

**Developing a Framework for Behavior Assessment of Bicycle Commuters: A
Cyclist-Centric Approach**

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Developing a Framework for Behavior Assessment of Bicycle Commuters:
A Cyclist-Centric Approach

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SUMMARY

This paper investigates the behavior of bicycle commuters using qualitative behavior research techniques. Bicycle commuters are observed in context of their commute rides and video taped for analysis. Interviews and cognitive mapping processes are used to draw out commuters' perceptions to external activity and their behavior modifications in response. The behavior and perception data are used to illustrate mental models of bicycle commuters: how they differ among riders and how an individual rider's mental model evolves along their commute. A clear understanding of bicycle commuters' mental models and behaviors associated with them can be used to create a framework for development of a tool for self-assessment of commuting experiences.

Chapter 1 : INTRODUCTION

”During the Twentieth Century, walking, cycling and riding public transit travel were stigmatized, but in recent years alternative modes have become more socially acceptable. For example, bicycle commuting is increasingly accepted and even prestigious” (Litman 2005)

“Walking and bicycling clearly are at the heart of what Americans want” (Pedestrian and Bicycle Information Center 2003)

Background

The purpose of this paper is to develop a novel method for assessing the ride behavior of bicycle commuters. Commuting by bicycle is an under-utilized transportation method in the United States, but one that has distinct advantages for certain types of travel. With rising per-mile fuel costs, increasing congestion and sprawl in U.S. cities, climate change and lifestyle health concerns, the bicycle is uniquely positioned as a transportation alternative.



Figure 1 Safety bicycle (Sharp 1977)

The venerable bicycle has changed little in configuration since the invention of the “safety bicycle” in the late 1800’s (figure 1). The diamond-shaped frame with wheels of equal size, cranks located at the bottom bracket and a direct-drive chain to a sprocket on the rear hub was a bold departure from the previous front-wheel-drive “high wheelers” (Hurst 2004). That same design layout has remained largely unchanged, as seen in the high-tech two wheeled machines sold in today’s bike shops. The bicycle has been adapted for many uses from recreation and exercise to cargo hauling and military applications. Figure 2 illustrates some of the many uses the bicycle has been adapted for.

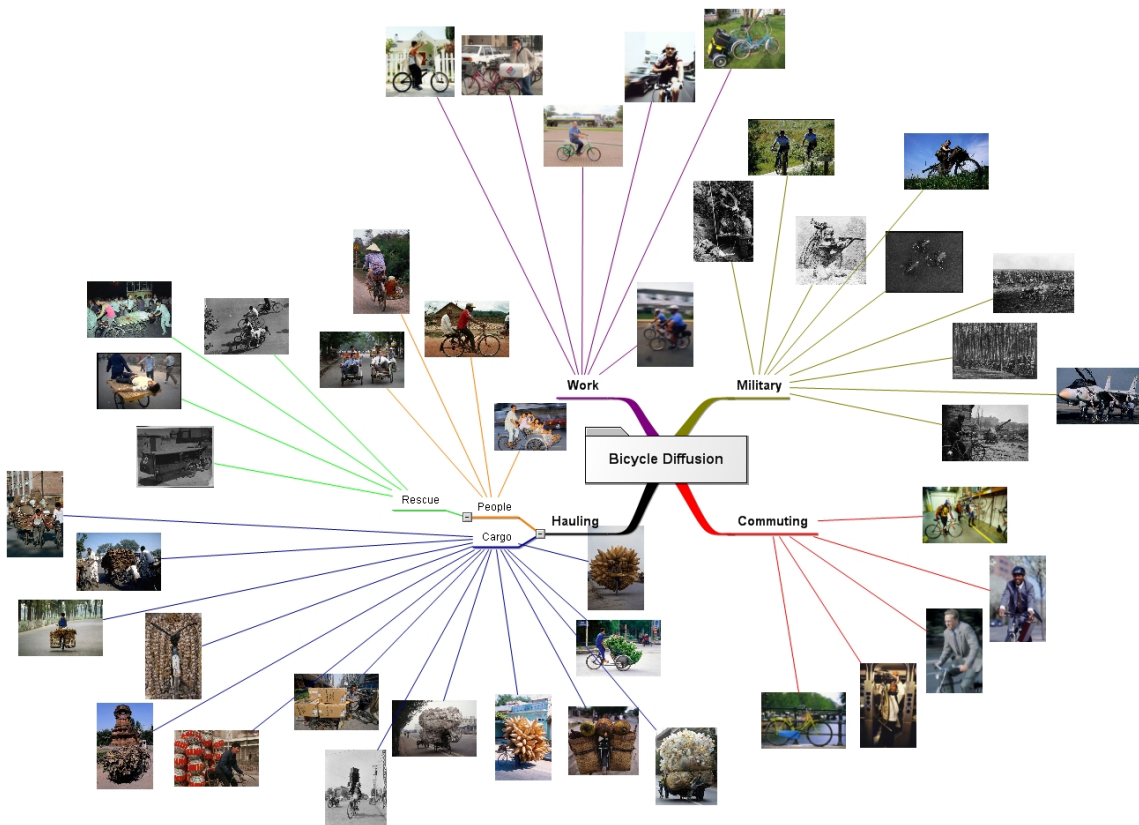


Figure 2 Diffusion of bicycle uses (Shankwiler 2006)

Although bicycle applications are diverse, this paper will focus on the commuting activity.

Fifteen percent of American adults bicycle weekly for exercise, and even greater numbers report owning a bicycle, though it is used less often, if at all. Can these numbers be increased?

Goals

This paper will develop a method for supporting bicycle commuters through a proposed ground-up community building application. Before the tool is proposed, a thorough understanding of bicycle commuters' perceptions and behaviors will be needed. The question of *how* cyclists commute will be investigated. The concept of mental models will be discussed and will be an integral part in the investigative process. Visualization of and understanding of mental models of bicycle commuters will be undertaken. This paper will show that not only do mental models vary among individual commuters, but that their mental models evolve during their commutes as a response to external activity. This will be an important part in concluding that bicycle commuters make decisions and function as individuals.

To ascertain the perceptions and behaviors of bicycle commuters, several methods will be utilized. Recruited subjects will participate in research rides. Two types of research rides will be undertaken. The first is a video-recorded observation of their ride. The second is

a self-recording of trip diaries. These rides will be followed by subject interviews and cognitive mapping exercises which will begin to give shape to the mental models of the cyclists.

Data collected from the research rides, interviews and cognitive maps will then be used to generate the final visual artifact: perception-activity-behavior maps. These maps will enable a graphical comparison of perceptions and behaviors amongst the subjects. The process used to develop the perception-activity-behavior maps will then be used as a framework for creating a concept of a self-assessment tool for bicycle commuters. Ways in which the self-assessment data could be used to support the individual cyclist will then be discussed.

About the research study

This research study takes place in Atlanta, Georgia. This is an unusual venue for a study of bicycle commuters, as Atlanta is not generally considered a great city for cycling. In fact, the March 2006 issue of *Bicycling* magazine voted Atlanta as one of the worst cities in the U.S. for cycling. Although there is an enthusiastic local community of cyclists, there is no city bike coordinator to give them a voice, as well as a 170-percent increase in traffic congestion over the last ten years (Fiske 2006). The magazine went on to quote the local newspaper as saying, “the bicycle is dead.” This investigating team does not believe the bicycle is dead. In fact, research shows otherwise. There is required, however, a greater amount of support for those already cycling and for encouragement of

those who are not yet bicycle commuters in order to increase the amount of bicycle commuting in the area.

The paper will begin with a discussion of the current state of bicycle commuting in the United States, followed by a review of past bicycle commuting research. The paper's main body of research and application, the cyclist-centric approach, will then be introduced and developed.

Chapter 2 : BICYCLE COMMUTING TODAY

"One wonders whether bicycle lanes are really installed for cyclists' benefit if lane use is mandatory." (Schimek 1997)

United States

According to an analysis of the 2000 US Census, there are 488,497 bicycle commuters in the United States. With the total number of American workers over the age of sixteen being over 128 million, bicycle commuters account for only slightly less than half of a percent of those workers. To put this figure in perspective, the following table is presented¹:

Table 1 Commuting methods (Reschovsky 2004)

Commute Method (2000)	United States		Georgia	
Bicycle	488,497	0.4%	42,039 ²	1.1%
Public transportation	6,067,703	4.7%	90,030	2.3%
Walk	3,758,982	2.9%	65,776	1.7%
Work from home	4,184,223	3.3%	108,986	2.8%
Drove alone	97,102,050	75.7%	2,968,910	77.5%
Average travel time	25.5 min. ³		27.7 min.	
Total workers (over 16)	128,279,228		3,832,803	

¹ As this body of research was performed in Atlanta, Georgia, figures for the state are included for context.

² Includes commutes by bicycle, motorcycle, and other.

³ This represents an increase of 3.1 minutes from 1990.

As can be seen, bicycling to work is the least utilized of all transportation options, both in the US as a whole, and in the state of Georgia.

Why is bicycling as a commuting method not utilized more extensively in the US?

Cycling is a pursuit that, in the US, remains largely a recreational exercise. 15% of American adults cycle for exercise at least once a week, while only 0.4% of them [workers age 16 and older] cycle for transportation to work (Reschovsky 2004; Moudon, Lee et al. 2005). There are a variety of explanations offered by various experts, researchers, planners and activists. Cited reasons include “excessive distance [to travel destination]; unsafe streets; lack of sidewalks; inadequate trip-end facilities such as showers and bicycle racks; the convenience, speed, and low cost of driving; the need to make multiple trips during the day; and a public perception that biking is not fashionable” (Baltes). A report on the influence of the built environment on cycling in the US showed barriers to cycling include “insufficient or unsafe cycling infrastructure, shortage of cycling amenities, and undesirable land use conditions” (Moudon, Lee et al. 2005).

At an individual level, there are other factors influencing whether or not to commute by bicycle, both subjective and objective. Subjective factors have to do with personal perception and interpretation of one’s needs; such as distance, traffic safety, convenience cost, valuations of time, exercise, and physical condition, as well as family circumstances, habits, attitudes and values, and as mentioned above, peer group acceptance (Dill and Carr 2003). Physical effort required to cycle due to slopes and frequent stops also plays a large role in the commute decision (Rietveld and Daniel 2004)

Objective assessments of reasons associated with the frequency of bicycle commuting involve more directly measurable and comparable factors. These factors are physical and exist for everyone, but are not necessarily weighed equally by everyone. These include climate, topography, presence of bicycle facilities⁴, traffic conditions, access and linkage, and transportation alternatives (Dill and Carr 2003). Studies have also shown there is a direct correlation between the amount of available bicycle facilities (in a given area – city, town, etc.) and the amount of bicycle commuting within the same area. The research analysis, however, does not support or indicate the existence of a cause-effect relationship. “People may be commuting by bicycle more because there are more lanes and paths. Alternatively, because people are commuting by bicycle, the city is building more bike lanes and paths. Both relationships may be occurring to varying degrees in each city” (Dill and Carr 2003). In other words, while the correlation between the two is demonstrated, no empirical evidence exists to explain whether one influences the other. Therefore, the construction of bicycle lanes alone is not likely to increase bicycle commuting. To have greater impact, bike lanes and bike paths should connect popular origins and destinations (Dill and Carr 2003).

Given the variety of factors involved in the decision to engage in bicycle travel as a means of commuting, the following chart explains an individual’s assessment of the commuting decision:

⁴ The term ‘bicycle facilities’ refers to those system artifacts built for the use of bicycle riders. These include on-road bike lanes and bicycle markings, off-road bicycle pathways and multi-use trails, and separate-from-road lanes and pathways.

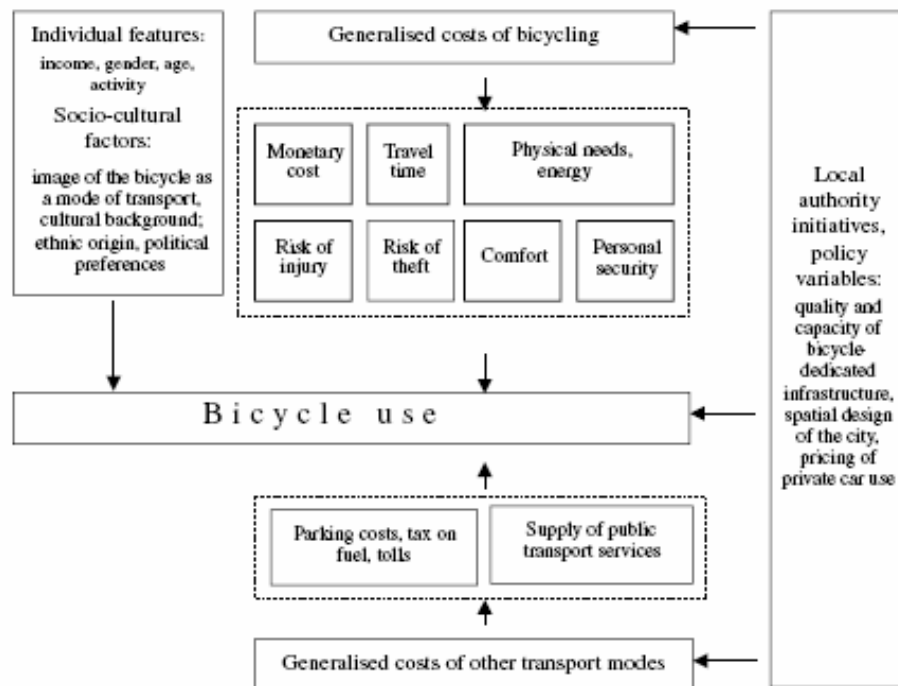


Figure3 General framework of factors explaining bicycle use (Rietveld and Daniel 2004)

This chart provides a framework for understanding an individual’s decision process when assessing whether to commute by bicycle. As the chart shows, factors influencing the individual are varied and range from individual features and socio-cultural factors, to costs associated with bicycling versus costs of other forms of transportation. Local policy initiatives also hold influence. Due to the large variety of influencing factors, a large proportion of which are subjective, it is apparent the decision to cycle is largely a personal one, and less influenced by environmental factors (Moudon, Lee et al. 2005).

To further illustrate the point, the Federal Highway Administration offers a similar matrix for travel decision-making:

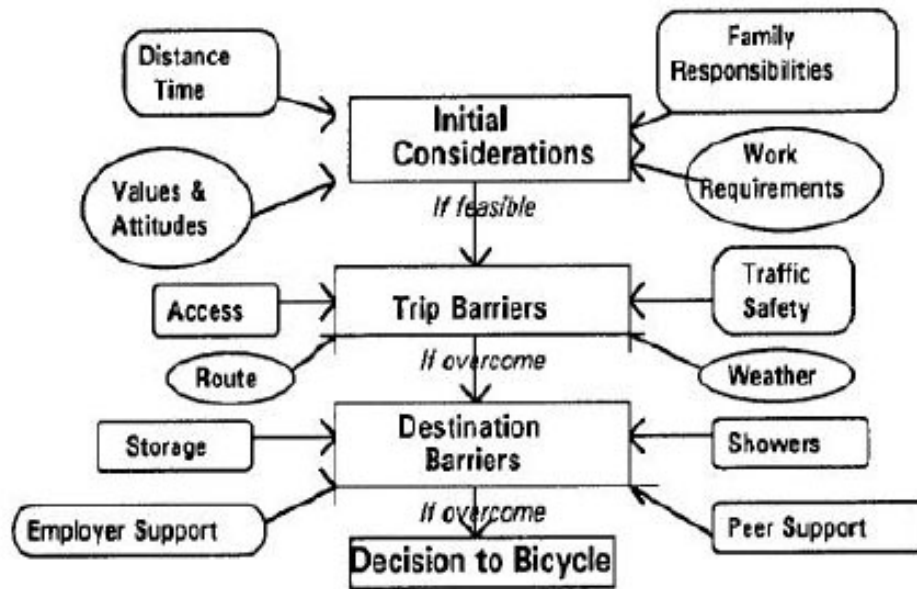


Figure 4 Three-tiered initial considerations in basic travel decisions (Federal Highway Administration)

Although the variables presented here differ from the previous chart, it can be seen that these variables would be weighed differently based on a person's situations and attitudes. This reinforces the fact that decisions made about bicycle commuting are largely an individual decision based on a variety of objective and subjective factors.

