporting of non-injury traffic incidents and near misses.

An observational approach is utilized in this study, as this method is well-suited to document and analyze how people use, or do not use, public spaces under normal, unscripted conditions (Gehl and Svarre 2013, 3). The purpose of a bicycle lane is to create a separate piece of infrastructure for bicyclists to travel in on the roadway (PBIC 2018). It is valuable to observe and document how people behave when interacting with unprotected bicycle lanes as the lack of physical protection provided by these facilities inherently allows encroachment into the bicycle lane and affords potential conflicts between road users. Furthermore, the design also allows bicyclists to easily encroach onto the sidewalk or vehicular travel lane to, for example, perform passing maneuvers. Although this element of the design is described as advantageous for bicyclists by Pucher and Buehler (2012, 122), bicyclists’ encroachments in to the travel lanes dedicated for pedestrians and vehicle drivers potentially have negative externalities for the functionality of these adjacent travel lanes.

Three studies have been identified applying observational methods to explore research questions similar to those of this study. One observational study of eight roadways with unprotected bicycle lanes painted on the vehicular roadway found that only 4-7% of bicyclists encountered drivers encroaching into the dedicated bicycle lane (City of New York 2011, 10). Another study of three streets with bicycle facilities at-grade with the sidewalk found that an average of 67.5% of bicyclists encountered pedestrians in the bicycle lane or bicyclists traveling the wrong way within the bicycle lane (Bernardi and Rupi 2015, 91). A third observational study explored the relationship between the width and capacity of eight bicycle lanes curb separated from the vehicular roadway and sidewalk, finding that the presence of on-street parking adjacent to the bicycle lane effectively reduced the capacity of the bicycle lane by 0.12 meters (Greibe and Buch 2016, 134).

Related to this finding, a significant relationship between objective traffic safety and on-street parking was found in a before-and-after study using crash and injury data to evaluate the safety impact of bicycle lanes. Jensen (2008, 10) found that street segments where on-street parking is not permitted are associated with a 24% increase in crashes and street segments allowing on-street parking decreased crashes by 14%, concluding illegally parked vehicles caused more crashes than legally parked vehicles. Street segments with unprotected bicycle lanes on vehicular roadways were associated with a 30% and 27% increase of crashes and injuries, respectively (Jensen 2008, 12). Bicycle lanes adjacent to the sidewalk, however, were only associated with a 10% and 4% decrease in crashes and injuries (Jensen 2008, 9). Lusk et al. (2011), likewise, used traffic safety data to compare injury rates for bicyclists using cycle tracks and residential streets without bicycle infrastructure. Bicyclist injury rates were found to be 28% lower on streets with cycle tracks than on the residential streets without dedicated bicycle facilities (Lusk et al. 2011, 133). Comparing these objective safety statistics to perceptions of safety, a stated preference study concluded that 74.1% of respondents would be more likely to ride their bicycle to work if cycle tracks were provided on the street network and 56.4% would be more willing if on-street bicycle lanes were provided (Caulfield, Brick, and McCarthy 2012, 414–15).

This research builds on the findings of this existing body of research on bicycle infrastructure by providing new insights into how people behave and interact on street segments with unprotected bicycle lanes, and what impact people’s actions have on how well this type of infrastructures function.

### 2.2 Grounded theory approach
This observational study follows a Straussian grounded theory (SGT) approach to qualitatively identify the variables to be used in a quantitative analysis of road users’ actions and the functionality of unprotected bicycle lanes. Variables analyzed in previous studies on unprotected bicycle lanes are reviewed to inform a deductive foundation of the core sets of variables related to bicycle infrastructure functionality inductively discovered through observation. The inductive-deductive SGT method stimulates “the discovery of theory from data”, includes a validation process, and mitigates a potential for neglecting to document elements of observed situations that are not anticipated in advance of data collection (Glaser and Strauss 1967, I; Heath and Cowley 2004, 143–46; Kenny and Fourie 2015, 1270–71).

