Turning Chaos into Chaos:

Analysis of a Multimodal Street Redesign

An exit project by

Emma Barnes

Master of
Community and Regional Planning

June 4, 2012

University of Oregon
Eugene, Oregon

Committee members: Marc Schlossberg and Yizhao Yang

Abstract

Observation of the retrofitting of a street segment in Eugene, Oregon represents a natural experimental moment to observe how rebalancing a roadway to better accommodate non-auto users without impeding existing automobile access in a chaotic, high volume, multimodal area performs. Redesign of the roadway involved transforming transportation facilities that provided one-way automobile traffic, two-way bicycle traffic, and on-street parking. The design elements renovated a chaotic environment wherein separation of space for different modes was paramount to a chaotic environment wherein integrated traffic and removed of physical barriers created a more fluid space. Using video footage to record activity across the right of way, this study examines how infrastructure changes affected the safety and functionality of users, as measured by changes in traffic volumes and the occurrence of traffic conflicts before and after the redesign was implemented. A review of literature concerning transportation facilities relevant to this analysis provides context for reviewing the redesign. This chaotic street became no less safe after redesign even though non-auto traffic volumes and free-form use of the space significantly increased. Bicycle, skateboard and pedestrian crossing volumes increased and vehicular traffic volumes showed little change after redesign. The integration of bicycle and vehicular traffic and removal of physical barriers did not affect safety, as no collisions occurred and the amount of serious conflicts remained the same, and the redesign provided new ways for convenient navigation around blockages. Examination of the particular elements of this redesign provides insight into ways other multimodal traffic streams can be improved.

ABSTRACT **2**

BACKGROUND **5**

RESEARCH FOCAL AREA 5

Alder Street and University District Streetscape Improvement Project *5*

ELEMENTS OF REDESIGN 9

Back-in Angle Parking *9*

Contraflow bicycle lanes *10*

Shared Lanes *11*

SCOPE OF RESEARCH **12**

PURPOSE 12

METHODS **13**

DATA COLLECTION 13

Data Consistency *13*

Site Selection *14*

DATA ANALYSIS 16

Data Reduction *16*

Defining traffic encounter and conflict *16*

SHORTCOMINGS TO DATA COLLECTION 17

RESULTS **18**

TRAFFIC VOLUMES 18

TRAFFIC ENCOUNTERS AND CONFLICTS 22

Wrong Way Traffic *24*

Motorist parks or turns into alley *27*

Motorist leaves parking stalls or pulls out of alley *27*

Motorist parked in the contraflow bicycle lane *27*

Motorist stopped in traffic lane *28*

Motorist stopped in traffic lane to discharge a passenger *28*

Pedestrian interactions with other road users *29*

Other observations *30*

SUMMARY OF FINDINGS **30**

GENERAL TRENDS 30

TRAFFIC VOLUMES 30

TRAFFIC ENCOUNTERS AND CONFLICTS 31

RECOMMENDATIONS **32**

FIGURE 1: EAST 13TH AVENUE, PRE-REDESIGN INFRASTRUCTURE ELEMENTS 7
FIGURE 2: EAST 13TH AVENUE, POST-REDESIGN INFRASTRUCTURE ELEMENTS 7
FIGURE 3: EAST 13TH AVENUE PRE-REDESIGN, EASTBOUND TRAFFIC AND BICYCLE LANES WITH PARALLEL PARKING . 8
FIGURE 4: EAST 13TH AVENUE POST-REDESIGN, EASTBOUND TRAFFIC AND BICYCLE LANE WITH BACK-IN ANGLE PARKING 8
FIGURE 5: EAST 13TH AVENUE CONTRAFLOW BICYCLE LANE, PRE- AND POST-REDESIGN 8
FIGURE 6: BACK-IN ANGLE PARKING, DRIVER VISIBILITY 10
FIGURE 7: CONTRAFLOW BIKE LANES 10
FIGURE 8: SHARROW 11
FIGURE 9: VANTAGE POINT FROM VIDEO CAMERA, PRE-REDESIGN 15
FIGURE 10: VANTAGE POINT FROM VIDEO CAMERA, POST-REDESIGN 15
FIGURE 11: TRAFFIC VOLUME CHANGES, PRE- AND POST-REDESIGN 19
FIGURE 12: EASTBOUND BICYCLE TRAFFIC VOLUMES, PER TIME SEGMENT AND PER DAY 20
FIGURE 13: WESTBOUND BICYCLE TRAFFIC VOLUMES, PER TIME SEGMENT AND PER DAY 21
FIGURE 14: EASTBOUND MOTOR VEHICLE TRAFFIC VOLUMES, PER TIME SEGMENT AND PER DAY 22
FIGURE 15: STREET LOCATIONS OF ENCOUNTERS, PRE-REDESIGN 24
FIGURE 16: STREET LOCATIONS OF ENCOUNTERS, POST-REDESIGN 24

TABLE 1: VIDEO RECORDING SCHEDULE 14
TABLE 2: TRAFFIC ENCOUNTER TYPES 17
TABLE 3: TRAFFIC ENCOUNTERS AND RESULTING CONFLICTS 23

Background

The creation of livable communities recently gained federal support as a policy goal in the U.S. Department of Transportation (U.S. DOT) strategic plan, drafted in 2010. U.S. Secretary of Transportation, Ray LaHood, describes livability as "…a community where if people don't want an automobile, they don't have to have one. A community where you can walk to work, your doctor's appointment, pharmacy or grocery store. Or you could take light rail, a bus or ride a bike." Formed to promote this kind of livable community, the Partnership for Sustainable Communities established livability principles that seek to "improve access to affordable housing, provide more transportation options, and lower transportation costs while also supporting public health and protecting the environment"(*1*).

Integral to creating livable communities is the development of infrastructure and laws supporting alternate transportation options in order to decrease auto-dependency, decrease overall cost of transportation, and make travel safer for different types of road users (*1*). A driving factor to developing livable communities is designing multimodal street infrastructure. This is the idea behind frameworks aimed at developing Complete Streets, "a street that works for motorists, for bus riders, for bicyclists, and for pedestrians, including people with disabilities. A complete street policy is aimed at producing roads that are safe and convenient for all road users"(*2*). Complete Streets provides a local-level blueprint for concretely developing multimodal transportation networks. This project studies one example of a local level, multimodal street design with a unique combination of design elements.