Given the variety of factors influencing modal choice for commuting to work, why do those who choose to commute by bicycle do so? Attitude surveys have shown that shorter trips are more conducive to cycling (Moritz). Aggregated survey results show

other common motivations for commuting by bicycle are (in descending order): health and fitness reasons, concern for the environment, congestion, cost of gasoline, and cost of car parking and availability. Another major factor influencing the decision to commute by bicycle is enjoyment – it is *fun* to ride to work (Moritz).

There exists a general perception that traffic discourages cycling. A recent study concluded, however, that the influence of perception of neighborhood traffic problems and automobile-oriented facilities are only moderately significant to the decision to commute by bicycle. This non-linear association suggests that having a moderate amount of traffic is desirable for cycling (compared to having too little or too much). Perhaps “these conditions offer a diversity of activities of interest to cyclists, along with perhaps some sensory or visual stimuli” that interest the cyclist (Moudon, Lee et al. 2005).

Having assessed the current state of affairs in regards to bicycle commuting, what can be done to increase the amount and frequency of bicycling as a transportation method? One method, from a community initiative standpoint, is to focus more on time and cost savings and door-to-door flexibility than on environmental campaigns. “If you need to get to work for a 9am start then saving the environment is unlikely to be a priority. [But] if it can be shown that cycling will save 10 minutes on the journey to work and 10 [dollars] per week on petrol, the argument becomes more convincing” (Guthrie 2001).

This requires a modal shift in thinking:

“The private car is the comfortable mode of transport, offering door-to-door convenience, weather protection and the easy carry of luggage. If the motorist is to be encouraged to switch modes, then the bike must also be made an easy option. While this bicycle remains a vehicle with no protection from chain oil and road surface water, requires a rider to carry luggage on their bike or on their back, needs the fitting and regular maintenance of battery-powered lights and provides an uncomfortable riding position, it is unsurprising that only those with no choice, or the 'cycle enthusiast', that do not prefer the car” (Guthrie 2001).

These proposed ways of thinking are all system-level and policy-driven means of encouragement. These and the construction of public bicycle facilities attempt to encourage cycle commuting from a community level. Governmental policies have also been put into place to encourage bicycling and other alternative modes of transportation. At the federal level, the Intermodal Surface Transportation Efficiency Act (ISTEA), and its successor, the Transportation Equity Act of the 21st Century (TEA-21), have increased public funding of non-motorized transportation infrastructure, including bicycle lanes and other cycling facilities. Nonetheless, investments in non-motorized safety and infrastructure remain a very small portion of transportation budgets (Moudon, Lee et al. 2005). These efforts, since they must be driven by and facilitated by government institutions, take a long time. Is there another avenue to encourage commuting by bicycle? It has already been shown that the decision to commute by bicycle is and individual one. This paper will investigate another, less examined route to support for the

bicycle commuter: a cyclist-centric investigative approach for understanding bicycle commuter behavior.

United States as compared to other parts of the world

In reference to bicycles, as purchased by citizens, Guthrie offers the following assessment:

“...in The Netherlands and Denmark, where levels of cycling are high, the majority of bikes sold are hybrids or utility bikes with mudguards, chainguards, racks or baskets, fitted lights, comfortable riding positions etc. In the UK,, however, the vast majority of bikes sold are designed exclusively for leisure or sports purposes - mountain bikes and road bikes” (2001).

The same appears to be true for the U.S. as well, where hybrid bicycles (most similar to the bicycles described above) account for just 10% of the bicycle market (according to sales) and road bikes accounting for 34% of the market (BPSA 2005). The remaining 56% of the market is accounted for by mountain bikes, juvenile bikes, and others.

It can be assumed that the factors identified in the previous section also apply to the decision to commute by bicycle in European countries, but the value that is placed on the different factors is weighed differently. Also, it can be assumed that there is a better

cycling infrastructure support, especially in Denmark and The Netherland, in place for the commuter.

Comparing bicycle commuting in the United States to European countries shows that cycling as a transportation mode is much more prevalent in Europe. As the quote above suggests, the highest frequency of bicycle commuting is found in the countries of The Netherlands and Denmark. As fig. 4 indicates, the automobile is used most extensively in the U.S., with Canada close behind. As a percentage of all trips undertaken, bicycling accounts for approximately 1 percent in the United States, while the car is the mode of choice in 84 percent of trips. Contrast this with The Netherlands and Germany, where the bicycle is used in 30 percent and 12 percent, respectively, of all trips taken and the car accounts for only 45 percent and 49 percent respectively (Rietveld and Daniel 2004).

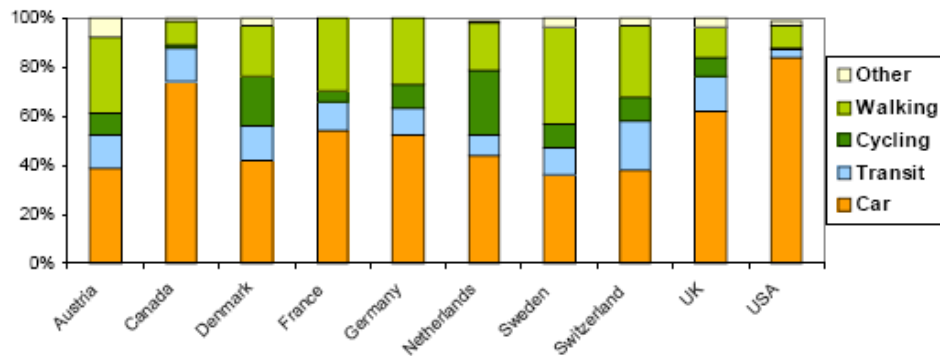


Figure 5 Urban mode split (Pucher and Lefevre 1996)

Visual research methods reveal cultural attitudes towards artifacts. This approach was applied to bicycling in regards to Africa, Asia, Europe and the United States. Figure 5

shows a graphical representation of that research (Shankwiler 2006). The spider chart shows cultural significance of the bicycle to the four different regions. The African and Asian images show a higher degree of utilitarian use of the bicycle. Europe shows a moderate amount of utilitarian use, but also a high degree of cultural significance. Aside from a few messenger applications, the bicycle is largely seen as a recreational and exercise vehicle.

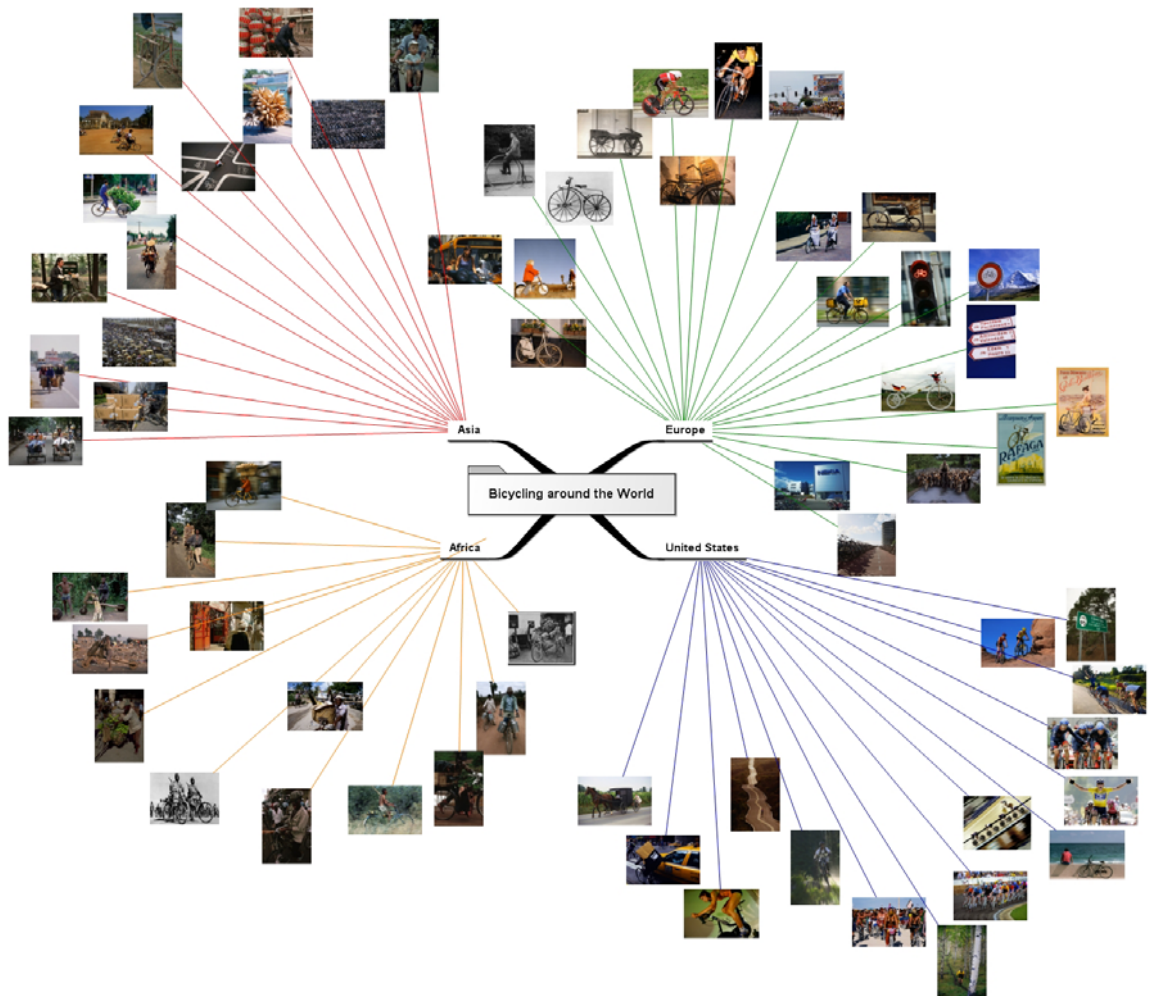


Figure 6 Bicycling activities in Africa, Asia, Europe and the U.S. (Shankwiler 2006)

Chapter 3 : REVIEW OF RESEARCH

“...we have very little data other than journey-to-work data from the census” (Snyder 2004).

There has been a significant amount of research conducted in the area of bicycle transportation. Previous bicycle commuter-related research has been classified into the following categories: bicycle rider characteristics, traffic flow, intersection control, capacity and level of service, computer models, and geometric design⁵ (Taylor and Davies 1999). The majority of these studies were performed in the context of traffic sciences and operations, as well as facility design. Bicycle rider characteristics include static and dynamic measurements of rider and bicycle and operational characteristics. Operational characteristics encompass quantifying perception-reaction times to traffic signals, bicycle travel speed distributions, work expended by cyclists on upgrades, braking forces and distances, acceleration, turning, and adherence to traffic ordinances (the “rules of the road”) (Taylor and Davies 1999). These are all metrics which can be measured and compared quantifiably.

Traffic flow characteristics are also a major consideration in studying bicycle and automobile interactions. These studies examine traffic flow through intersections and

⁵ Geometric design refers to the design of bicycle facilities and the guidelines used to do so.

mid-block areas⁶. Data gained from these studies can be used to model traffic flow systems, at macroscopic or microscopic levels within a community area. Other variables such as gap acceptance and queuing are also studied. Again, these are quantitative methods.

Evaluative Research

Evaluation of bicycle lane and lane markings installation represent good examples of quantitative research in the bicycle commuting context. A variety of innovative on-street bicycle treatments have been implemented, including bike boxes, bicycle boulevards, raised bike lanes, and use of painted areas (Hunter, Harkey et al. 1999). Discussed below are case studies of blue lanes at intersections, bike box implementations, and wide curb lane conversions.

Blue Lanes in Portland, Oregon

This study focused on colored (blue) pavement and accompanying signage at or near intersections, where inter-weaving of cyclists' and motorists' paths occur. The intent was to evaluate whether painted bicycle lanes reduced incidents of car-bike conflicts.

Colored pavements have been used to facilitate bicycle movement through intersections in Europe and Canada, but such an approach was a novel concept for the United States (Hunter, Harkey et al. 1999). In this case, bicycle lanes and recommended paths through intersections were painted blue, with accompanying signage installed.

⁶ Mid-block areas are those zones in-between intersections where traffic flows unabated by traffic signals.

Overall, it was found the percentage of bicyclists following the recommended paths through intersections increased after the coloring of lanes, and the percent of motorists yielding to cyclists also increased. This may have created a false sense of security for the cyclists, however, as it was found significantly fewer cyclists turned their heads to check for approaching traffic, and significantly fewer cyclists used hand signals to indicate their movements (Hunter, Harkey et al. 1999).

An oral survey of bicyclists riding through some of the study sites indicated the majority of them felt motorists yielded more than before [the markings were installed], and the locations with blue pavement were safer than before. Similarly, it was found motorists thought the locations were safer and increased motorist awareness of conflict areas (Hunter, Harkey et al. 1999).

Bike Box in Eugene, Oregon

Another European treatment being evaluated in the United States is the “bike box.” A bike box is a right-angle extension to a bike lane at the head of an intersection (see fig. 3). This configuration allows bicyclists to get ahead of traffic on a red signal and proceed first through the intersection when the traffic signal changes to green. This positioning is intended to eliminate conflicts between cyclists in a right-side bicycle lane and right-turning vehicles and to also make cyclists more visible (Hunter 2000).

This particular study involved the installation of a bike box on a one-way street with a bicycle lane running on the left side of the street, inboard of a row of parked cars. This

intersection has average daily traffic volumes of 8,500 vehicles per day with peak-hour total about 1,000 vehicles (Hunter 2000).

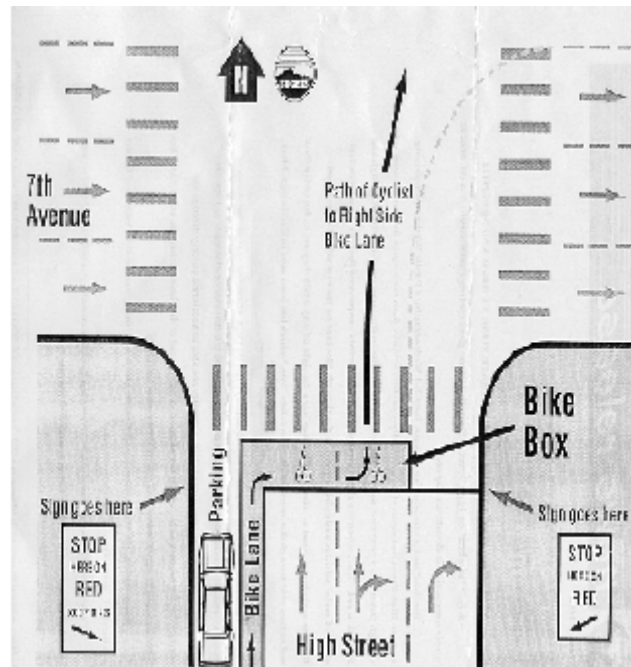


Figure 7 Bike box on High Street in Eugene, OR (Hunter 2000)

Evaluation of the bike box showed it “is a promising tool to help bicyclists and motorists avoid conflicts due to certain kinds of intersection movements” (Hunter 2000). No conflicts between cyclist and motorist were reported when the bike box was used as intended. More evaluations in different settings were recommended in order to understand how it might be further improved (Hunter 2000).