The coding procedure used in SGT is comprised of steps: a) ‘open coding’ – identify categories of data and define the range of the categories; b) ‘axial coding’ – find the relationships between categories and sub-categories to establish a paradigm model; and c) ‘selective coding’ – abstract the meaning of the categories to build and refine a theory (Strauss and Corbin 1990; Thai, Chong, and Agrawal 2012; Kenny and Fourie 2015). Using the categories found through coding, a ‘conditional matrix’ is created to summarize core categories, define sub-categories, and refine the structural relationships between categories (Strauss and Corbin 1990; Kenny and Fourie 2015). Through the development of the ‘conditional matrix’, a key element of this methodology is the act of iteratively validating the theory against collected data. Whereas classic grounded theory inductively discovers a theory and assumes validation, the STG process actively applies induction and deduction in the theory building process (Heath and Cowley 2004; Kenny and Fourie 2015).

3. Conceptual model

The methodology developed for this study aims to create a systematic approach for understanding how people behave on roadways to inform decision-making regarding infrastructure design, policy, and traffic regulations applying to unprotected bicycle lanes. A conceptual model (Fig. 1) was developed to steer the research. This section briefly introduces each step of the conceptual model, with a focus on the observational methods employed during step four.

![Conceptual model describing research design approach.](image)

The first three steps of the conceptual model relate to data collection and analysis done to support the observational study. During the first step, jurisdictional policy documents are reviewed in search of goals and policy statements which directly or indirectly apply to bicycle infrastructure in general and unprotected bicycle lanes specifically. The purpose of this step is to identify long-term policy goals and performance measures to frame an understanding of the stated purpose and intent of bicycle infrastructure in the study area. In the second step, engineering standards, bicycle facility design guidelines, and traffic regulations related to bicycle traffic are reviewed to catalog the requirements for how unprotected bicycle lanes should be built and used in the study area. A key assumption of the model is that the
regulations identified through the second step are shaped by the policy goals found through the first step. Acknowledging that each street segment is unique, and it is possible that the implemented roadway geometry and design does not automatically mirror the requirements, the third step involves documenting and mapping the precise context of each observation location.

The fourth step represents the observational study and grounded theory analysis of road users’ behavior on and adjacent to unprotected bicycle lanes and is described further detail in Section 3.1. The fifth step involves a descriptive and inferential analysis of road users’ behavior and interactions documented and codified through the observational study. In the sixth step, the findings of this statistical analysis are used to inform recommendations for potential adjustments to the goals, policies, and specific context of observation locations to improve the functionality of unprotected bicycle lanes.

3.1 (re)Action

The observational phase of this study is represented as the fourth step in the conceptual model (Fig. 1). The purpose of the observational study is to document the variety of actions and interactions actors engage in to identify what consequences these interactions have for how well unprotected bicycle lanes function as a dedicated travel lane for bicyclists. This study considers actors to be people using all modes of transportation as well as any permanent and temporary objects on the roadway that have potential influence on how people behave. It is assumed that the human actors observed in the study will be bicyclists, pedestrians, drivers, and motorcyclists. These categories of actors may be expanded if people are observed using unexpected modes of transportation, such as people traveling on segways or dogs observed being walked on the street. Objects considered to be actors are expected to include: 1) permanent infrastructure—signs in place, utility poles and boxes, benches, planter boxes, bicycle parking, or parking meters; 2) temporary infrastructure—construction traffic control devices or sidewalk café furniture; and 3) movable objects on the roadway—boxes or parked vehicles, including bicycles and motor vehicles.

Video recordings of peoples’ behavior and interactions on street segments with unprotected bicycle lanes are coded following the three step SGT coding procedure introduced in Section 2.2. Through this process, this study first discovers actor-actions, then categorizes events, and lastly identifies the consequences events have on the bicycle infrastructure’s functionality as a dedicated travel lane for bicyclists. Each of these coding steps is depicted in Figure 2 and described below.