Research Focal Area

Alder Street and University District Streetscape Improvement Project

One interpretation of a livable streetscape is represented in the Alder Street and University District Streetscape Improvements Project (Improvements Project) in Eugene, Oregon (*3*). The construction of the project was completed by the City of Eugene in late summer and early fall of 2011. The East 13th Avenue portion of the redesign was completed with the goal of making the environment more accommodating for bicyclists and pedestrians without compromising motor vehicle access. This portion of the Improvements Project occurred on just one block, between Alder and Kincaid Streets, but its effects were notable. The transportation infrastructure elements implemented on East 13th Avenue are not unique to Eugene or elsewhere, but the combination of these elements in conjunction with the immediate surrounding area is unique. East 13th Avenue is immediately west of the University of Oregon campus, which has approximately 24,000 students and 4,500 faculty and staff (*4*). This block serves as a gateway to campus, provides access to a local shopping and dining district, and is part of an important bus route access point. The street segment is lined with food, beverage, and retail establishments, which bring in significant local traffic. It functions as a hub for various modes of transportation. It serves as an access point to the university, particularly for bicyclists and pedestrians who frequent East 13th Avenue. Several bus stops exist within a block radius of the area and are served via East 13th Avenue. Specifically, Lane Transit District's (LTD) bus station is divided into north and south bus stops along Kincaid Street, on the edge of the University of Oregon campus. Given the location, there is and will continue to be a high level of activity for all modes of travel on this block.

Construction of the new design occurred concurrently with the construction of a two-way cycle track on adjacent Alder Street, other bicycle- and pedestrian-focused streetscape improvements, and repaving of the roadway, as part of the City of Eugene's Pavement Preservation Program (*3*). The three primary aspects of the redesign are: 1) expanding sidewalk width to accommodate high pedestrian volumes and pedestrian uses; 2) improving two-way bicycle access on the one way vehicular road; and 3) changing from right and left side parallel parking to single side back-in angle parking. Specifically, major changes to the streetscape on East 13th Avenue included:

1. Back-in angled parking on the south side of the street replaced on-street parallel parking, which flanked both sides of the street. The number of parking stalls was reduced from 22 to 19.
2. An alteration from a separately delineated eastbound bicycle lane and automobile lane to a single shared lane. The width of the traffic lane was decreased from 15 to 12 feet.
3. The westbound contraflow bicycle lane was left intact, but physical traffic lane separators were removed and replaced with pavement markings, separating the traffic lane from the contraflow bicycle lane. The width of the contraflow lane remained the same.
4. Sidewalks were widened five feet, achieved by narrowing the roadway (curb-to-curb) from 44 to 39 feet.
5. A single motor vehicle pay station replaced parking meters along the roadway.

Figure 1 illustrates the streetscape before redesign and Figure 2 illustrates the streetscape after redesign. The numbered areas on each image in Figure 1 and Figure 2 correspond to the numbers listed above. Figure 3 and Figure 4 show another angle of the traffic lane before and after redesign, respectively. Figure 5 shows two images of the westbound contraflow lane, pre- (left) and post-redesign (right).

Observation of the redesign on East 13th Avenue represents a natural experimental moment to understand how retrofitting a street to better accommodate alternate modes without impeding vehicular access performs. While the eastbound bicycle lane was removed in favor of implementing a shared lane, physical barriers that protected the westbound contraflow lane were removed, and the street profile was narrowed and the sidewalks widened, the redesign intended to make an overall more comfortable environment for active transportation. Through observations of the streetscape before and after the design was implemented, this research study evaluates whether the intent of the redesign matched the reality; whether the infrastructure elements implemented on East 13th Avenue improve the ability of modes to safely use the space. The unique combination of the infrastructure elements implemented on East 13th Avenue informs whether part or all of this design could function effectively on other blocks in Eugene, or in parts of other cities of similar size or street with similar multimodal volume.

Figure 1: East 13th Avenue, pre-redesign infrastructure elements

Figure 2: East 13th Avenue, post-redesign infrastructure elements

Figure 3: East 13th Avenue pre-redesign, eastbound traffic and bicycle lanes with parallel parking

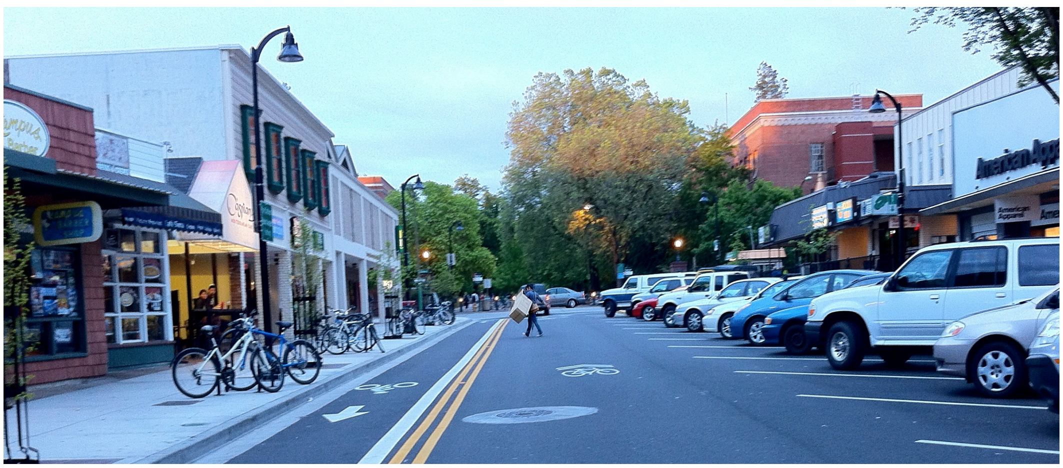

Figure 4: East 13th Avenue post-redesign, eastbound traffic and bicycle lane with back-in angle parking