Several recommendations were proposed to increase the efficacy of further installations of bike boxes. First, education of bicyclist and drivers as to proper use of the box is important. This could be accomplished through public service announcements, brochures, and educational signs at intersections. Second, bold demarcation of the box is important. Finally, motor vehicle encroachment was found to be a problem and steps should be taken to limit the behavior. When vehicles encroached into the bike box, it severely limited its intended usage (Hunter 2000). This report demonstrated a promising application of a European solution in an American setting.

Wide Curb Lane Conversions in Florida

This study evaluated the conversion of a 14-foot wide curb lane to an 11-foot travel lane with a 3-foot undesignated lane (stripe added to roadway, creating a 3-foot wide lane along the outermost edge of the roadway without specific bike lane markings), along several road ways in Broward County, Florida. Roads varied between 4 and 6 lanes of traffic and speed limits ranged 40 to 45 miles per hour. The study included six mid-block sites and 4 intersection sites. Before and after comparisons were made via video-tape footage (Hunter 2004).

The study showed the lateral spacing of both bicyclists and motorists from the lanes' edge was greater with the addition of the striped lane. More importantly, most cases showed the lateral spacing between bicycles and motor vehicles was greater with the lane. The striped lane also reduced the amount of motor vehicle encroachment into the bicycle lane (Hunter 2004).

This study has its limitations, however. The roadways chosen for the observation tended to be relatively high-speed and had high traffic volumes. As a result, few local bicyclists actually used the route. The study was undertaken largely with subject riders, who had to be instructed how to behave in the lanes. Consequently, even though the results showed promising results in reference to car-bicycle interactions, it was recommended further evaluations be performed along routes where larger numbers of bicyclists are a natural part of the traffic stream (Hunter 2004).

Attitude Surveys

The other major category of bicycle commuter research is attitude surveys. This method is used to gain greater understanding of the reasons, conditions and policies that influence people's decisions whether or not to commute by bicycle. Many of the reasons identified by these surveys were discussed previously in Chapter 2.

A good example of this type of survey was conducted by the University of Calgary to aid in upgrading the city's travel forecasting model. They used a stated preference survey to quantify attitudes and references to measure attractiveness of a cycling option based on its characteristics (Abraham, McMillan et al. 2002).

The results showed "cyclists are attracted to shorter journeys, but are also willing to travel substantially further to ride on specific types of routes; and / or to destinations with specific destination facilities." In specific reference to bicycle commuters, "cyclists were

willing to spend slightly more time cycling...but placed a higher value on end-of-trip facilities (except for a “standard bike rack” which many commuters may feel is inadequate for all-day regular parking). For meeting trips, cyclists were more willing to spend money on parking facilities (perhaps because they imagined being reimbursed by their employer) and placed a higher value on the various clothing change facilities” (Abraham, McMillan et al. 2002).

In the end, the survey confirmed the “average cyclist strongly prefers off-street cycling facilities and low-traffic residential roads” (Abraham, McMillan et al. 2002). The chart below shows their findings as a numerical comparison between specific facilities and their influence on the commuting decision:

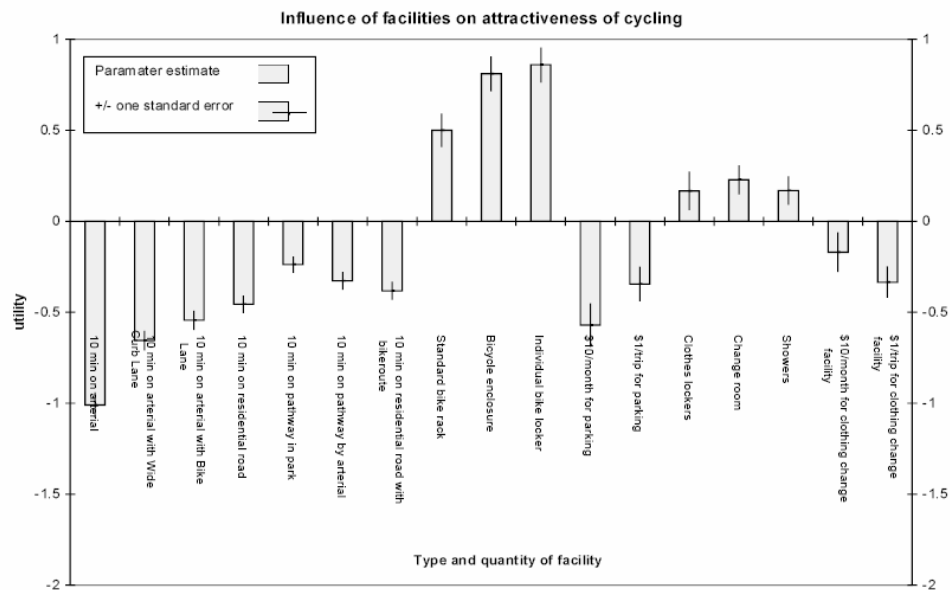


Figure 8 Influence of facilities on the attractiveness of cycling (Abraham, McMillan et al. 2002)

This chart could be used to prioritize types of facilities to be constructed or to encourage the private sector to provide certain amenities. It could also be used to predict the efficacy of a facility project before it is implemented.

Need for further research

While significant research has been performed in the areas of streetscape evaluation and cyclist attitude surveys, the majority of data collection has been focused on the promotion of bicycle commuting at a community level or for installation and evaluation of bicycle facilities. More research into the behavior and cognition of bicycle commuters is still needed in order to better understand and serve the needs of this population. “It is obvious that significant research is required in almost all areas. For example, research directed at gaining a fundamental understanding of rudimentary bicycle/rider unit behaviors, such as perception-reaction...seems long overdue” (Taylor and Davies 1999). In order to increase the amount of work trips made by bicycle, “further attention is needed to determine the obstacles that discourage existing bicyclists from bicycle-commuting and how to overcome these obstacles” (Jackson and Ruehr). In addition, Snyder states: “we have very little data other than journey-to-work data from the census” (2004).

Chapter 4 : A CYCLIST-CENTERED APPROACH

"Bicycling is a complex, acquired skill that requires a certain level of both cognitive and motor development. It requires a substantial amount of practice, experience, and exposure to the environment in which riding takes place as well as use of protective devices such as helmets. The degree of motor and cognitive maturity required for the bicycle rider to be able to negotiate on the roadways with motor vehicles has not been defined." (Agran and Winn 1993)

Understanding mental models of the bicycle commuter

A key to accurately understanding the behavior of an individual within a given system, environment or product is having a good representation of their mental models of that situation. Mental models, also referred to as cognitive models or conceptual models, are the pictures we form in our heads of how a product or system operates. It is a mental representation of how a thing works that dictates our understanding of cause-effect relationships within a given context. Mental models are a very useful tool for explaining how people 'figure things out.'

In his book *The Design of Everyday Things*, Donald Norman explains the concept of mental models:

“...mental models [are] the models people have of themselves, others, the environment, and things with which they interact. People form mental models through experience, training, and instruction. The mental model of a device is formed largely by interpreting its perceived actions and its visible structure.” (2002)

It is mental models that drive our interactive actions with products, situations and environments. By accurately understanding others’ conceptual models of a given situation, designers can provide better support for users within a given context, be it in the form of a product, a set of instructions, or education. It is this effort to accurately understand and represent mental models that will be applied to the study of bicycle commuters.

Research Methodology

For this investigation, two methods of data gathering were developed: Ride-along observations and creation of audio-visual diaries. Eight subjects were recruited who currently commute by bicycle at least once a week. Ten research rides were undertaken: Five ride-along observations, and five audio-visual diaries (2 subjects participated in both types of research rides). The studies were performed in the metro area of Atlanta, Georgia between February and May of 2006.

Ride-along observation

In this study, bicycle commuters would be video-taped along their commute routes. The investigator would follow behind the subject, wearing a helmet-mounted camera and a lapel-mounted microphone to capture the cyclist in action and to record any vocal observations of the investigator.

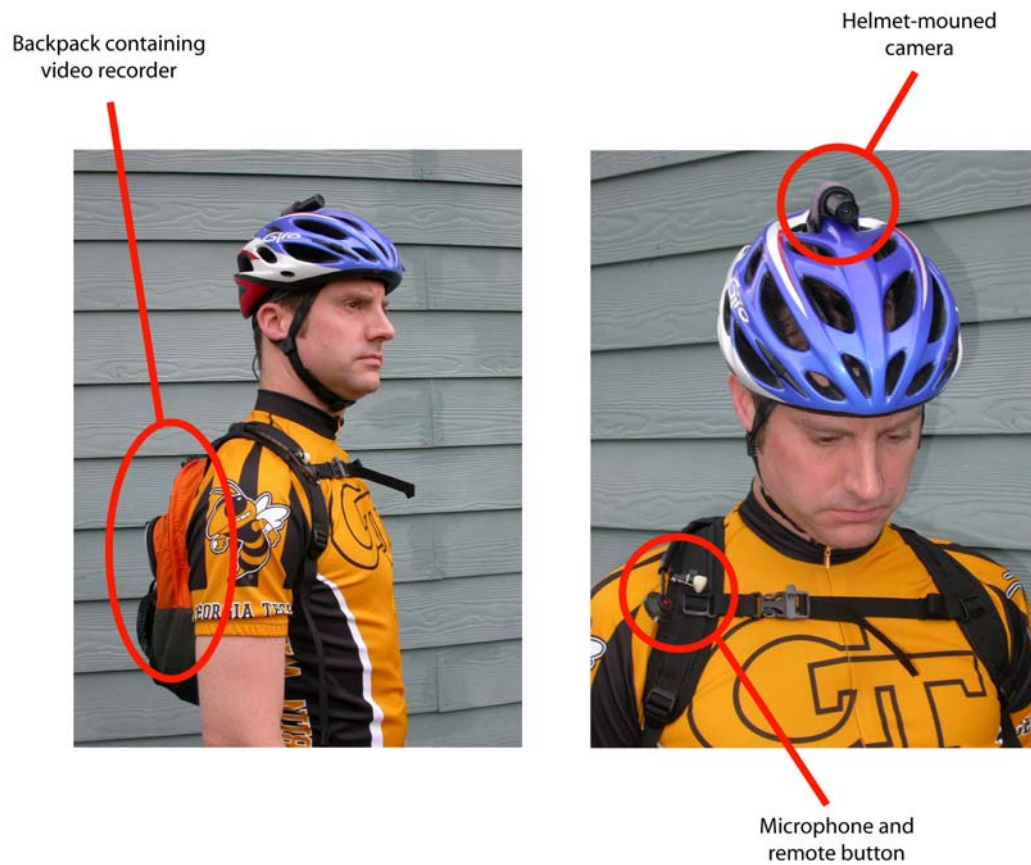


Figure 9 Video recording rig

The purpose of this study was to identify a variety of behaviors of the cyclists; communication behaviors, unique behaviors and compensatory behaviors. Compensatory behaviors are those a user (subject) performs in order to compensate for an external condition or stimulus while in the process of trying to achieve a specific outcome. Compensatory behaviors can be a planned compensation or a subconscious reaction. Compensatory behaviors once identified, can present design opportunities.

The investigator met up with the subjects at their homes prior to the subjects' departure for work or for school. The camera equipment was set up on the investigator and tested for proper functioning. The subjects were instructed to follow their normal behaviors, routines and pace. In the event of equipment or mechanical failure of the investigator (flat tire, dropped equipment, etc.), the subjects were instructed to continue on with their commutes as normal.

When ready, the subject departed and began their commute. The investigator followed behind, maintaining a gap of 5-6 bike lengths, allowing sufficient room for one or two cars to merge in between the investigator and subject, if needed. This was done to minimize the investigator's impact on the interaction between the subject and passing automobile traffic as well as minimizing influence on the subject's riding habits and behavior.

At the conclusion of the ride, subjects were quickly debriefed for general observations of the day's commute and for any unusual happenings or incidents.

Video tapes were collected, converted to digital format for viewing and archiving, and later reviewed for mapping exercises.

“Think-along” audio-visual diary

In this study, subjects self-recorded their commute, creating audio-visual diaries of their trips. The purpose of this study was to gain insight into the in-context observations and perceptions of the cyclist, dynamic and static elements of the environment through which a cycle commuter travels (including streetscape, vehicles, and people), and to identify compensatory behaviors, rituals and other unique behaviors as performed by the cyclist.

The subjects were given helmet-mounted cameras (same configuration as the investigator wore in the previous research activity) connected to a video recorder worn in a small backpack. On the shoulder strap of the backpack was a small microphone to capture the subjects’ spoken comments. Also on the shoulder strap was a remote control button which controlled the video equipment. Subjects were instructed how to operate the remote control for instances where they may have wanted to terminate the recording session, as per IRB guidelines for voluntary cessation of study participation.

Prior to their commute ride, the subjects were met at their point of departure by the investigator – either home, work or school, depending on their direction of travel (to work or back to home at the end of the day). The recording equipment was fitted to the subject, tested for freedom of movement so as not to impact the riding posture and

movements of the cyclist, and tested for proper function. The subjects were then instructed to “think out loud” during their ride, vocalizing their thoughts, observations, and reactions to their commuting experience. With the video recording equipment in place, head movements could be recorded to identify direction of glance and attention-grabbing items or events. The subjects embarked on their commute rides, without the investigator following. This greatly reduced the possibility of investigator influence on their environment interactions.

Subjects “thinking out loud” and vocalizing their thoughts during their commute rides allowed investigators to capture the subjects’ insights and gain significant understanding of the perceptions and reactions of the cyclists in the context of the studied commute ride.

At the conclusion of the ride, the investigator met the subjects at their destination, shut down and disconnected the recording equipment. In a couple of instances where the investigator was not able to immediately meet up with the subjects, they were instructed in the procedure for disconnecting and removal of the equipment for later retrieval by the investigator. Again, subjects were quickly debriefed for general observations of the day’s commute and for any unusual happenings or incidents.

Review of commute videos and identification of routes

The videos of the subjects’ commute rides were later reviewed by the investigating team. They were used to identify the exact routes taken by the subjects during their trips. These routes were then plotted on a satellite map using the mapping program *Google Earth*.

Through the use of *Google Earth*, all of the commute routes could be tracked and plotted in a single view and be printed out for later interactions with the subjects.