![Fig. 2. Thematic Focus of Each Coding Step Following Straussian Grounded Theory](image)

Open coding: The aim of this step is to identify the different types of actors on observed street segments and document the types of actions they perform on or adjacent to the unprotected bicycle lane. During this initial phase of data collection, the different types of actor-actions observed are grouped into categories and sub-categories. The dimensional ranges of each actor-action category is also defined—for example, the length of time or discrete values describing the nature of a given actor-action category. Once no new categories of actor-actions are found, data saturation is achieved and open coding concludes.

Axial coding: The purpose of this step is to explore the relationships between the actor-actions identified during open coding in order to identify categories of interaction events with a potential or apparent impact on the functionality of the unprotected bicycle lane. A conditional event matrix is created through this step as a tool for comparing the nature of actor-actions involved in each event to refine a list of event typologies.

Selective coding: The final step is to identify what consequences the observed actor-actions and events have on the functionality of the unprotected bicycle lane. This is done through a quantitate analysis of the data coded through
open and axial coding to identify the core set of actor-actions influencing events that impact how observed unprotected bicycle lanes function. Actor-actions found to be significantly correlated with particular events are then used to frame the evaluation of findings and inform recommendations of mitigation measures for goals, policies, and site-specific contexts to avoid undesirable or unsafe behaviors and interactions.

4. Research Methods

As the explicit intention of this study is to investigate how people respond to unprotected bicycle lanes and interact with other people and objects on street segments, an observational approach is employed to conduct the research. The method of observation developed for this study is, at its core, influenced by the methods used in public space and public life studies. As is standard in the tradition of public life studies, people on the street segment are not interviewed or surveyed, “rather they are observed, their activities and behavior mapped in order to better understand the needs of users and how city spaces are used” (Gehl and Svarre 2013, 5). All people observed in this study are unidentified, unidentifiable, and not informed that their behavior on the street segment is being documented. This method minimizes the likelihood that people will adjust their behaviors to appear more favorable in the study given that subjects are unaware they are under investigation (Landsberger 1958).

Observations of peoples’ behavior on and adjacent to unprotected bicycle lanes are documented using video cameras. All footage collected is reviewed and coded manually. While time-consuming, a manual review of the observational video footage ensures that the detailed circumstances contributing to each behavior and interaction captured in the study (Gehl and Svarre 2013, 6). Moreover, using video recordings for data collection allows all observations to be viewed multiple times and at various speeds, with the footage either slowed down or sped up. This ability to view the video recordings multiple times is especially important for adequately performing the three SGT coding tasks, as the videos can be re-viewed during open, axial, and selective coding with the goal of ensuring accuracy and quality control throughout the coding period.

4.1 Pilot study

In the process of designing the methods used in this observational study, a pilot study was deployed in December 2017. The primary purpose of this study was to collect video recordings of street segments where unprotected bicycle lanes are in place to test and refine the conceptual model guiding this study. The pilot study was also used to train the researcher to perform the SGT coding procedure and refine the data collection methods to be used in a larger, subsequent observational study of multiple case study sites. From a technical standpoint, the purpose of the pilot study was to test the relative advantages and disadvantages of recording observations from two perspectives. The first option was to install cameras on buildings, looking down on street segments where unprotected bicycle lanes are present (Fig. 3a). The second option was to install cameras on the handlebars of a bicycle being used by a bicyclist traveling along street segments where unprotected bicycle lanes are in place (Fig. 3b).

![Fig. 3. (a) Recording from above; (b) Recording from a bicyclists point of view.](image)

Based on the initial analysis of the pilot study video footage from both perspectives, it was determined that the
most appropriate way to conduct this study is to film selected street segments with unprotected bicycle lanes from above. One advantage of filming from above is that the volume of each mode of transportation traveling along the street segment during the observation periods can be documented. This allows a comparison of the percentage of people using each mode, the percentage of non-bicyclists who encroach into the unprotected bicycle lane, the percentage of bicyclists riding outside of the bicycle lane, and the percentage of bicyclists who have interactions and conflicts with other people or objects on the street segment. Filming from above further enables the documentation of how often, and for how long, movable objects blocking the unprotected bicycle lanes under observation. Another key benefit of this method of filming is the ability to observe and analyze the before-and-after circumstances contributing to observed actor-actions and events.