Figure 5: East 13th Avenue contraflow bicycle lane, pre- and post-redesign

Elements of Redesign

Back-in Angle Parking

Back-in angle parking is an on-street parking method used in cities like Vancouver, WA; San Francisco; CA; and Pottstown, PE among others (*5)*. To use back-in angle parking, a motorist drives past a parking stall and reverses to maneuver into it, so the front of a vehicle is facing the street. At first glance, this parking method is commonly held to be dangerous to road users when waiting behind a motorist that is back-in angle parking. However, there are benefits to this method, particularly in areas with multimodal traffic streams. Back-in angle parking is easier and takes less time than parallel parking. Benefits of back-in angle parking over parallel parking include:

- Parallel parking requires steering the front of a vehicle against the curb, whereas back-in angle parking only requires backing a vehicle straight backward, toward the curb (*5*).
- Parallel parking often requires multiple forward-backward maneuvers. If, for instance, a parking stall is narrow or the driver is inexperienced parallel parking, it may take multiple attempts to successfully angle a vehicle correctly to back into a stall. Whereas when back-in angle parking, a motorist only needs to angle the vehicle correctly once before backing into a stall.
- Passing bicyclists do not have to worry about being hit by, or coming in close contact with opening car doors, as they do when parallel parking stalls are along the street, since motor vehicle doors are not adjacent to the traffic lane, the front of the vehicle is.
- Backing into a back-in angle parking stall requires the driver to turn at a larger angle than it does a driver who is parallel parking, which shows back-in angle parking requires more space. It therefore may require other road users behind the parking motorist using the back-in angle method to stop and wait. In comparison, road users behind a motorist who is parallel parking may be able continue moving, potentially creating safety hazards; A motorist backing up in a traffic lane has limited visibility, and when traffic in or next to that lane is moving, it is more dangerous than if other traffic were to stop and wait for the vehicle to park (*6*).

It is commonly held that bicyclists and other road users are better able to steer clear of a motorist who is backing into a parking stall than one who is backing out of one (*6*). Back-in angle parking also improves driver visibility when exiting a parking stall (*7*) (*8*). Figure 6 shows a driver's field of vision when preparing to pull out of a parking stall, illustrating the motorist has a clear view of oncoming traffic since the front of the vehicle faces the street (*5)*.

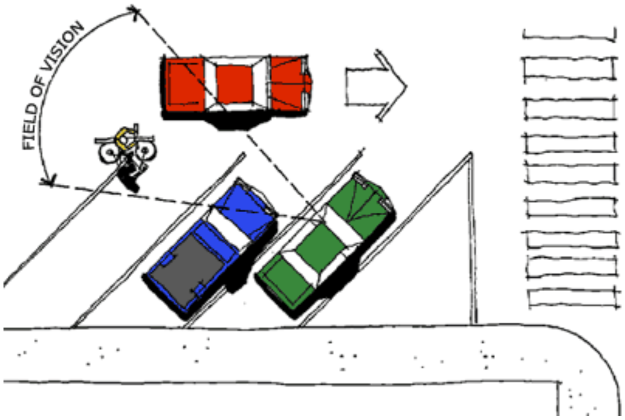

Figure 6: Back-in angle parking, driver visibility (*9*)

Contraflow bicycle lanes

When two-way bicycle access is desired on a one-way street, a right way contraflow lane allows bicyclists to travel in the opposite direction of other traffic. Contraflow lanes also enable the following safety benefits:

- Delineating a separate area for contraflow bicycle travel may increase user awareness and minimize conflict in a right of way, as fewer bicyclists illegally travel the wrong way in a one-way lane (*5*).
- More direct access to high-use destinations (*11*).
- Serve as safe travel routes for easily entering or leaving a lane since contraflow lanes are typically situated adjacent to a traffic lane and bicyclists can make right turns directly onto them (*11*).

Figure 7 shows two types of contraflow lanes, both adjacent to a traffic lane. The image on the left shows line pavement markings separating the contraflow lane from other traffic, while the image on the right shows a cement median separating the contraflow lane from other traffic. When a physical median is present, the bicycle lane is considered a one-way protected cycle track.

Figure 7: Contraflow bike lanes (*12*)

Shared Lanes

A shared lane or roadway is a bikeway that integrates automobile and bicycle travel in a single lane. Similar to a woonerf, or right of way shared by pedestrians, bicyclists and motorists (*12*), the intent of implementing sharrows is to promote the safety and mobility of non-vehicular road use. Like woonerfs, sharrows affect traffic calming, as they improve motorist awareness and help decrease speeding on low-speed streets (*13*).

In comparison to a bicycle lane, a shared lane does not delineate a specific portion of the road for bicyclists. Shared lanes commonly include lane markings, or sharrows (Figure 8). The use of sharrows on shared lanes has the following benefits:

- Encourage bicyclists to ride in the right of way and inform motorists where to anticipate bicyclists (*14*). This is particularly important in narrow lanes, where bicyclists may need more space; sharrows are especially helpful because they remind motorists to give bicyclists adequate space (*15*).
- Are known to improve spacing between motorists and bicyclists, when both modes are present in the same lane.
- In lanes next to a curb or on-street parallel parking, they are believed to help bicyclists position themselves away from swinging car doors or too close to a curb (*15*).
- A bicyclist sharing the lane, rather than riding in a bicycle lane on the side of a lane, allows slightly more time to react if a motorist pulls into or backs out of the lane from a side street or an adjacent parking stall (*16*).

Figure 8: Sharrow (*17*)

While the use of shared lanes and sharrows has many known benefits, there is disagreement that they are safer for bicyclists compared to designating separate bike lanes. While separate bicycle lanes and shared lanes alike have benefits and drawbacks, there is little evidence that shows one is safer than the other. It is held that separate bicycle facilities are safer for bicyclists overall, since elders, young children, or those with disabilities may be unable to safely navigate in mixed traffic streams (*18*) (19). Surveys have shown people feel comfortable bicycling in a lane separate from vehicular traffic, but these findings are contextual and may not accurately indicate preferences of bicyclists in other cities and many not accurately indicate actual cycling habits (*20*) (*21*). Moreover, the use and safety of sharrows on shared lanes has not extensively been studied yet (22). Advocates of mixed traffic streams argue that bicyclists should cycle on the roadway just as motorists (*23*). Acknowledgement is given to the fact that speed of vehicular traffic affects the safety of shared lanes, and that generally low vehicular traffic volumes are optimal on shared lane streets, yet the use of sharrows are recommended on streets with high volume bicycle traffic (24). While there is inconclusive evidence as to whether shared lanes or separate bicycle facilities are safer or more functional for bicyclists, examination of the East 13th Avenue redesign will help shed light onto the topic.