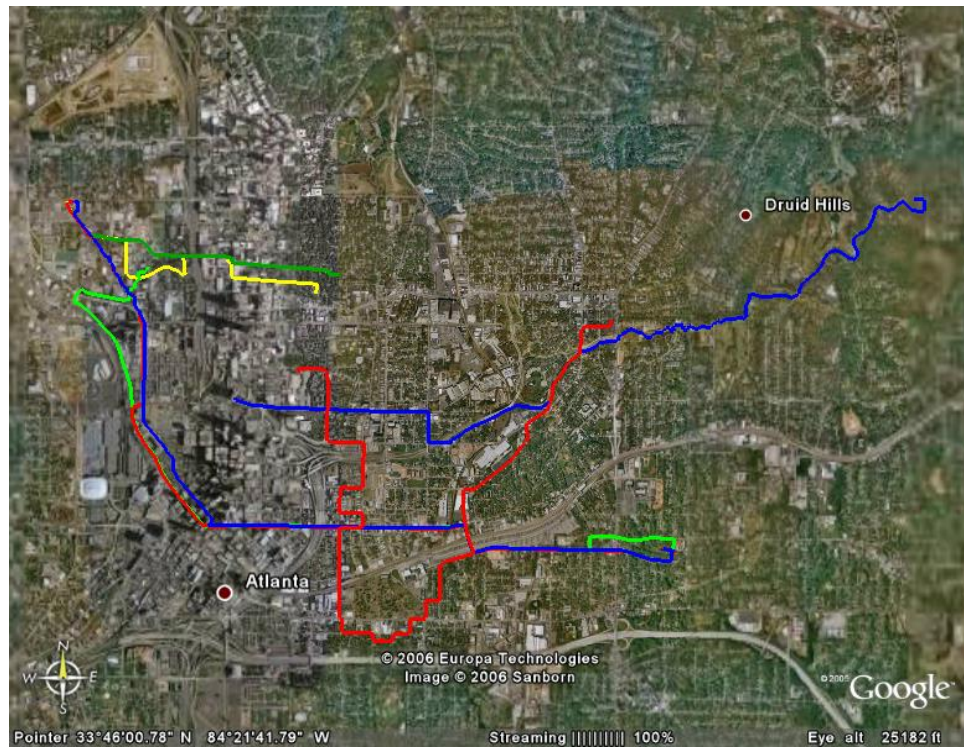


Figure 10 Assorted downtown commute routes as plotted in Google Earth

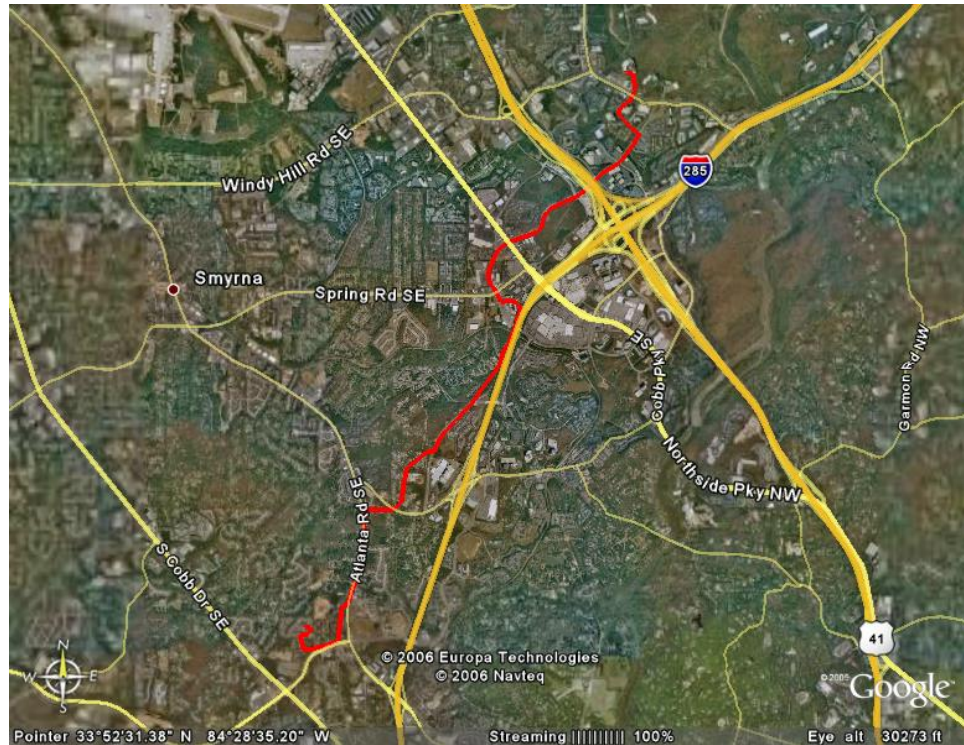


Figure 11 Satellite map of individual commute route (in red)

Interviews

After the satellite maps were plotted and compiled, the subjects (same as those who participated in the research rides) participated in follow-up interviews. Subjects were interviewed individually. The purpose of these interviews was to gain further insight into the riders' perception and understanding of their commuting environment, so as to begin to understand the structure and nature of their mental models of their commutes. The interview sessions were video recorded for later review and analysis.

The subjects were first asked background questions:

- How long they had been commuting by bicycle?
- Frequency by which they commute by bicycle.
- Their perception of their own skill level as a cyclist (novice – intermediate – experienced).

Cognitive Mapping

Subjects then performed a cognitive mapping exercise. Cognitive maps are a valuable qualitative tool in that they represent information which is most salient to the subject and context at hand. They are “mental representations of places” (Sommer and Sommer 2002) and are a very useful tool for investigators to understand a subject’s perception of their environment or of an experience.

Subjects were given a blank sheet of paper and asked to “draw their routes.” Subjects were provided with extra paper, if needed, and a variety of colored markers. Without further explanation, the subjects drew how they envisioned their commutes. After the subjects were finished, the investigator asked the subjects to ‘talk through their map.’ This led to significant insights into route choice, incident occurrence, and compensatory actions. An example of a cognitive map is shown below:

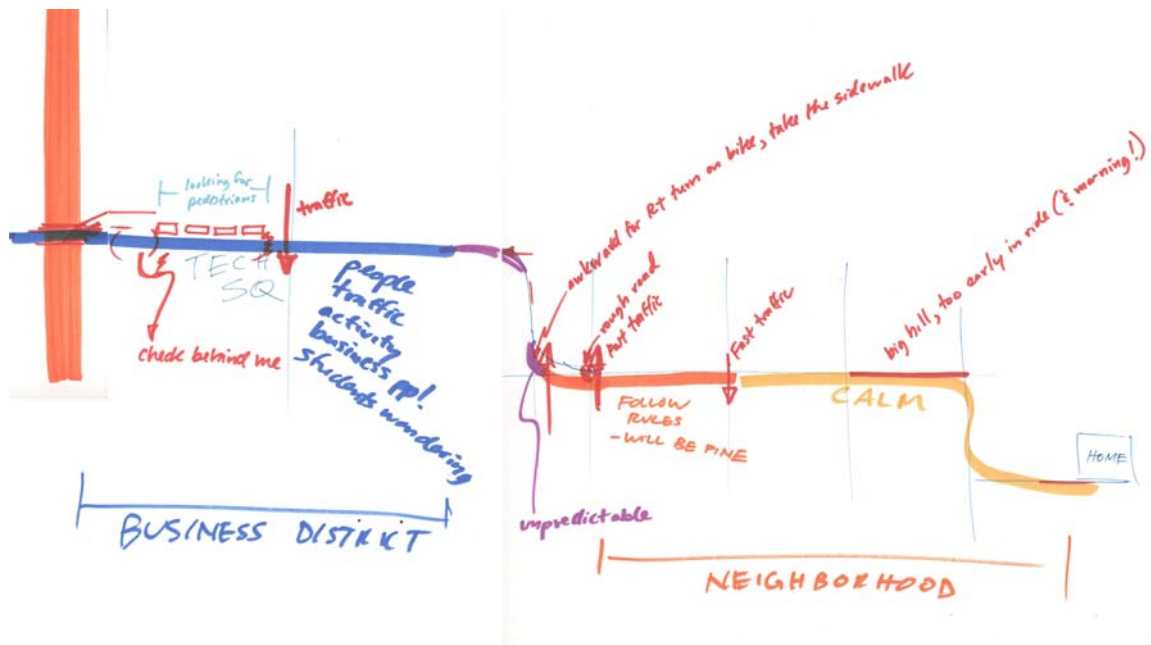


Figure 12 Enlarged section of cognitive map

The subjects were then asked to identify the zones where they felt ‘inferior’ or ‘uncomfortable.’ Participants highlighted these areas in red and were asked to explain what it was that made them feel this way. The subjects were then asked to identify the opposite: zones where they felt ‘superior’ or ‘comfortable’ and highlight them in yellow. Again, the subjects explained their reasoning. It is important to note that these comparisons of ‘comfortable’ versus ‘uncomfortable’ or ‘superior’ versus ‘inferior’ are relative only within a single cognitive map. As different cyclists viewed their commute environments differently, it cannot necessarily be said that the same activities which make one rider uncomfortable will have the same reaction in another.

Satellite Mapping

The subjects were then shown the satellite maps of their commute routes (previously generated by the investigators). The same procedures of identifying ‘comfortable’ and ‘uncomfortable’ zones were repeated. It was noted whether having a highly accurate map and satellite imagery changed the level of detail the subjects identified within the yellow and red zones. Subjects were then asked to write down the words or activity they associated with each zone.

The subjects were then asked to explain the major differences in their perceptions of the two types of identified zones. Responses included:

- Two vs. Four lanes [roads]
- “Feel a part of traffic” [in comfortable zones]
- “Greater traffic and injury potential” [in uncomfortable zones]
- Traffic frequency
- Speed differential [between bikes and cars]
- Size of vehicles
- Room / space between cars and bicycle
- “Fear of what other cars will do” [uncomfortable zones]
- Traffic density
- Expectation of bikes by drivers vs. drivers surprised/angry by bicycle presence
- Pace of riding
- Degree of relaxation

Subject Associations with zone labels:

Table 2 Zone label associations

Comfortable / Superior (yellow)	Uncomfortable / Inferior (red)
Comfortable	Thinking ahead (of drivers and pedestrians.)
Have free passage	Vulnerable
Uninhibited	Anxious
Safe	Conflict (possibility of)
Recognized	Cars speeding past
Protected	Cars trying to pass
Respected	Busy traffic
Relaxed	Not respected
Visible	Not recognized
Not an obstacle	Invisible
Not an annoyance for drivers	Likely to be squished
Beat traffic	Less safe
Calm	Need to be aware
2 lane roads	Danger
Same speed as traffic	Large difference in speed
Office park	Frequent lane changes
Slow traffic	Stop & go
Drivers expect bikers	Left hand turn
Cars react positively	Heavy traffic
Cars leave room	Low visibility
Peaceful	Merging lanes
Nice views	Pressured
Better than folks sitting in cars	Cars too close
Safe point	“Crap, a car is going to run me over”
	“DOT is gonna kill me” (pot holes)
	Sketchy

Planning and behavior alteration

The interviews and mapping exercises also revealed that subjects would alter their behavior patterns *post* ride. They would fine-tune certain elements of their commute in order to achieve a more desirable condition. This is evidence of “pre-planning,” where people alter their mental models in response to an experience and engage in a planning (or processing) behavior to overcome or compensate for an activity. “To plan is to consider several alternative courses of action, weigh the implications of each of those alternatives, compare, then select” (Norman 1993). Evidence of behavior alteration post-ride included:

Physical artifacts

- Choosing a mountain bike over a road bike to allow flexibility for jumping up onto sidewalks.
- Narrowing of handlebars to allow for maneuvering in and around traffic.
- Addition of visual recognition aids such as lights and bright clothing.

Planning

- Route choice alteration. Certain subjects modified their commute routes to avoid certain external activities they had encountered.
- Decisions made to make their rides more comfortable, enjoyable or safer than what they had previously experienced.

Analysis of mapping and interview data

After completing the interviews, the mapping data was analyzed by the investigating team. The cognitive maps created by each subject were compared against the corresponding satellite maps. Additionally, all maps (cognitive and satellite) were compared against all others and evaluated. After the comparative analysis, the taped interviews were reviewed and various user perception data was overlaid onto the subjects' cognitive maps to develop perception-activity-behavior (PAB) maps. A useful tool in illustrating the developing and changing mental models of cycle commuters, PAB maps will be discussed later in this section.

Comparative Analysis

Cognitive maps and the corresponding satellite maps were paired and pinned up on display boards for evaluation.



Figure 13 Comparison of cognitive map and satellite map

The first observation revealed an issue of scale relative to real-world. The cognitive maps tended to be drawn out of scale in reference to specific comfort zones. For instance, areas that were drawn larger (or longer) in relation to the rest of the map were zones which the subjects labeled as ‘inferior’ or ‘uncomfortable.’ Conversely, areas that were drawn smaller (or shorter) in relation to the rest of the map were those zones labeled

as 'superior' or 'comfortable.' Distortions in cognitive maps reveal information about what people believe to be important in their environment and the routes they use (Sommer and Sommer 2002). These indicate a different mental representation of the various zones, where more attention was paid by the bicyclist to the stressful areas or where vulnerability was felt. Whereas in the comfortable zones, less attention was paid to the environs and activity, and the cyclists relaxed. Another way of interpreting this information is to say cyclists' perceive dangerous activity as taking more "time." It could be said that differences in external activity, as indicated by the interview responses, caused different levels of focus within different zones. This demonstrates the evolving mental models of cyclists throughout their commutes.

Also noted were differences in perception between different cyclists in relation to routes or areas common to several commute routes. One voyage in particular was undertaken by two subjects. The two subjects are roommates and commute to the same college campus – one for work, the other to attend class. Both subjects followed almost the exact same route, but had distinctly different perceptions of their rides. Review of research ride video footage reflected the differences in their riding behaviors.

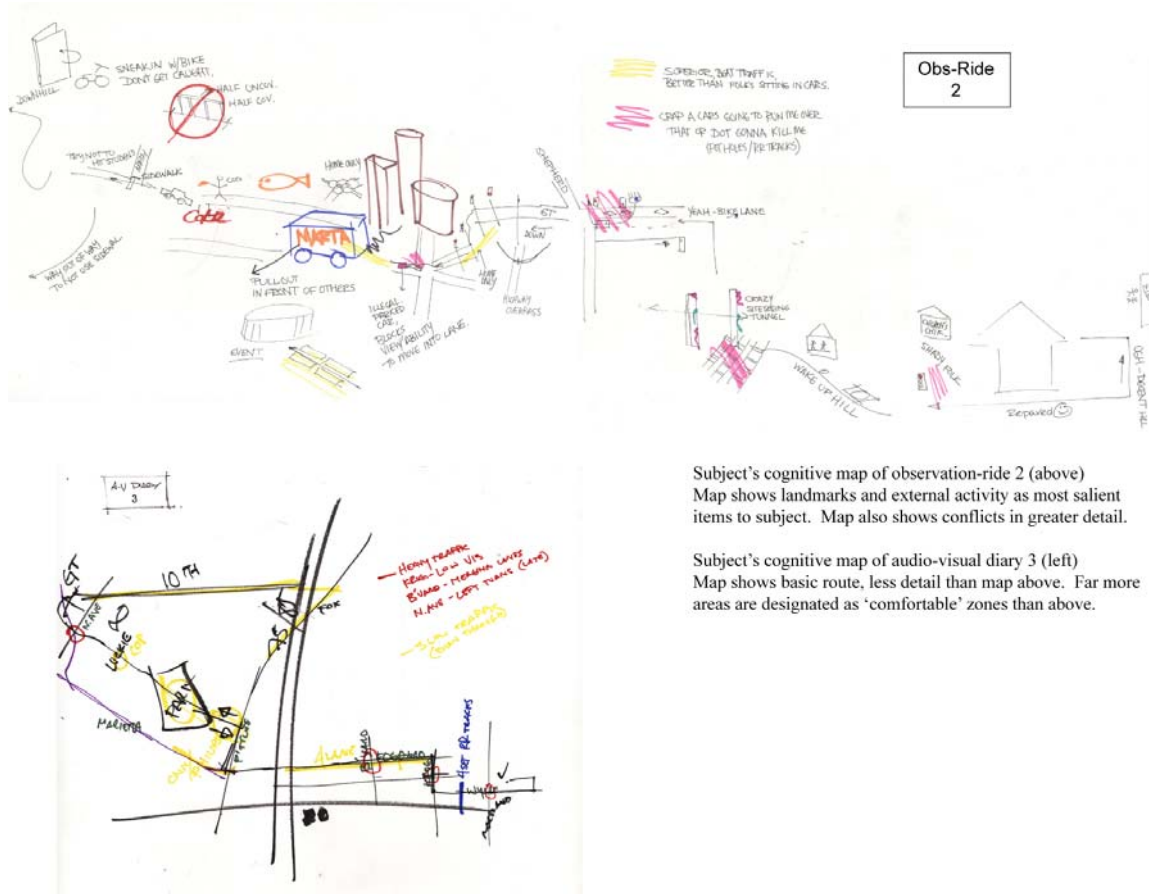


Figure 14 Comparison between different cognitive maps of same route

Analysis of interviews and video footage also revealed that cyclists’ tailored their riding behavior to the activity around them, whether actual or *anticipated*. The term ‘actual’ activity is defined as external activities currently happening and experienced by the rider. Conversely, ‘anticipated’ activities are external activities not currently happening around the rider, but rather through experience or intuition, are recognized by the rider as having a likelihood of occurring. This illustrates pre-planning, where the riders are preparing themselves for the possibility of certain external activities. It could be seen as a preparatory behavior in the sense the commuters are preparing themselves for the

likelihood of an external activity, or as a preventative behavior with the motivation of “if I do X, it will prevent Y from happening.” The idea that perceived [anticipated] external activity influences behavior has been discussed in previous literature, although the findings here are in conflict with a previous idea presented when examining the efficacy of municipal policies: “It is plausible that accident risks do play a prominent role in non-motorised transport because cyclists and walkers are relatively vulnerable per kilometre travelled, compared with car drivers. The issue of perception of risks versus actual risks is of course a matter of concern: for the explanation of behaviour, the latter is more important than the former.” (Rietveld and Daniel 2004)