When filming from a bicyclist’s perspective, the bicyclist is aware that their actions are being recorded. This awareness has the potential to impact how the bicyclist behaves and may influence how they react to other people they pass and interact with along the street segments (Landsberger 1958). As the bicyclist is directed to ride on unprotected bicycle lanes, this method of filming only provides insights into what is happening immediately ahead of and adjacent to the bicyclist. Where on-street parking is allowed, filming from this perspective restricts the ability to make reliable observations of behaviors and interactions occurring on the other side of parked vehicles—for example, bicyclists traveling on the roadway may be unseen. The constant forward movement of footage recorded from a bicyclists’ perspective furthermore restricts the ability to document and analyze behaviors and interactions occurring after a bicyclist has passed another actor on the roadway.

5. Coding framework

The coding framework used in this study was developed using an inductive-deductive approach to identify the variety of actor-actions contributing to events with a potential or apparent effect on how well an unprotected bicycle lane functions as a dedicated travel lane for bicyclists. Variables included in the framework were first coded through open coding, then organized into a conditional event matrix through axial coding to compare the nature of actor-actions observed along street segments which were associated with observed events.

Actors listed in the matrix include people observed on the case study street segments using any mode of transportation as well as permanent, temporary, and movable objects on the roadway which have an apparent influence on people’s behavior and interactions during observed events. Each actor is marked as being directly involved in an event if they interacted with another actor during the event. Actors are marked as indirect participants of an event if their presence influenced the behavior of someone directly involved in an event interaction, but they themselves did not experience the interaction. This would include, for example, an event during which a pedestrian standing on the sidewalk causes a second pedestrian to move onto the bicycle lane to perform a pass maneuver at the same time a bicyclist is approaching or passing the second pedestrian in the bicycle lane.

Actions in the matrix represent the behaviors people were observed engaging in with a potential or apparent impact on the functionality of the unprotected bicycle lane. The list of actions inductively identified as being associated with events include actors traveling, standing or stopping on, and crossing the unprotected bicycle lane, sidewalk, or vehicular travel lane. Observed events also frequently involve people engaged in passing maneuvers and/or people traveling the wrong way in a given travel lane on the street segment. Other variables identified as interesting for analysis included the following four categories of variables:

- **Lateral Position**—The specific position of a person in a given travel lane at the time of an event.
- **Speed of Travel**—The speed that a person is traveling along the road segment.
- **Secondary Activity**—The secondary activity a person is observed to engage in on the street segment, beyond using the street segment as a transportation facility. For example, the observational study documents if a person is observed entering or existing a shop, talking on their phone, walking a dog, or waiting to meet another person.
- **Change of Mode of Transportation**—If a person is observed transitioning from one mode to another mode of transportation before, during, or after an event, the observational study will document this to differentiate these actors from other actors observed using only one mode of transportation.
6. Results

The conditional event matrix (Fig. 4, below) was developed using the categories of actor-actions described in Section 5. This coding matrix was used in the pilot study to compare the characteristics of actor-actions contributing to observed events. Through this comparison the four following event typologies were discovered:

- **Encroachment**: A person encroaches into the unprotected bicycle lane or an object is placed within the unprotected bicycle lane. The person encroaching may be using any mode of transportation, including a bicyclist who is traveling the wrong way in the bicycle lane. No bicyclist lawfully traveling in the dedicated bicycle lane is present at the time of an encroachment event. The consequence of an encroachment event is considered to be minimal, as the path of travel of a bicyclist lawfully using the bicycle lane is not affected by the act of encroachment.
- **Disturbance**: A person or object encroaches into the unprotected bicycle lane when a bicyclist lawfully traveling in the bicycle lane is present. A disturbance can also be caused by a person or object immediately adjacent to the bicycle lane when a bicyclist is observed changing their lateral positioning when passing the adjacent actor. The bicyclist is able to remain in the bicycle lane during the event, but the bicyclist’s path of travel is disturbed and the consequence is that the bicyclist must, for example, adjust their speed or lateral positioning as they continue to travel in the dedicated bicycle lane.
- **Disruption**: A person or object encroaches into the unprotected bicycle lane while a bicyclist is present. The bicyclist is able to continue traveling forward, but they must exit the bicycle lane and move onto the sidewalk, or vehicular travel lane to avoid a collision with the encroaching person or object.
- **Conflict**: A person or object encroaches into the unprotected bicycle lane while a bicyclist is present. The bicyclist’s path of travel is interrupted to the point that they must stop their bicycle to avoid a collision or a collision with the encroaching person or object.

All shaded actor-interactions in the matrix represent incidences of encroachment events. The lighter shaded boxes indicates an encroachment performed by a bicyclist traveling the wrong direction in the bicycle lane. Disturbance, disruption, and conflict events are identified when a bicyclist engaged in action ‘A’, ‘B’, and ‘C’, respectively, has an
interaction with another actor engaging in an action marked with an ‘X’. For example, a conflict is identified when a bicyclist stops at any place on the roadway (marked with a ‘C’ on the matrix) as a result of another person or object blocking the dedicated bicycle lane (marked ‘X’ for standing/stopped on the bicycle lane).

To demonstrate how the matrix functions, the following sub-sections present observed examples of each of the four event typologies identified through the pilot study. Using the matrix, actor-actions associated with an event are noted in two ways. An ‘X’ is used to indicate an action that an actor engaged in throughout the length of the observed event. If an actor engaged in a series of actions during an event, the sequence of these actions is notated with the numeric sequence beginning with the number one. For example, if a pedestrian is observed walking on the sidewalk before encroaching into the bicycle lane to pass another actor on the sidewalk, a ‘1’ would be noted under ‘pedestrian traveling on the sidewalk’ and a ‘2’ would be noted under both ‘pedestrian traveling on the bicycle lane’ and ‘passing maneuver’. An actor’s involvement in an event is labeled as ‘D’ for directly participating in the event and ‘I’ for indirectly associated with the occurrence of the event.

6.1 Encroachment

This event involved two pedestrians walking together who crossed the bicycle lane, one after the other. The pedestrians exited a building together, walked on the sidewalk, and crossed over the bicycle lane before crossing the street. Both pedestrians appeared to look for approaching bicyclists before crossing the bicycle lane. As no bicyclists were present at this time, this encroachment event did not result in any negative consequences for bicyclists using the unprotected bicycle lane.

![Conditional Event Matrix for encroachment event](image)

**Fig. 5.** (a) Conditional Event Matrix for encroachment event; (b) Photo of encroachment event.

6.2 Disturbance

This event involved eight pedestrians and one bicyclist. One of the pedestrians stepped into the unprotected bicycle lane and walked in the bicycle lane for an extended period as they passed the four pedestrians walking in the same direction and three pedestrians walking in the opposite direction. This pedestrian was holding a bag in their left hand, increasing the width of the bicycle lane they encroached into during this passing maneuver. The bicyclist was able to remain in the unprotected bicycle lane as they passed the encroaching pedestrian, but they visibly slowed down and moved from the center of the lane toward the parking lane in order to pass the encroaching pedestrian. Although the bicyclist was able to remain in the bicycle lane, the disturbance caused by the presence of this pedestrian appears to result in an mild breakdown in the bicycle lane’s functionality as a dedicated travel lane for bicyclists.
6.3 Disruption

This event involved three bicyclists and one driver. The driver pulled out of a driveway and parked across the width of the sidewalk and most of the width of the bicycle lane for a period of several minutes, never exiting the vehicle. As a three bicyclists traveling in a line within the unprotected bicycle lane approached the parked vehicle, each slowed their speed considerably and maneuvered onto the vehicular roadway to pass the parked vehicle. After passing the parked vehicle, each bicyclist returned to the bicycle lane. Although the bicyclists were able to continue traveling along the street without stopping or colliding with the parked vehicle, this disruption event represents a true breakdown in this infrastructure’s function as a dedicated travel lane for bicyclists.