Scope of Research

Purpose

The purpose of this study is to understand the impact of the redesign of East 13th Avenue on the functionality and safety of road users that travel through the space. Using video footage to record activity across the right of way before and after redesign, this project examines road user behavioral responses to physical infrastructure changes that occurred on East 13th Avenue. Behavioral responses to the new design, as measured by changes in overall traffic volumes for each mode, as well as traffic conflicts among or between traffic modes, inform whether the infrastructure changes improved the functionality and safety of this block. For each pre- and post-redesign element of East 13th Avenue, a few key questions speak to the overall research:

- Did bicycle traffic volumes increase or decrease after redesign, given the elimination of a bicycle lane and physical barriers separating the contraflow lane and the traffic lane?
- Given the sidewalks were widened and the roadway was narrowed after redesign, were there noticeable changes in pedestrian behavior?
- How did traffic safety or flow change with the conversion from parallel parking on both sides of the street to back-in angle parking on just one side of the street?
- Was use of the contraflow lane “abused’ by non-bicycle users after redesign, given the physical barriers between the contraflow and traffic lane were removed?
- Was this road segment measurably more or less safe after redesign, in terms of close calls or traffic collisions that occurred?

- Overall, how did this road segment function after redesign, in terms mode usage and perception?

Methods

The study quantitatively measured traffic volumes and traffic conflicts that occurred between and among road users before and after redesign. The behavior of road users, in relation to traffic volumes, determined whether, and how, conflict occurred between or among road users. There are many road users along the right of way, including motor vehicles (including cars, trucks, buses, motorcycles, mopeds, etc.), bicycles, skateboards, and midblock pedestrian crossings. Traffic volumes and road user behavior, as they relate to traffic encounters and conflicts, inform the safety and functionality of the East 13th Avenue redesign. The following information was encoded from video recordings and used for analysis:

- Number of eastbound bicyclists, skateboard users, motorists, and other road users that traveled on East 13th Avenue, from Alder to Kincaid Street.
- Number of westbound bicyclists, skateboard users, and other non-motorized road users that traveled on East 13th Avenue, from Kincaid to Alder Street.
- Number of pedestrian crossings from north and south sides of East 13th Avenue.
- Number of road users that traveled in the wrong direction a lane was intended for.
- Descriptions of possible conflicts, including the road users involved in the situation, and the action(s) that occurred, and any consequences.

Data Collection

Data Consistency

Data was collected from videotape recordings and was manually reviewed and encoded. A total of 54 hours of video observations were collected, including 27 hours pre-redesign and 27 hours post-redesign. Pre-redesign videos were recorded in the spring of 2011, in the weeks of March 17 to 20 and March 24 to 27. Post-redesign videos were recorded in the fall of 2011, in the weeks of October 11 to 14 and October 18 to 21. Table 1 below shows this video recording schedule, before and after redesign.

	Day	Date
Pre-redesign	Tuesday	17-May-11
	Wednesday	18-May-11
	Friday	20-May-11
	Tuesday	24-May-11
	Wednesday	25-May-11
	Friday	27-May-11
Post-redesign	Tuesday	11-Oct-11
	Wednesday	12-Oct-11
	Friday	14-Oct-11
	Tuesday	18-Oct-11
	Wednesday	19-Oct-11
	Friday	21-Oct-11

Table 1: Video recording schedule

To ensure consistent data collection, all recording segments for each day of video recording were conducted at the same times of the day, on the same days of the week, and from the same location and precise vantage point before and after redesign. Video recording occurred on Tuesdays, Wednesdays and Fridays for two contiguous weeks before redesign. Each day, 4.5 hours of video recording occurred, including three 1.5 hour time segments. Recording times only captured daytime activity between the hours of 9:00 am and 4:00 pm, including the following time segments: 9:15 am to 10:45 am, 11:15 am to 12:45 pm, and 2:15 pm to 3:45 pm. All time segments started 15 minutes past the hour and ended 45 minutes past the hour in order to capture traffic volumes at peak and non-peak hours, related to the ebbs and flows of university student course schedules.

Tuesdays, Wednesdays, and Fridays were selected as recording days in order to capture road users with different class schedules, including Monday/Wednesday classes and Tuesday/Thursday classes. Fridays were added because there is variability in course schedules that have Friday classes and Friday is also perceived as the day of the week students or faculty are more likely to leave early, which may have created variability in traffic activity on East 13th Avenue.

Site Selection

One site was used for video recording East 13th Avenue traffic, and was chosen among four other potential vantage points. Before data collection began, video recording equipment, including a tripod and camcorder, was tested at each site. The site chosen for video recording was located on a second-story roof of East 13th Avenue. This vantage point was selected because it was close to East 13th Avenue traffic activity and crucial activities would be visible both before and after the redesign. The second-story roof is located on the south side of East 13th Avenue, positioned to capture the midblock area to the end of the block, facing west. Figure 9 and Figure 10 shows screenshots from the video camera during pre- and post-redesign video recording.