Perception-Activity-Behavior (PAB) Mapping⁷

Perception-activity-behavior (PAB) maps were created to further examine bicycle commuters’ mental models. The PAB maps were generated by building upon the subjects’ drawn cognitive maps. Responses and insights from interview notes and video review were layered onto maps of the commute routes. External activity as encountered by the cyclist, perceptions, and behavior were mapped along the route. They are defined as follows:

- Emotion: Subjects’ perception and level of comfort with the external activity.
- External activity: The activity happening or perceived to possibly happen around them⁸

⁷At this time, the investigating team is not aware of another term to better describe this mapping concept, therefore, the investigator claims the terms and concepts of ‘perception-activity-behavior map’ and ‘PAB map.’

- Behavior: Subjects' identified behavior
- Goals: Any specific goals of the cyclist identified in a certain zone.

Five of the ten rides, the audio-visual diary rides, were chosen for this phase. Video recordings of the audio-visual rides were viewed as better indicators of subject perception and behavior, as opposed to video recordings of the observation rides, and therefore could be used to validate the application of perceptual and behavioral information as presented in the cognitive maps and interviews.

The cyclist's route is shown at the top of the map and is the actual scale route as represented in the satellite maps. Cross-streets are indicated, but only those identified in the subject's cognitive maps are included. External activities are categorized and represented as colors. External activities are categorized from subject-supplied information.

⁸ Although a distinction is made between actual activity and perceived activity around a cyclist, the cyclists' behavioral response may be the same. For example, on a given stretch of road, cars may be passing by very close to the cyclist which will cause the cyclist to ride as far to the right as possible to accommodate the traffic. At the same time, there may be only the possibility (however likely) that a car may pass closely, but the behavioral response of the cyclist, riding far to the right, is the same.

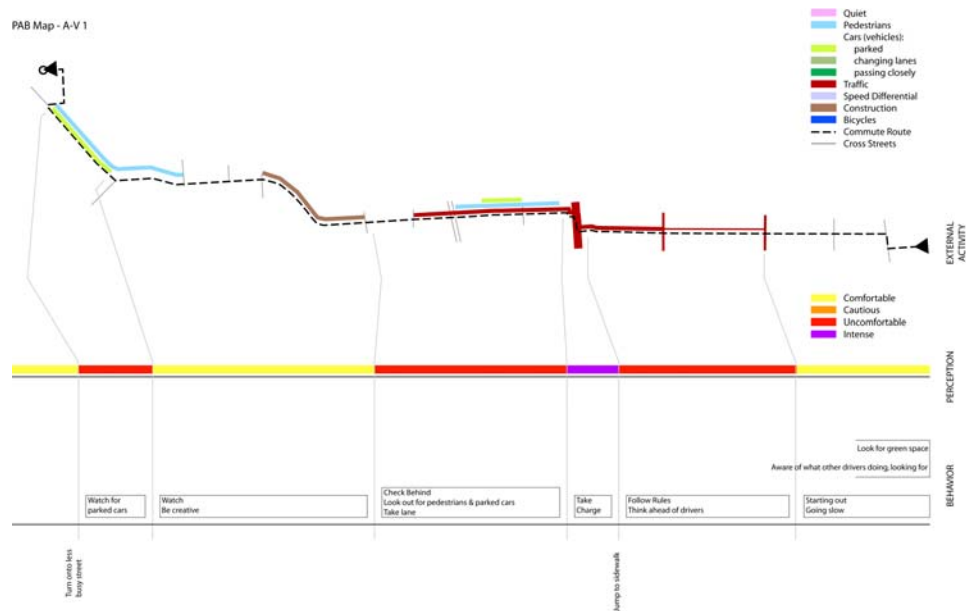


Figure 15 Sample perception-activity-behavior (PAB) map

The external activities as listed on the maps are described as follows:

- Quiet: Peaceful zone where little or no activity is seen or heard.
- Pedestrians: The presence of people walking or crossing the street.
- Cars (parked): Cars parallel parking or parked cars opening doors.
- Cars (changing lanes): Cars moving in and out of commuter’s travel lane.
- Cars (passing closely): Vehicles passing in very close proximity to cyclist, so as to cause discomfort or provoke a reaction.
- Traffic: Where subjects take notice of the amount of traffic on the road. This may be heavy traffic volume as well as light traffic.
- Speed differential: Where differences in speed between cyclist and motor vehicles are noted. This may vary in actual difference.
- Bicycles: The presence of other cyclists traveling or crossing paths.

Certain activities can have varying levels of volume, differential, intensity, etc. The differences are indicated by varying line weights. For example, PAB AV-1 shows varying volumes of traffic and correspondingly, the 'traffic' line is depicted in a variety of line weights.

The resulting maps yielded an illustration of changing stimuli, evolving perceptions and emotions, and changes in behavior of the cycle commuter. This was a good graphical representation of the commutes and proved a useful means of comparing perception and behavior across the different rides. They show perceptions and behaviors evolve as external activities change. Different external activities which were encountered led to different perceptions and changes in emotional states. Cyclist behavior evolved to address the new external activities as they were encountered, or were expected to be encountered. This change in perception along with modification of riding behavior demonstrate evolution of cycle commuters' mental models, as a function of time and as different zones of activity are encountered.

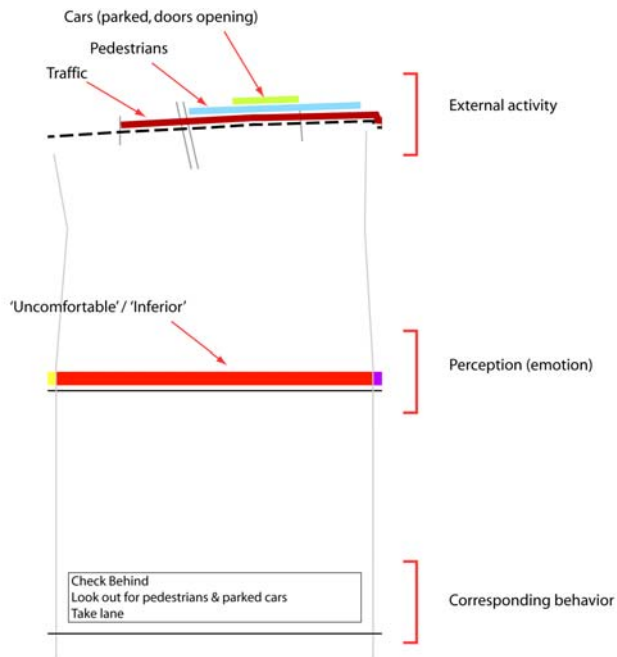


Figure 16 External activity, emotion, and behavior relationship in PAB map

PAB map observations yielded interesting insight into cyclist behavior. Three types of behavior (as performed by the cyclist along their routes) were identified. First are ‘responsive’ behaviors. These are specific responses to specific external activity or stimulus, and are shown written vertically on the map. These include: “accelerate to make light” when negotiating a left-hand turn and “jump to sidewalk” when approaching a busy, multi-lane intersection. This finding is validated by previous research, where it was found bicyclists increase risk-taking behavior (wrong-way riding, sidewalk riding) on multilane roadways because of difficulty they have crossing and threats perceived from increases in traffic volumes (Dixon).

Second are ‘situational’ behaviors. These are behaviors that are influenced by the cyclists’ perceptions of the zones they are passing through. For example, PAB AV-1

shows the subject's behavior change from "starting out" and "going slow" to "follow the rules" and "think ahead of drivers" when they progress from the first 'comfortable' zone into the first 'uncomfortable zone' where the external activity of traffic begins and continues to build. It is the changing and modification of the situational behaviors in relation to changing external activity which indicate a shift in the cyclist's mental model. The final sets of behaviors are the 'guiding' behaviors. These are behaviors which guide or lend an overall theme to the commute. For example, "look for green space" is considered a guiding behavior as the subject seeks green space throughout their commute because of a perception that these areas have less traffic and are more pleasant to be near. "Stop as little as possible" indicates a commute where the rider aims to not have to stop their bicycle at all. Also, "use hand signals" shows the subject uses hand signals throughout the ride to indicate their intentions to other traffic.

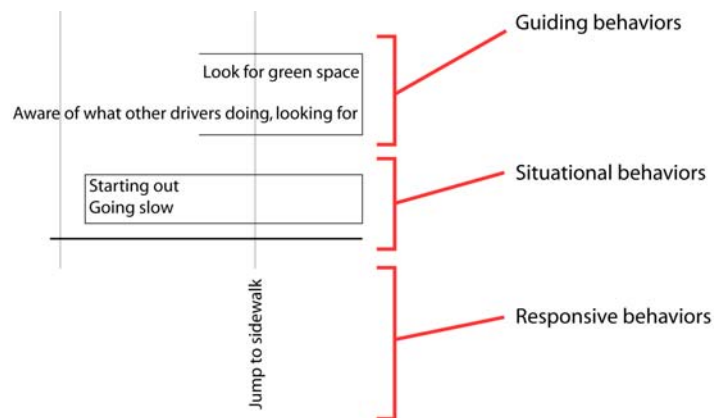


Figure 17 PAB map behavior legend

When comparing PAB maps against each other, it becomes apparent that each rider has a different mental model of his/her entire ride than do others of theirs. The earlier

cognitive mapping exercises illustrated points which were most salient to the subjects. This salience carried over to the PAB maps. Salient items, however, were not always similar among subjects. For instance, PAB AV-2 shows a high sensitivity to speed differential and to vehicles changing lanes, but no mention of traffic volume or any of the other external activities. This model is contrasted with PAB AV-4, where the identified activities are traffic volume, bicycles, cars passing closely, and quiet areas, with no mention of either speed differential or of vehicles changing lanes. This contrast and comparison can be seen among all of the PAB maps. Again, this illustrates uniqueness in mental models throughout the subjects.

Different behavior drivers among the PAB maps were also noted. This refers to the previously identified ‘guiding’ behaviors. Different subjects demonstrated different guiding behaviors, leading to the conclusion that while all commuters share the goal of getting to their destination, *how* that is achieved varies. For instance, PAB AV-5 shows guiding behavior of ‘taking the lane whenever possible’ and ‘tend to be mildly confrontational and indignant (to drivers),’ where PAB AV-2’s guiding behaviors were to ‘use hand signals’ and ‘avoid left-hand turns.’ So it can be seen that the subjects demonstrate different means of achieving their ultimate goal. All subjects did display one behavior in common, however: being ‘aware.’ All PAB maps showed an awareness guiding behavior, including:

- ‘aware of what others are doing, looking for’ (PAB AV-1)
- ‘aware of speed differential’ (PAB AV-2)
- ‘aware of what’s out there’ (PAB AV-3)

- ‘aware of traffic flow’ (PAB AV-4)
- ‘aware of big trucks’ (PAB AV-5)

Although all demonstrate a behavior to constantly be aware of an activity, the points of which the subjects are aware vary among each. This also reinforces the notion of differing mental models and points to the uniqueness of rider perception.

Despite the fact that all subjects encounter areas of discomfort along their rides, all continued to ride. Not only is the decision whether or not to ride an individual one, but the benefits that each subject saw in commuting by bicycle are largely personal as well.

The benefits that the subjects saw included:

- Exercise
- Enjoyment
- Creating challenges
- The ability to make revisions to strategies, or create new ones for successfully navigating their commutes.

The PAB maps proved a useful tool for examining bicycle commuters’ experiences. The qualitative nature of the process is given credibility by the fact that all shown variables on the maps come directly from the subjects as a result of their interviews and mapping exercises. This also helps demonstrate the individual nature of the bicycle commuter. As more bicycle commuters participate in similar studies, the pool of knowledge will continue to grow. As this was a small study with 8 riders, it can only speak to the

uniqueness of each representation. To achieve greater generalization of the results, further exploration is needed.

Chapter 5 : DISCUSSION AND CONCLUSION

“Since cycling is an individual activity, private encouragement might work better than governmental encouragement.” (Forester 1994)

Discussion

This paper effectively demonstrates a unique method of evaluating the ride behavior of bicycle commuters by taking a cyclist-centric approach. The decision to commute is an individual one, based on many factors that are unique to each rider. The relative importance of these reasons is different among various riders. While much research has been undertaken in efforts to quantify and aggregate attitudes of bicycle commuters and evaluate specific bicycle facilities, it has been aimed at assisting system-level transportation and social planning. This has left a general lack of qualitative research and a need for further understanding of individual bicycle rider behavior (Taylor and Davies 1999). Understanding behavior of bicycle commuters is not about the aggregate, but about the unique and the variety. This paper has shown how cyclists commute, not just why they choose to do so. It has demonstrated the bicycle commute to be an individual and interactive experience based on external activity, perceptions and the factor of time.

Mental models were shown to be an integral part of riders navigating their commutes.

They govern the behavior of the bicycle commuters at a guidance level. Additionally, the

models evolve as external activities change, leading to changes in behavior at the responsive and situational levels. It has been shown that mental models are as individual as the cycling commuters themselves, a unique finding that is not noted in previous research endeavors.

Therefore, not only is the decision to commute an individual one, but the method, execution and perception of the commute is largely an individual one as well. This means the community of bicycle commuters cannot be aggregated into a whole statistically for behavioral reasons. Support efforts for bicycle commuters have traditionally taken an aggregated approach, in the form of facility construction, social planning and community encouragement. Though, as this paper shows, the bicycle commuter is an individual, and a support solution should aim to serve and support the individual.