6.4 Conflict

This event involved one bicyclist, one pedestrian, and two drivers. One driver parked on the unprotected bicycle lane for approximately forty-minutes. After the driver had returned to their vehicle and sat in the driver’s seat, a second driver slowly turned right into a driveway. As this second driver was attempting to access the driveway, an approaching bicyclist maneuvered out of the bicycle lane and onto the sidewalk to get around the parked vehicle and then came to a stop as they waited for the driver of the second vehicle to complete their entry into the driveway. This
second driver’s turning maneuver was delayed as the driver yielded to a pedestrian walking on the sidewalk. Once the second driver successfully entered the driveway, the bicyclist was able to begin riding their bicycle again, but continued to ride on the sidewalk after this conflict event. The actor-actions observed during this event exhibit a complete breakdown how well the unprotected bicycle lane functioned as a dedicated travel lane for the bicyclist.

**7. Discussion**

It is vital to advance an empirical understanding of how road users interact with unprotected bicycle lanes, or any type of transportation infrastructure, as “[v]iolations of rules and accidents may be evidence of shortcomings in the infrastructure” (BMVBS 2013, 30). This perspective highlights that when encroachments into unprotected bicycle lanes occur, the person who violated the rule may not be at fault. Rather, violations and accidents may signal that something in the designed system may not be functioning well. The applied aim of this ongoing research is to develop new insights into how people behave and interact with one another on street segments with unprotected bicycle lanes using observational methods to inform design and regulatory decisions regarding urban bicycle facilities.

A key purpose the pilot study deployed in this research was to test the use of the Straussian grounded theory coding procedure as a method for coding qualitatively defined data describing people’s behavior and interactions on street segments with unprotected bicycle lanes. Through the application of this coding procedure for documenting road users’ observed behavior and interactions, four typologies of events with some impact on the functionality of the unprotected bicycle lanes were identified. Encroachment events were found to be inconsequential to the infrastructure’s functionality, while disruption and conflict events were found to have a greater impact on how well this type of infrastructure functions as a safe, dedicated travel lane for bicyclist traveling along street segments.

It is expected that the event matrix and the categories of events will be refined and expanded to include undiscovered events emerging through a larger, subsequent observational study conducted in Autumn 2018. For example, no collisions or single-person accidents were observed during the pilot study which means that the existing matrix cannot be used to identify such events. Beyond validating and refining observed typologies of events, a key goal of the future development of the conditional event matrix is to code and analyze the causal patterns occurring before, during, and after events. The inclusion of actor-actions causing or caused by observed events will enhance the insights used to develop any recommendations for the design or regulation of unprotected bicycle lanes. Furthermore, the matrix will be expanded to include coded variables describing the context of the specific section of the street segment where observed events occur as well as the involvement of permanent, temporary, and movable objects directly or indirectly participating in an event.

The findings of this research are limited by the fact that the matrix developed through the pilot study was conducted
using a single case study street segment with unprotected bicycle lanes built at-grade with the sidewalk. In the Autumn of 2018 observational study, several street segments with both types of unprotected bicycle lanes will be video recorded. The existing conditional event matrix may be revised based on similarities and differences found between actor-actions and events observed on the two types of street segments. If the nature of actor-actions and events observed on street segments with the two types of unprotected bicycle lanes are distinct, the open and axial coding phases of the observational study may result in the creation of separate conditional event matrices to identify unique events on each type of infrastructure.

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References


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