Figure 9: Vantage point from video camera, pre-redesign

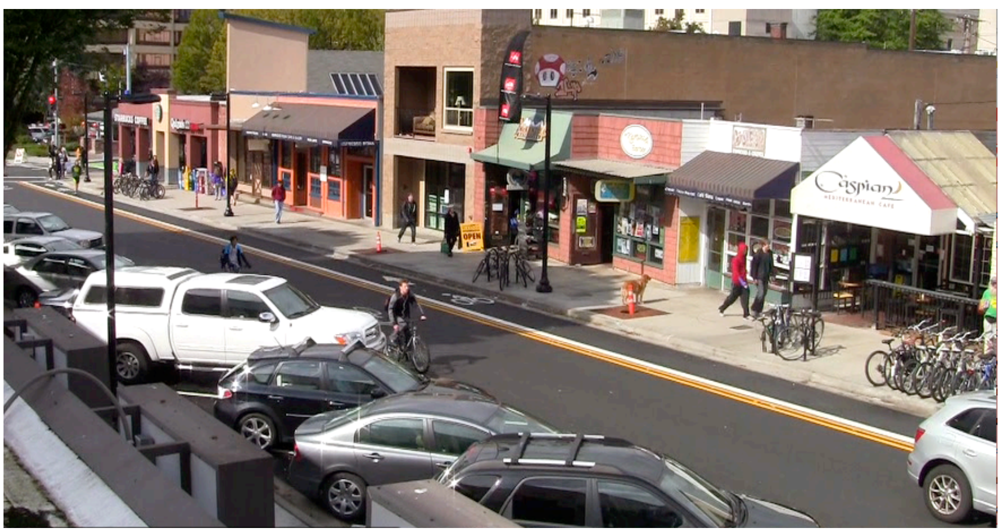

Figure 10: Vantage point from video camera, post-redesign

Traffic volumes were counted during video analysis and conflict types were determined after video analysis, and were codified by type. Weather patterns and other unusual traffic patterns were also noted during each time segment, and this information was codified and factored into analysis. Each observed interaction was quantified by the following: conflict type, road users involved and their direction of travel, and the location each incident occurred (in the traffic lane, contraflow bicycle lane, or parking area).

Data Analysis

Data Reduction

Each 1.5-hour video recording segment was divided into 15-minute sections while counting traffic volumes to aid in detailed compilation and analysis of travel behavior. Traffic counts by mode and direction of travel were collected, and road user interactions were documented with manual descriptions, which were later used to form conflict types.

Defining traffic encounter and conflict

This study extends existing transportation literature and traffic studies that focus on road safety. Within this literature, a "traffic conflict" is often considered a precursor to a potential or actual traffic collision (*25*) (*26*). Through this lens, the definition of a traffic conflict is similar to the following: "a…situation for which there is imminent danger of a collision between two or more [road users, a road user and a person, or a road user and an object]" (*27*). Here 'imminent' means an anticipated result that is about to happen, and 'danger of a collision' means conflict situations are only those that result in physical contact.

In this context, traffic conflicts are examined in various contexts, including those that occur at intersections (*28*) (*29*) or mid-block locations (*26*). Some studies research the effects of a street network design (*30*), of design "treatments" (e.g. traffic calming measures or trees close to a street) (*31*), of time of day or location (*32*), or of an area's density. However, a commonality is that road safety is measured by the occurrence of traffic collisions, and whether or how the preceding traffic conflict(s) impact the result. Motorists are typically the main actors involved in traffic conflict analyses, even if conflict between motorists and other types of road users, such as bicyclists or pedestrians, are analyzed (*28*) (*31*) (*33*).

However, this study diverges from other road safety-focused research. Here traffic conflicts are not considered precursors to potential or actual traffic collisions. Rather, recognition is given to the reality that there are a variety of interactions that occur between road users that can be considered traffic conflicts, even if such interactions do not result in collision, and even if a motorist is not involved. Therefore, a "traffic encounter" describes an action taken by a road user within the right of way, which causes or has the potential to cause one or more detrimental resulting action(s), taken by one or more affected road users. The resulting action is a "traffic conflict". Traffic conflicts include 1) blocking portions of the road, 2) close calls, or 3) collisions. In the case that the instigating road user blocks a portion of the road, the resulting conflict can occur cause the affected road user(s) to either stop or to navigate around the blockage.

A close call is an unexpected traffic event between two or more road users, wherein one or more road user is able to move, swerve, or stop to avoid contact. The difference between an action that causes a close call and one that blocks traffic is perceived speed and proximity. In close call situations, the preceding event or action that causes the close call occurs in close proximity to a road user or object traveling at a fast speed, in which case there is little reaction time, yet contact is avoided; or the preceding event or action that causes the conflict occurs when one or more road user does not see the other(s), until they are within close proximity, but conflict again is avoided. Conversely, in situations when a portion of the road is blocked, the preceding event or action that causes the conflict occurs *before* one or more road users approaches the blockage, in which case there is enough reaction time to stop, slow down and navigate around the blockage.

A traffic encounter that precedes a traffic conflict can cause more than one traffic conflict, meaning the number of traffic conflicts can exceed the number of traffic encounters. This is most frequent in situations wherein traffic volumes are high and there is little space for maneuvering. Table 2 below delineates eight types of traffic encounters observed in this study, organized by mode. The action type 'pedestrian interaction' includes interaction between a pedestrian and a bicyclist, a skateboard user, or a motorist. Interactions occur when a pedestrian is: crossing the traffic or contraflow lane, stepping out of a motor vehicle and crossing the traffic lane, or walking in the contraflow bicycle lane.

Action		Road users
1	Wrong way in contraflow lane	Biclyclists, skateboarders
2	Wrong way in traffic lane	Bicyclists, skateboarders
3	Parks in stall or turns into alley	Motor vehicle users
4	Leaves parking stall or leaves alley	Motor vehicle users
5	Parks in contraflow lane	Motor vehicle users
6	Stops in traffic lane	Motor vehicle users
7	Stops to discharge passanger	Motor vehicle users
8	Pedestrian interaction	Bicyclists, skateboarders, motor vehicle users

Table 2: Traffic encounter types

Shortcomings to data collection

The presence of uncontrolled variables that existed during and affecting data collection and analysis are worth noting. First, video observations did not occur at the same time of the year pre- and post-redesign. The time of the year, as it relates to university class schedules, patterns in traffic volumes or traffic throughput variations may have been different at different times of the year. Pre-design video observation occurred during the spring, the end of the school year, and post-redesign observation occurred during the following fall, at the beginning of the following school year. It is possible that at the end of the school year, pre-redesign, more students and faculty were busier studying or grading, and at the beginning of the following school year, post-redesign, it is possible more people frequented this area to buy books, try new restaurants, etc. While there is no way to know the true viability of these possibilities within the scope of this study, they were noted.

Second, weather patterns may have affected traffic volumes. While weather patterns were not integral to the results of this study, they were accounted for when analyzing changes it traffic volumes and conflicts. Generally there were a similar number of rainy and cold days pre- and post-redesign, but changes in weather patterns are often sporadic in Oregon, and therefore were difficult to track. While weather variations may have affected traffic volumes in part, the decision to video record on consistent days, times, and consecutive weeks intended to help control for this variation.