This paper develops a means by which a bicycle commuter's experience can be effectively analyzed. It is this method which will be used to create a framework for self-assessment of one's bicycle commuting experience.

Recommendation

“...there is no substitute for having the basic skills and knowledge necessary to ride on ordinary roads. Bicycle paths do not develop these skills (since they do not follow the rules of ordinary roads), and the presence of bicycle lanes does not substitute for knowing how to operate in traffic” (Schimek 1997).

As the mapping exercises have shown, even experienced cyclists feel certain amounts of stress along their commutes. To make commuting by bicycle more enjoyable and more comfortable for both novices and experts, a support solution could be implemented that would help turn the ‘red’ zones into ‘yellow’ ones. Based on the methods demonstrated in this paper, a means of commute self-analysis is proposed.

The self-analysis procedure would provide bicycle commuters a means to visualize their commute experiences and review and project those experiences in a clinical manner. This tool could help them overcome uncomfortable or stressful zones by providing a less emotional evaluation of them. This information could be used for better practicing, planning, or preparing on the bicycle commuter’s behalf. Furthermore, the diagnosis can be integrated with external support measures such that upon completion of the self-analysis, several recommendations are made:

- Specific beneficial components, or
- Behavior modification, or
- Tailored cycling skill education.

Building from the performed research (interviews, cognitive mapping, audio-visual diaries), an example of a self-assessment questionnaire is presented:

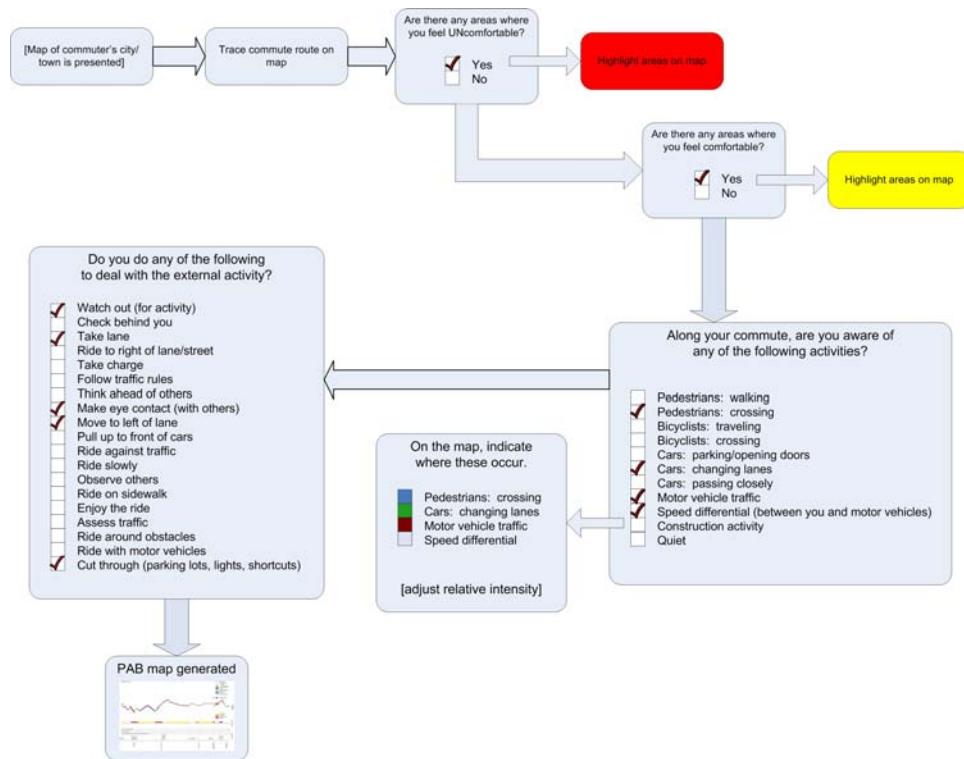


Figure 18 Sample self-assessment interactive questionnaire

The questionnaire could be integrated with software that would also allow the commuter to trace their route within a mapping function (similar to *Google Earth* as used in this study). From that information, graphic output similar to a PAB map would be produced. The bicycle commuter would have a visual representation of their commute experience to assess that experience as a function of external activity. This visual representation allows

the commuter to make any necessary adjustments to behavior or equipment, as previously proposed.



Figure 19 Sample interface of self-assessment software

The self analysis kits can be used by the individual or be a service provided by a local bike shop. The bike shop can assist in the self analysis procedure and then assist with the necessary recommendations. For instance, the shop can offer specific beneficial components needed, provide tailored instruction for riding as a part of traffic, or suggest riding behavior modifications.

This tool can also be used to build support communities. If configured as an online application, PAB analyses would serve to build a database of route and preference information. In this way, commuters could log on to the site, perform their analysis, and be able to glean insight from others. This would allow commuters to get advice from others of similar preferences and behavior, and thus be able to tailor their ride as they see fit, or get advice on how to handle specific situations. The more people participate in the analyses, the richer the data grows, giving visitors to the site a great wealth of insight from cyclists similar to themselves. Since the motivation to commute by bicycle as well as the benefits received from it are individual, it is most appropriate for the support network to be built ground-up from a network of individuals.

Conclusion

The goal of this paper is to demonstrate a novel method of evaluating the ride behavior of bicycle commuters. During the early stages of research, it became apparent there was a need for such a method. The qualitative behavioral approach taken in this study shows unique results – that bicycle commuters are all individuals with different motivations, perceptions, and behaviors. Other research has looked at systems and policies as a way to change individuals. This study believes the opposite, a ground-up approach, will bring the best results to bicycle commuters.

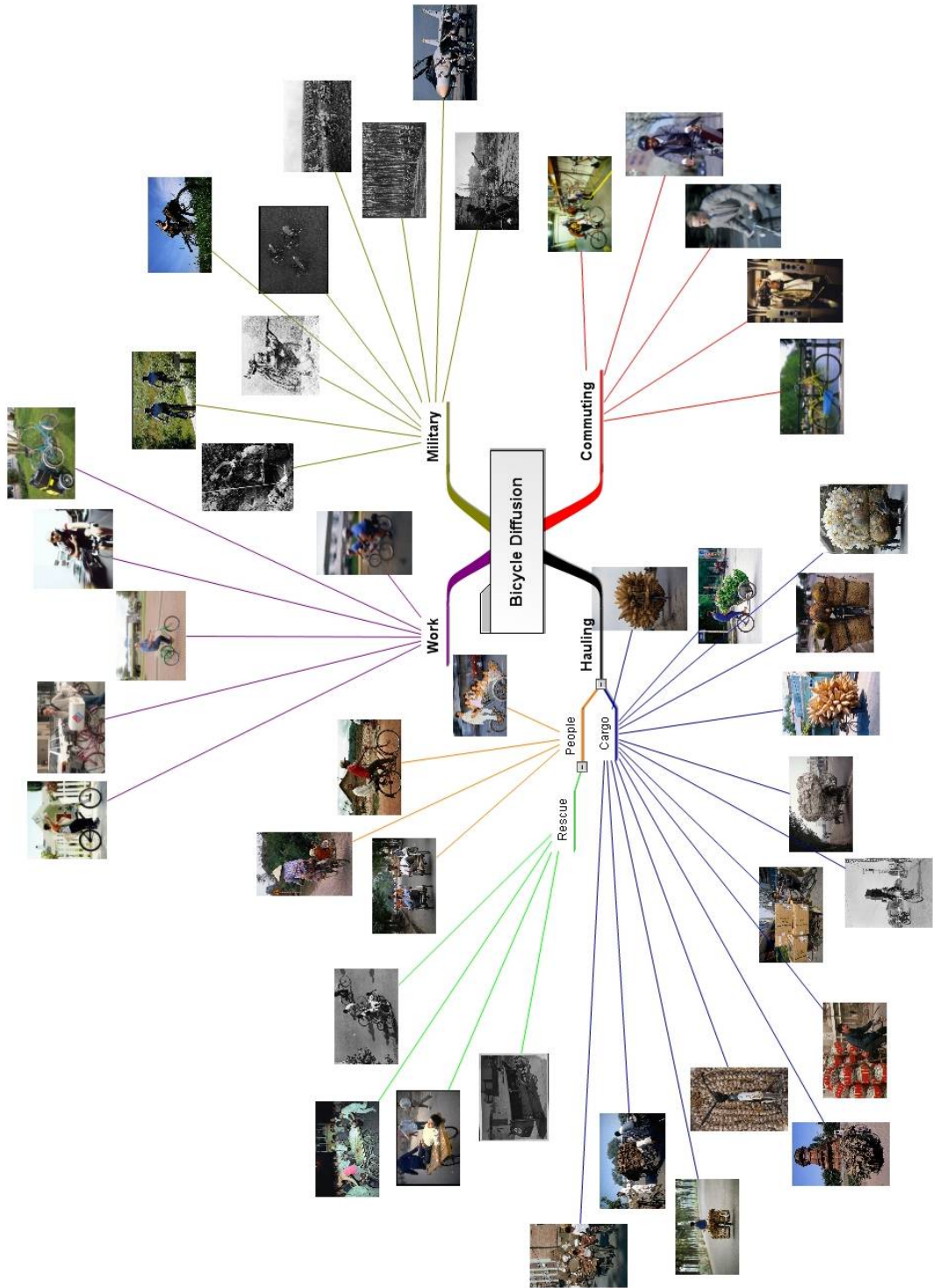
The relevance of the bicycle as a transportation vehicle is becoming more and more relevant, beyond being just an exercise machine. Current social issues today, including climate change, fossil fuel consumption, rising cost of per-mile fuel, and congestion and sprawl make the bicycle a more viable option for getting around. There are many hurdles to be crossed for the individual and the community before bicycle commuting is more widely adopted. It is hoped, however, that the results shown in this paper and the self-analysis recommendations made will help increase bicycle commuting, if even in a small way.

Perhaps through the visual analysis of commute experiences, we can come closer to riding the streets as envisioned in the *vehicular-cycling principle* of John Forester:

“The vehicular cyclist not only acts outwardly like a driver, he knows inwardly that he is one. Instead of feeling like a trespasser on roads owned by cars he feels like just another driver with a slightly different vehicle, one who is participating and cooperating in the organized mutual effort to get to desired destinations with the least trouble” (Forester 1994)