Results

Traffic Volumes

After redesign, overall bicycle traffic volumes traveling east and west increased, pedestrian crossings increased, and vehicular traffic volumes slightly decreased. Figure 11 shows traffic volume changes for each road user, separated by direction of travel, including eastbound motor vehicles, east and westbound bicycles, and east and westbound skateboards. The graphic separates skateboard traffic volumes, as these users were not as frequent as the other road users. In total, the number non-pedestrian road users increased from 16,325 pre-redesign to 20,464 post-redesign, a 25.35 percent increase after redesign. The graphic also shows that most road user traffic volumes increased, but that motor vehicle traffic volumes slightly decreased after redesign.

Normalizing each road user type by traffic volume per hour contextualizes data. The volume of eastbound motor vehicles per hour decreased only slightly from 240.74 pre-redesign and 229.96 post-redesign, 4.48 percent decrease after redesign. However the volume of eastbound bicycles per hour increased from 104.19 pre-redesign to 175.59 post-redesign, a 68.45 percent increase after redesign. The volume of westbound bicycles per hour drastically increased from 54.70 pre-redesign to 107.70 post-redesign, a 96.89 percent increase after redesign. While the volume of midblock pedestrian crossings per hour increased from 193.96 pre-redesign to 227.78 post-redesign, a 17.43 percent increase after redesign. The volume of eastbound skateboards per hour increased from 6.07 pre-redesign to 10.70 post-redesign, a 76.22 percent increase. Finally, the volume of westbound skateboards per hour moderately increased from

4.96 pre-redesign to 6.19 after redesign, a 24.23 percent increase. These numbers indicate that non-auto mode share significantly increased post-redesign, a notable result even separate from conflict analysis.

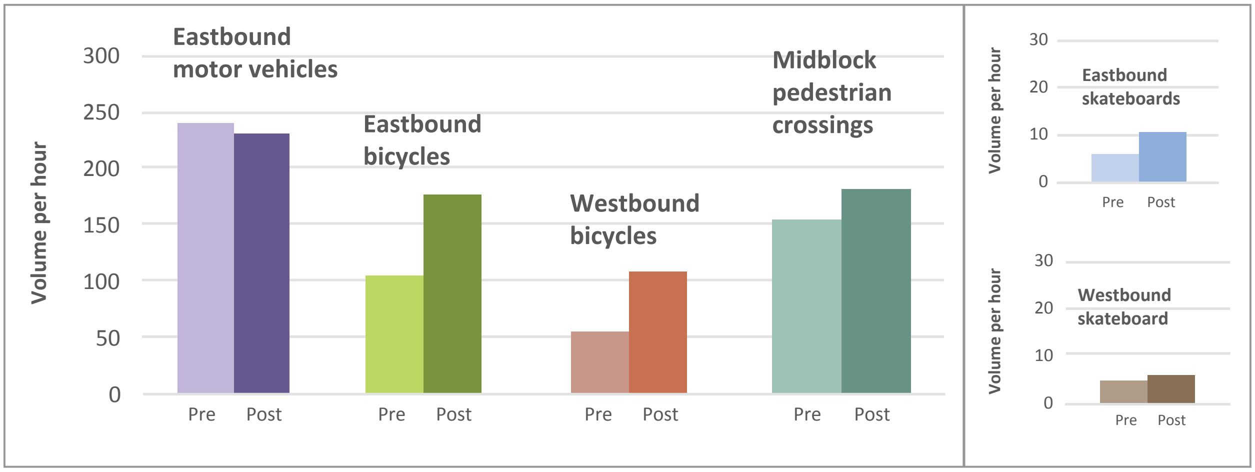

Figure 11: Traffic volume changes, pre- and post-redesign

Given each day of data collection includes three time segments; 'traffic volume per day' represents the sum of these time segments, separated by road user and their direction of travel. Figure 12 shows eastbound bicycle traffic volumes for each time segment of observation, morning, afternoon and late afternoon, as well as daily traffic volumes before and after redesign. Within each graph, the x-axis shows the days of the week and the week number before and after redesign. The time segment graphs, the row of small multiples at the top, show that eastbound bicycle traffic volumes were highest during the morning and lowest in the late afternoon before and after redesign. Average morning traffic volumes increased by 79.45 percent, average afternoon traffic volumes increased by 65.47 percent, and average late afternoon traffic volumes increased by 53.62 percent after redesign.

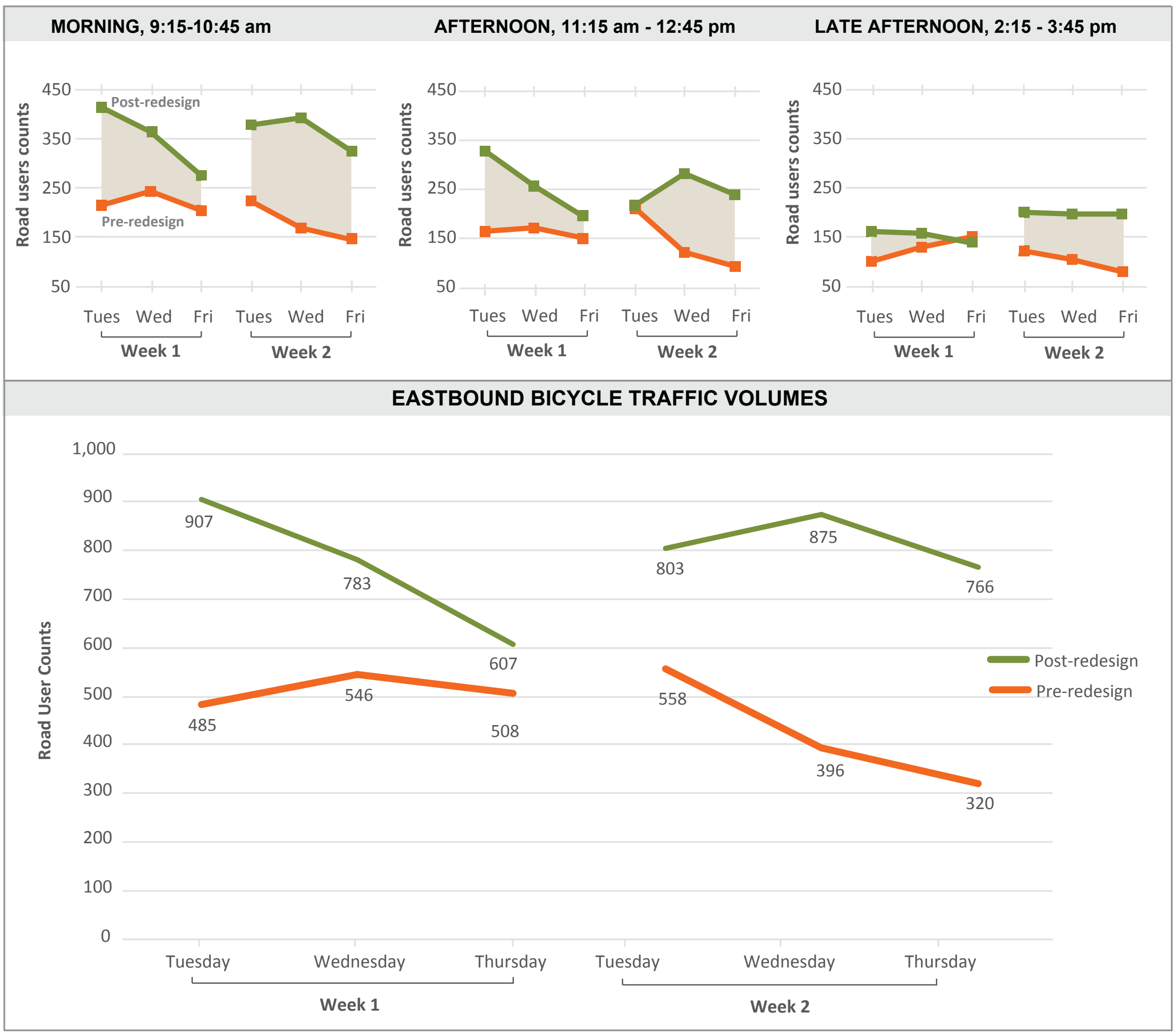

Figure 12: Eastbound bicycle traffic volumes, per time segment and per day

Traffic volumes for westbound bicycles are shown in Figure 13, which includes time segment and daily total volumes. Average morning traffic volumes were relatively constant across days in either the pre- or post-redesign periods, but show an average increase of 139.15 percent after redesign. Average afternoon traffic volumes increased by 92.13 percent and average late afternoon traffic volumes increased by 83.63 percent.

Figure 13: Westbound bicycle traffic volumes, per time segment and per day

Traffic volumes for eastbound motor vehicles are shown in Figure 14, including traffic volumes by time segment and as daily totals. Average morning traffic volumes decreased by 2.91 percent, average afternoon traffic volumes barely increased by 0.05 percent and average late afternoon traffic volumes decreased by 9.63 percent post-redesign. These numbers demonstrate little change in motor vehicle traffic volumes, compared to changes in bicycle traffic volumes after redesign.