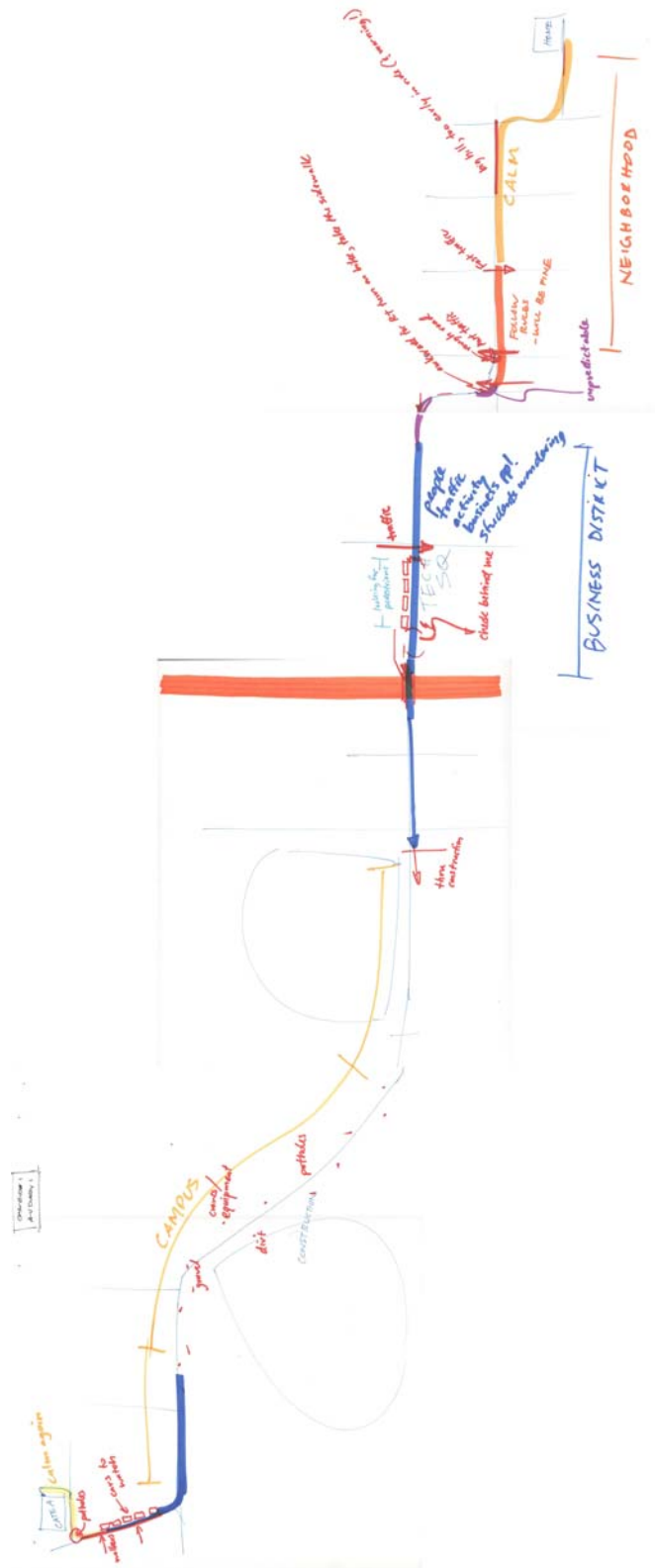
Appendix A: Spider charts

Bicycle diffusion chart

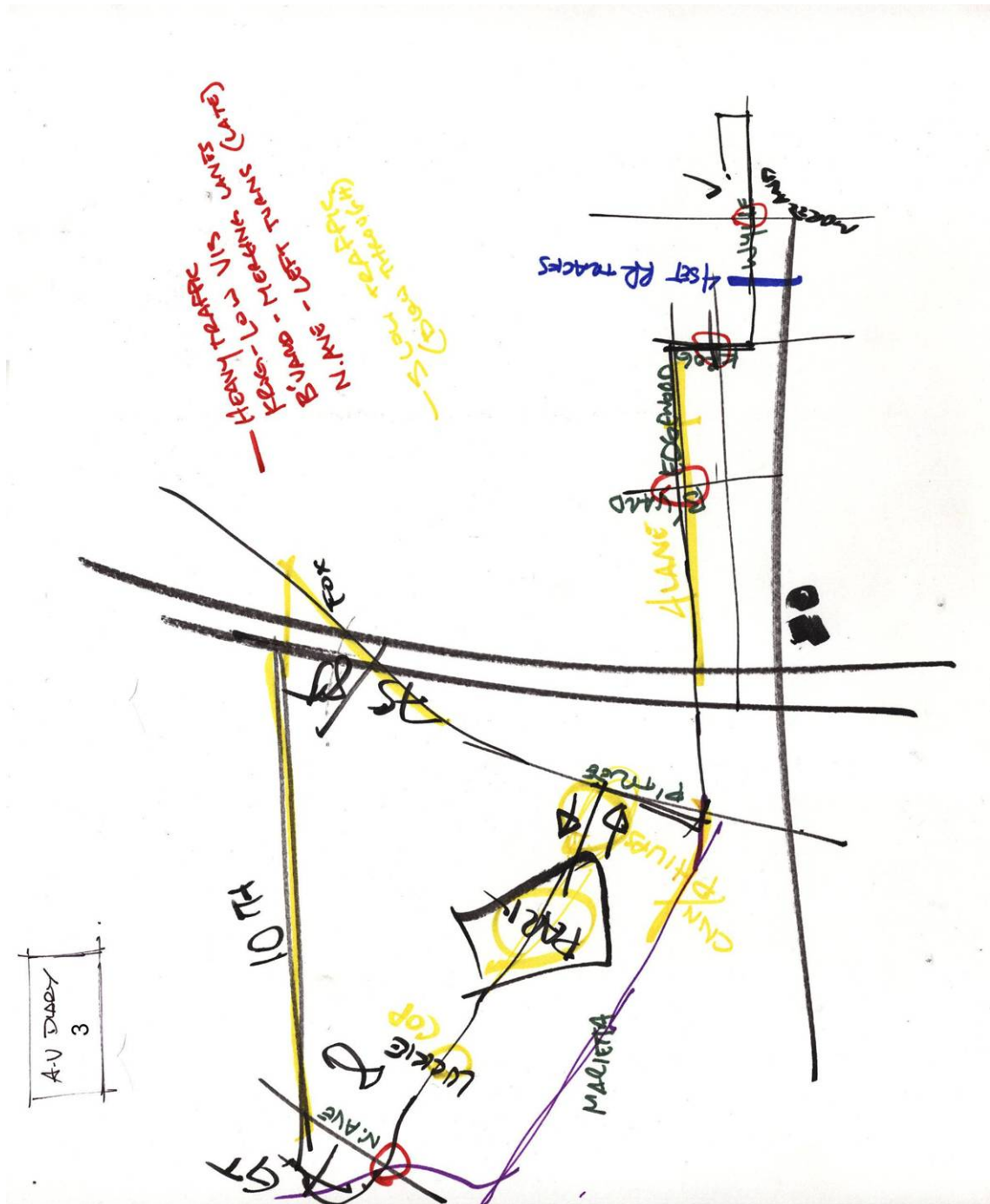


Appendix B: Cognitive Maps

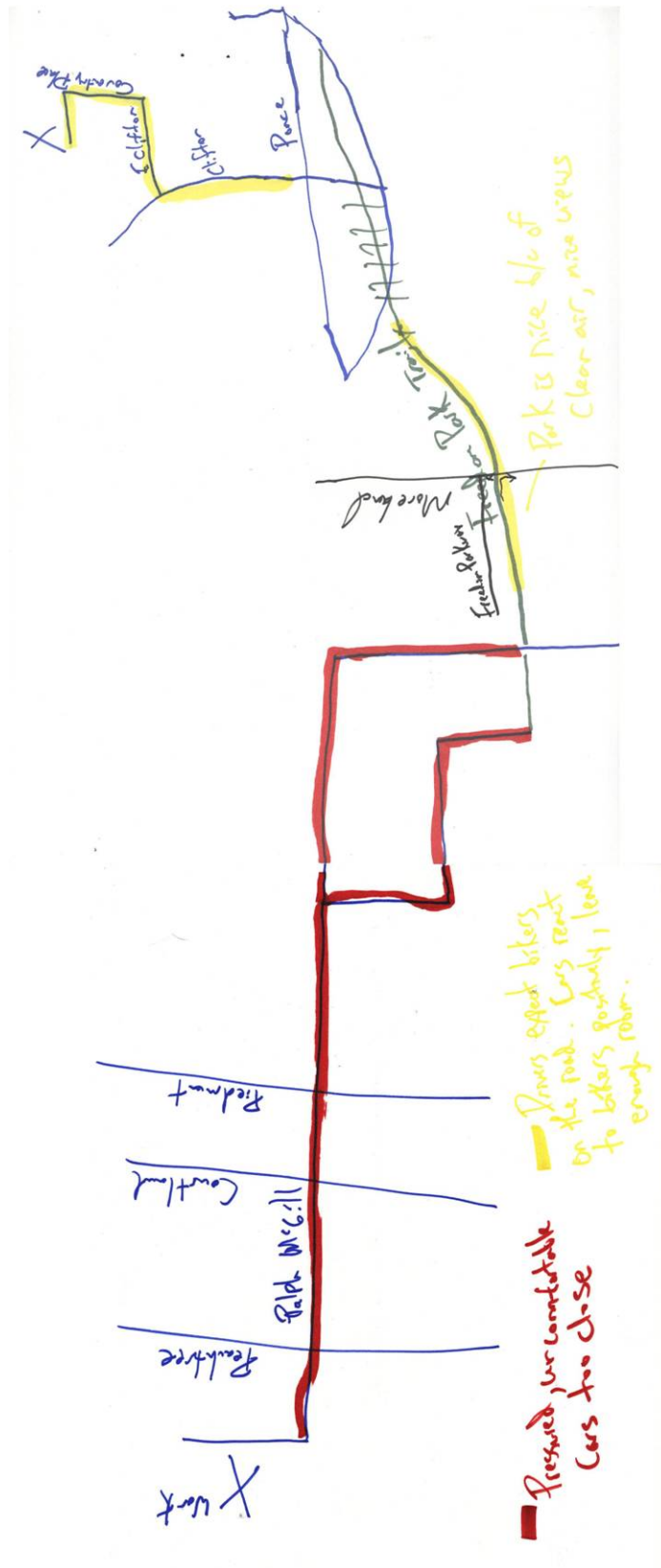
Audio-Visual Diary 1



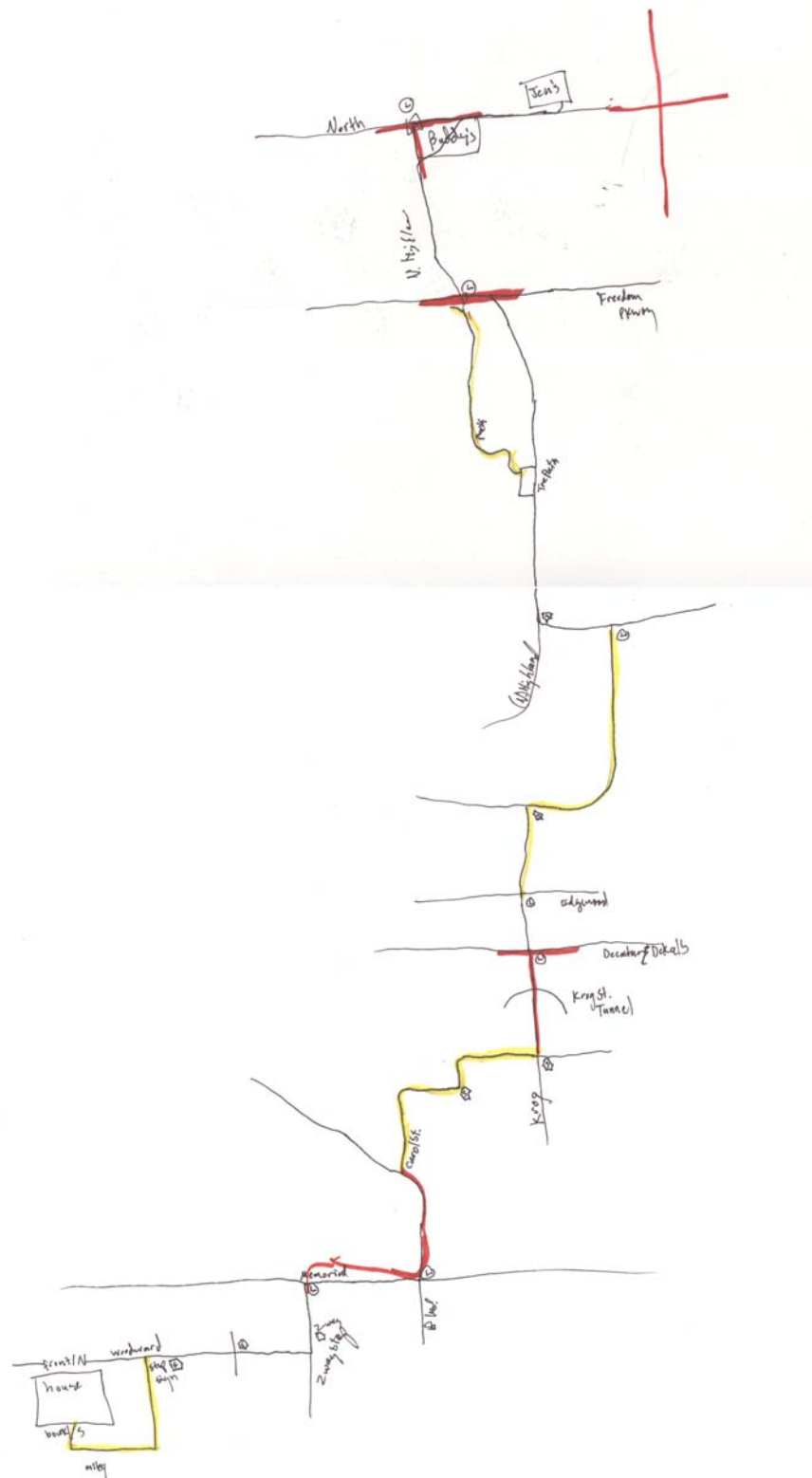
Audio-Visual Diary 3



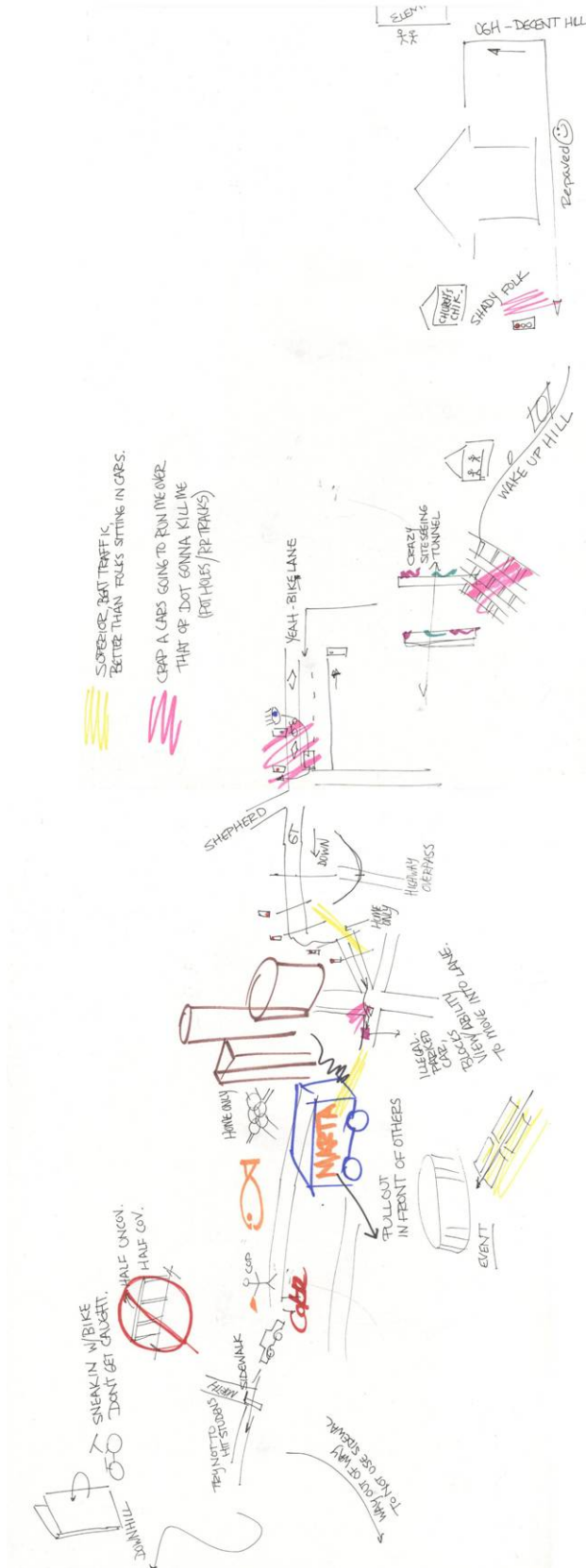
Audio-Visual Diary 4



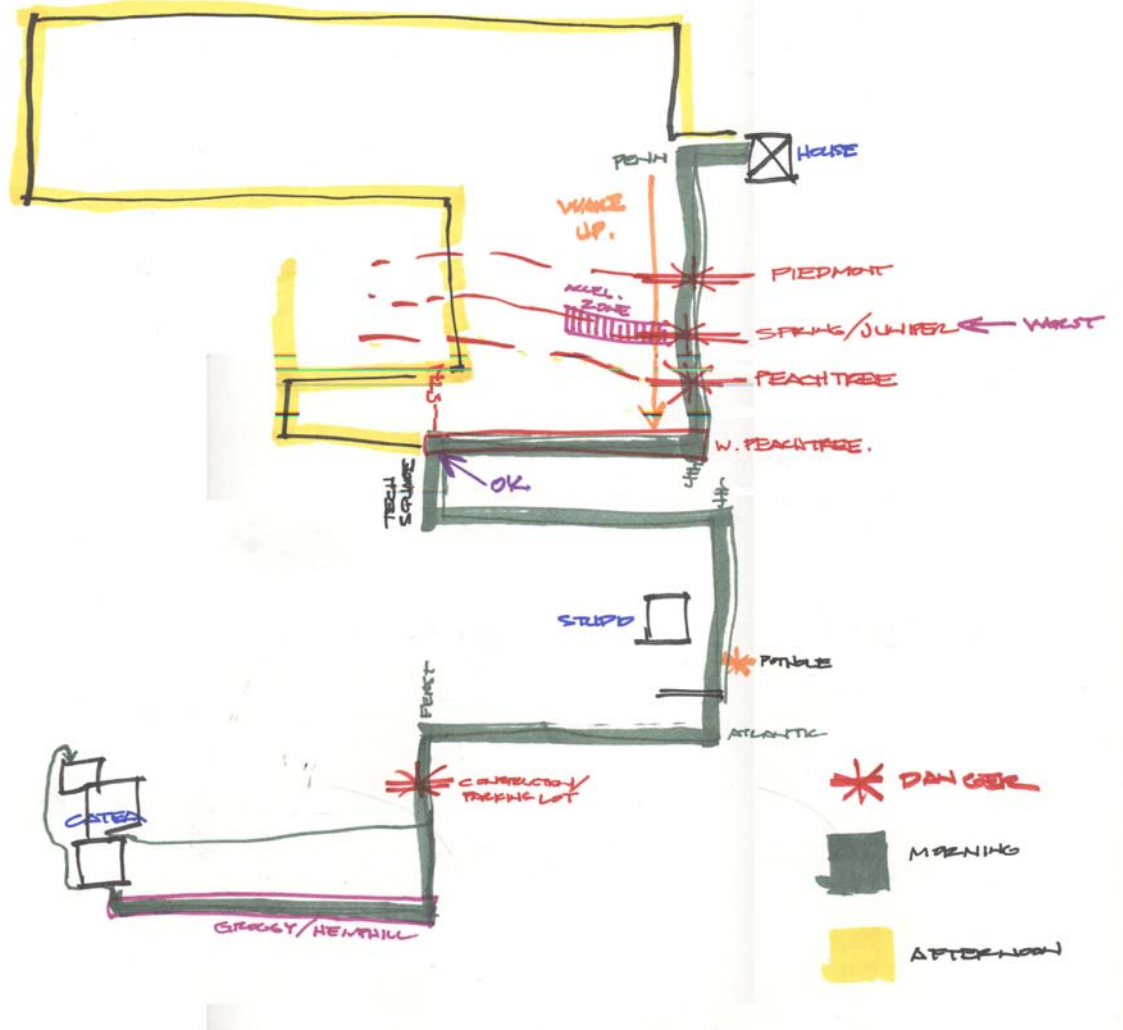
Audio-Visual Diary 5



Observation Ride 2



Observation Ride 3



Observation Ride 5



Appendix C: Satellite maps

Satellite Map AVD-1, OR-1



Satellite Map AVD-2



Satellite Map AVD-3

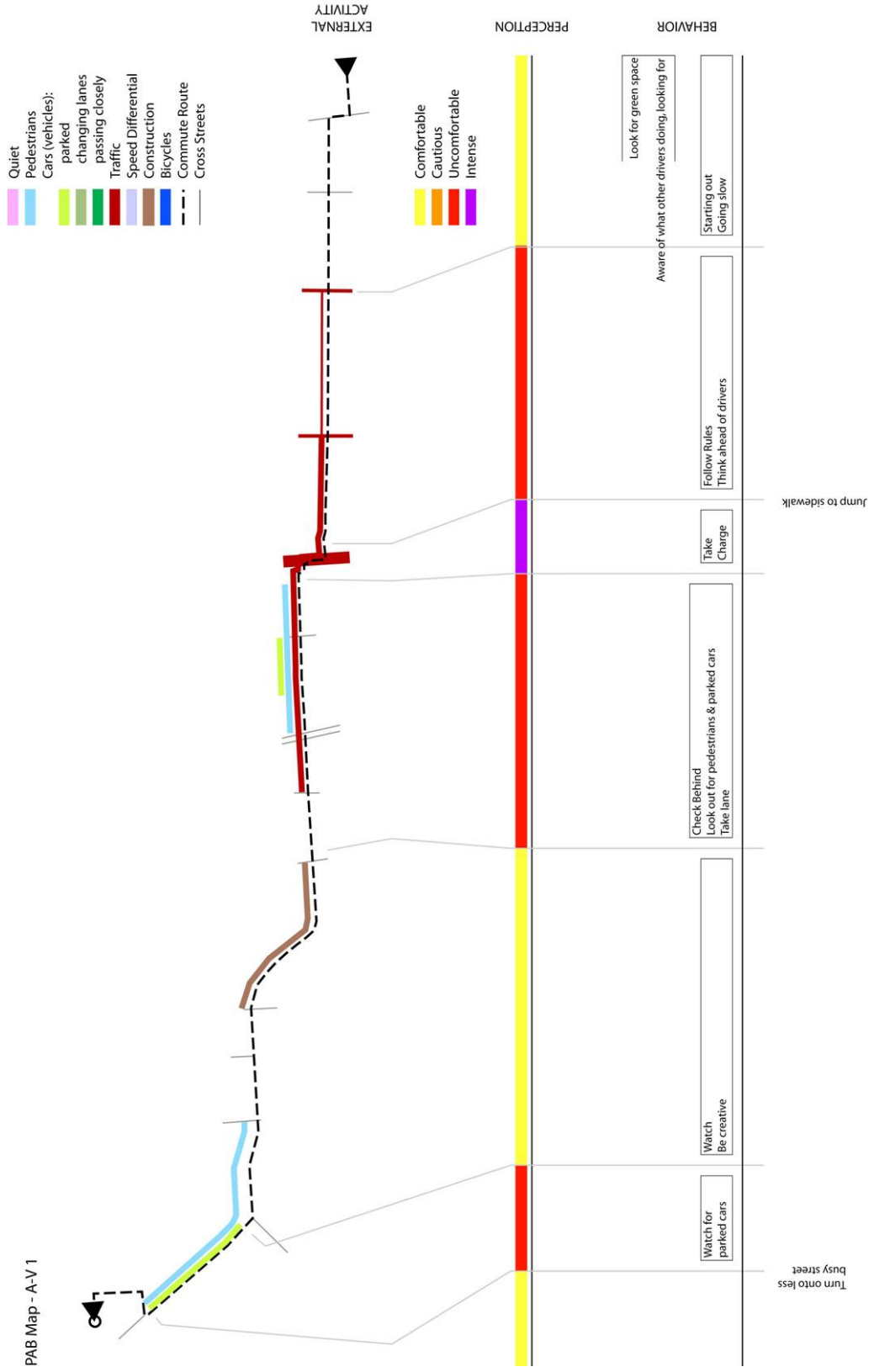


Satellite Map OR-3

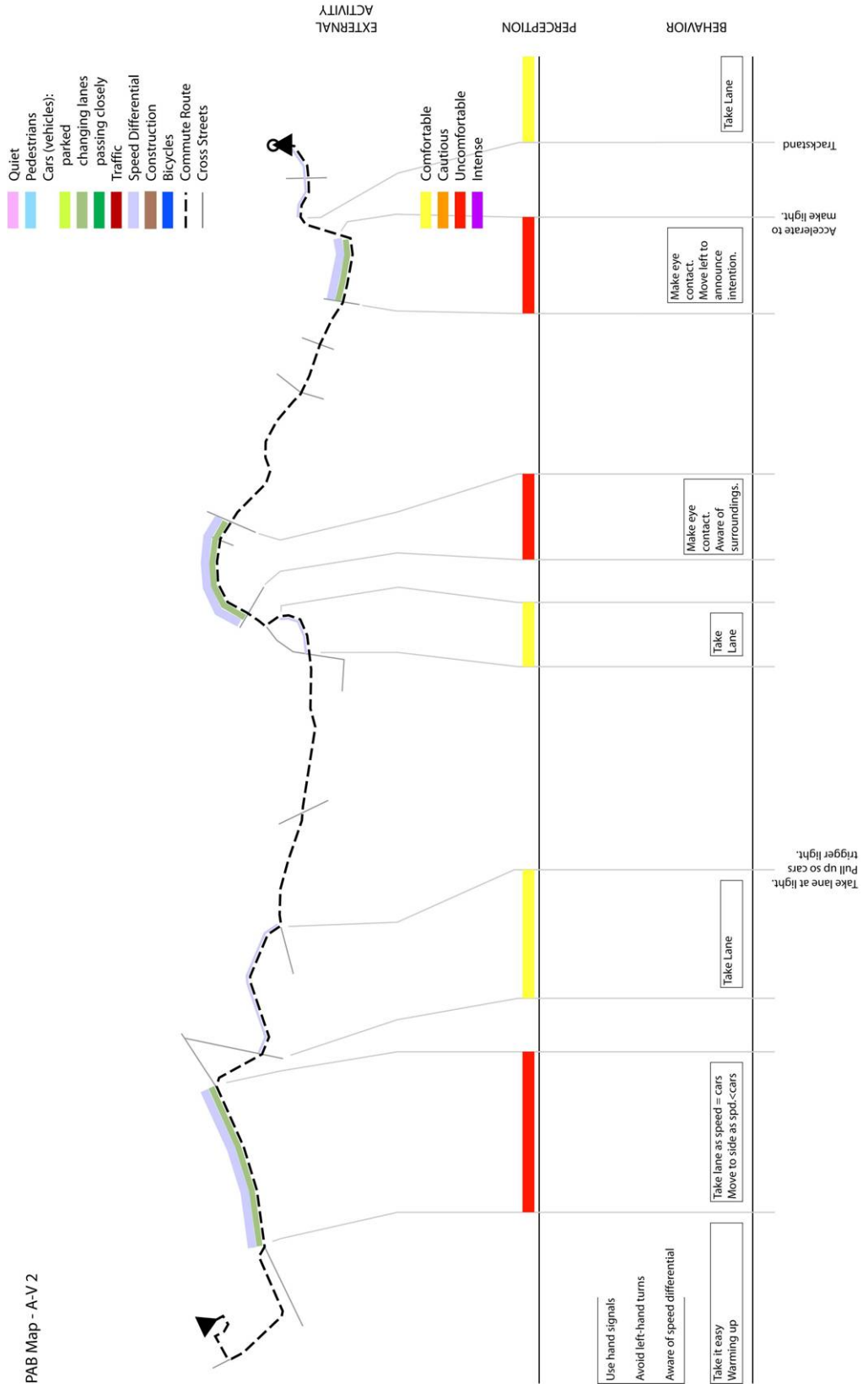


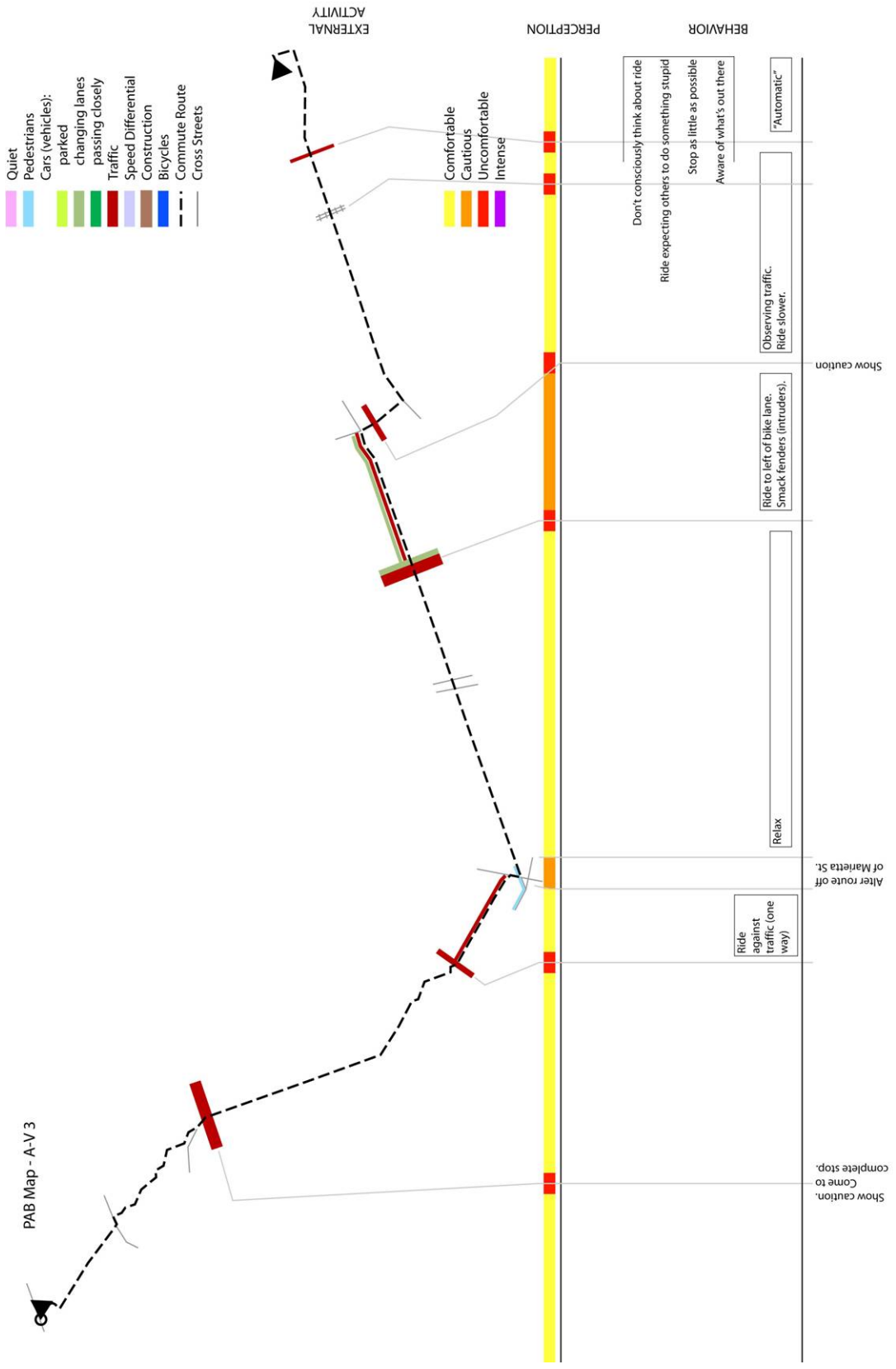
Appendix D: Perception-activity-behavior maps

PAB Map - A-V1

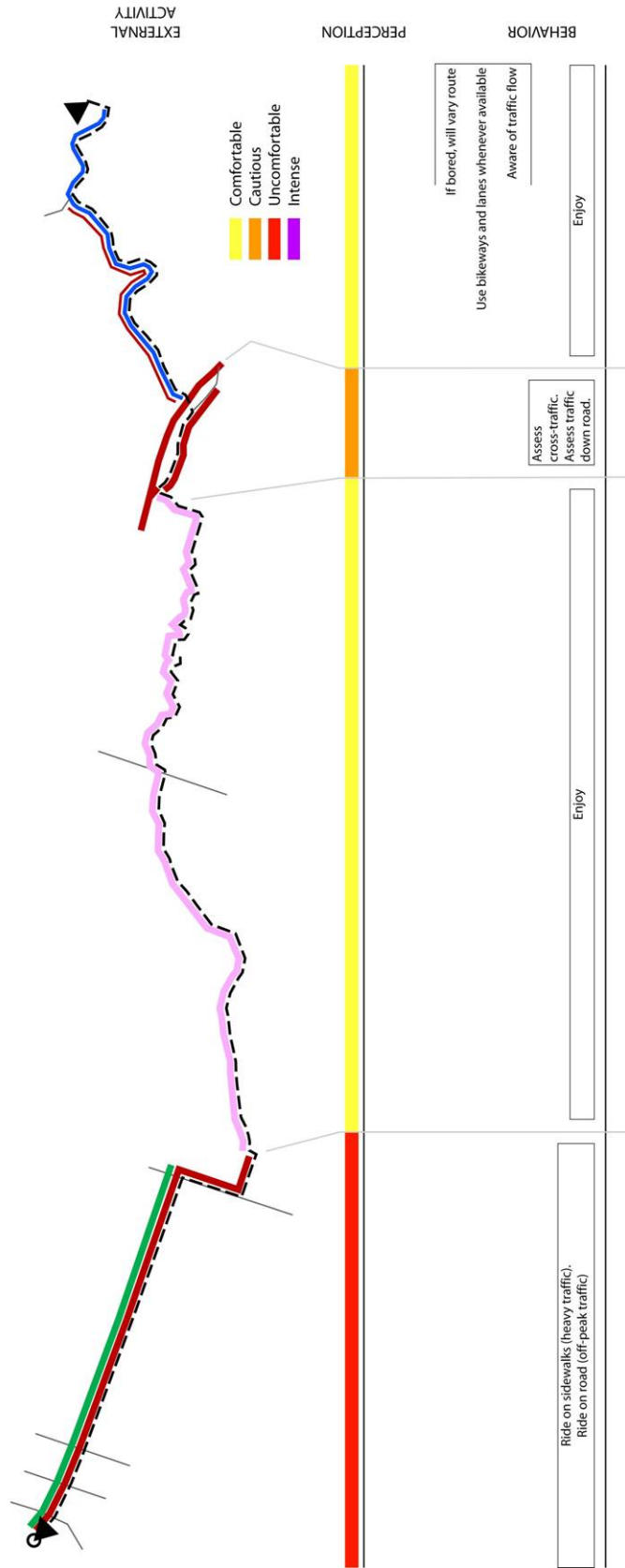


PAB Map - A-V 2





- Quiet
- Pedestrians
- Cars (vehicles):
 - parked
 - changing lanes
 - passing closely
- Traffic
- Speed Differential
- Construction
- Bicycles
- Commute Route
- Cross Streets



- Quiet
- Pedestrians
- Cars (vehicles):
 - parked
 - changing lanes
 - passing closely
- Traffic
- Speed Differential
- Construction
- Bicycles
- Commute Route
- Cross Streets



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