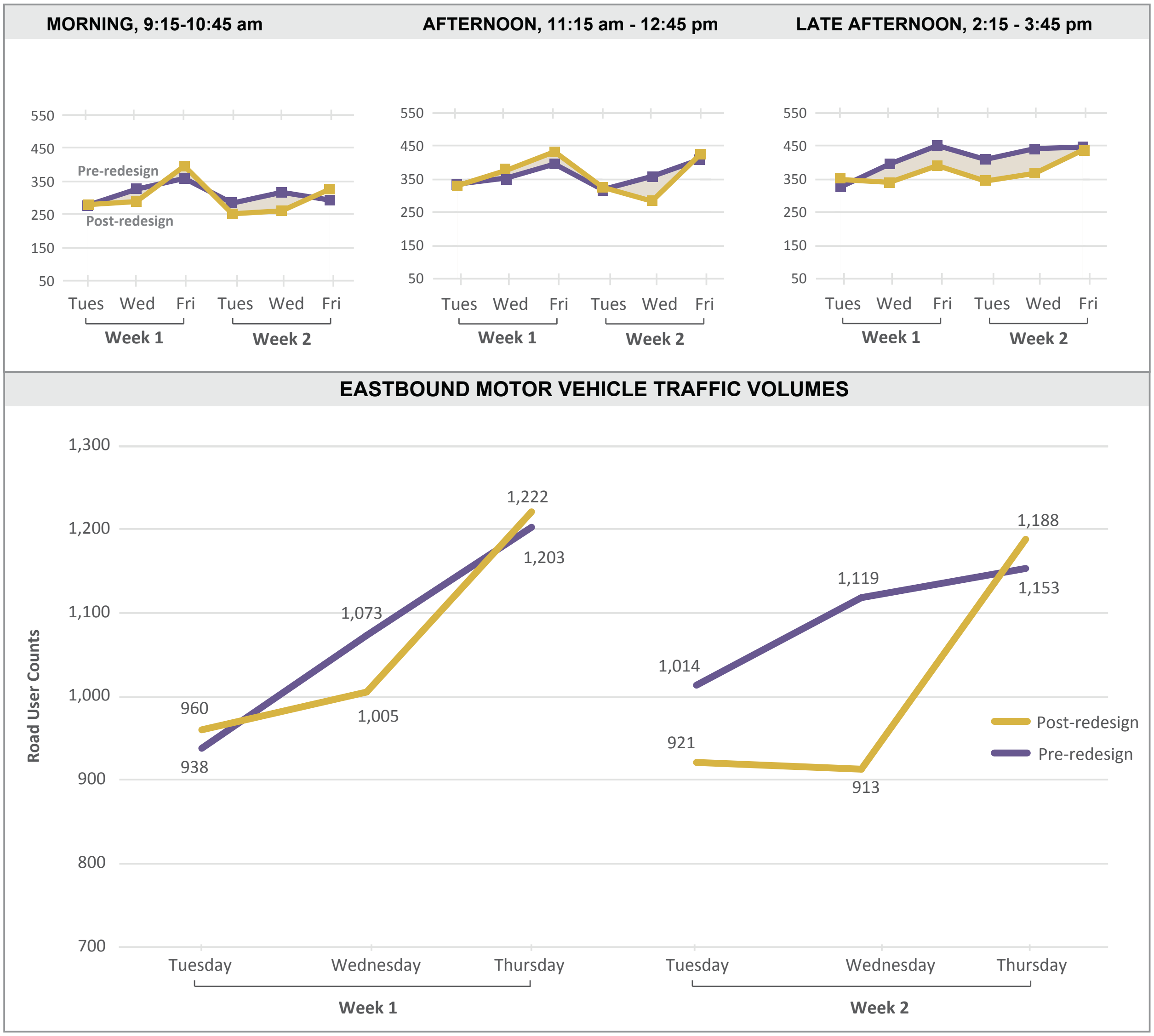

Figure 14: Eastbound motor vehicle traffic volumes, per time segment and per day

Traffic Encounters and Conflicts

As explained earlier, a traffic encounter is an action taken by a road user that causes or has the potential to cause a traffic conflict. Traffic conflicts include 1) blocking portions of the road, 2) close calls, and 3) collisions. If the offending road user blocks a portion of the road, the resulting conflict can occur in two ways, it can cause the affected road user(s) to stop or to navigate around the blockage. The occurrence of a traffic conflict was contingent upon the initial traffic encounter, and in some cases the level of traffic volume present. Several types of traffic encounters were observed and assessed based on their nature of causing conflicts, including: wrong way traffic, motorists parking or turning into the alley, motorists leaving parking stalls or the alley, motorists parking in the contraflow lane, motorists stopping in the traffic lane, motorists stopping in the traffic lane to discharge a passenger, and pedestrian interaction with another mode.

The roadway was reshaped from a restricted space before redesign, with separated lanes and physical barriers between the traffic and contraflow lane, to a more fluid and free-flowing space post-redesign, with a shared lane and removed physical barriers between lanes. The openness of the redesign significantly impacted road user behavior. Table 3 below shows the frequency of traffic encounters and resulting conflicts that occurred pre- and post-redesign. Figure 15 and Figure 16 show the general location within the right of way where each encounter occurred, numbered according to encounters numbered in Table 3. Since a single action can cause more than one conflict, often the number of conflicts caused exceeds the number of initial actions, or traffic encounters. Analysis of traffic encounters and conflicts and factors that impacted their occurrences are explained below.

Traffic encounters					Conflicts caused							
	Action	Road User	Number of occurrences		Blocks portion of road				Close call		Collision	
					Road user stops		Road user navigates around					
			Pre-redesign	Post-redesign	Pre-redesign	Post-redesign	Pre-redesign	Post-redesign	Pre-redesign	Post-redesign	Pre-redesign	Post-redesign
1	Wrong way in contraflow lane	Bicyclists	1	5	0	4	0	2	1	0	0	0
		Skateboards	0	4	0	0	0	4	0	1	0	0
2	Wrong way in traffic lane	Bicyclists	4	6	0	0	3	7	0	1	0	0
		Skateboards	0	4	0	2	0	3	0	3	0	0
3	Parks in stall or turns into alley	Motor vehicles	9	5	7	3	1	2	7	2	0	0
4	Leaves parking stall or leaves alley	Motor vehicles	4	6	2	4	1	2	2	0	0	0
5	Parks in contraflow lane	Motor vehicles	N/A	8	N/A	5	N/A	6	0	0	0	0
6	Stops in traffic lane	Motor vehicles	2	12	1	3	1	6	1	1	0	0
7	Stops to discharge passenger	Motor vehicles	1	8	0	2	1	4	0	1	0	0
8	Pedestrian interaction	Bicyclists	14	3	9	2	5	2	2	1	0	0
		Skateboards	0	1	0	0	0	1	0	0	0	0
		Motor vehicles	4	5	4	1	0	3	0	3	0	0

Table 3: Traffic encounters and resulting conflicts

Figure 15: Street locations of encounters, pre-redesign

Figure 16: Street locations of encounters, post-redesign

Wrong Way Traffic

The total number of times a road user traveled the wrong direction in the traffic or contraflow lane was counted, but not all of these occurrences caused traffic conflicts. Therefore, for wrong way actions, there are three levels of analysis pre- and post-redesign: 1) the change in frequency of the total number of wrong way occurrences; 2) of the total number of wrong way occurrences, the number of such occurrences that caused traffic, and 3) the specific traffic conflicts that occurred, and how they changed post-redesign.

Overall, wrong way travel in the contraflow and traffic lane was frequent. The total number of bicyclists and skateboard users that traveled the wrong direction in the contraflow lane increased, and the total number of skateboard users that traveled the wrong direction in the traffic lane also increased after redesign. Yet the total number of bicyclists that traveled the wrong direction in the traffic lane decreased after redesign. Despite this decrease, of the total number of bicyclists and skateboard users that traveled the wrong direction in both the traffic and contraflow lanes, the number of incidents that caused traffic conflicts increased after redesign.

It is suspected that wrong way behavior increased in general because the physical lane separator, between the contraflow and the traffic lane, was removed post-redesign, making it easier to swerve out of a lane to avoid oncoming traffic. Also, though wrong way incidents caused by bicyclists in the traffic lane decreased, traffic conflicts increased, as they commonly occurred during high traffic volumes, when space was restricted.

Bicyclists

The total number of bicyclists that traveled the wrong direction in the contraflow lane increased from 44 occurrences pre-redesign to 130 occurrences post-redesign, an average increase of 195.55 percent after redesign. Of the total number of bicyclists that traveled the wrong way in the traffic lane, less than one percent of incidents caused conflicts, but the number of such incidents increased after redesign. Pre-redesign there was just one occurrence that caused a traffic conflict and post-redesign there were five occurrences. Post-redesign, the traffic conflicts caused include just five situations in which a bicyclist traveled the wrong direction in the lane, and this caused other bikes and skateboards to stop in order to avoid close interaction.

The total number of bicyclists that traveled the wrong direction in the traffic lane decreased from 56 occurrences pre-redesign to 34 occurrences post-redesign, an average decrease of 39.29 percent after redesign. The decrease in overall occurrences of bicyclists traveling the wrong way in the traffic lane was likely impacted by the presence of construction on the sidewalk, next to the contraflow lane before redesign. Sidewalk construction blocked pedestrian access, and in effect, pedestrians walked in the contraflow lane, which often blocked westbound bicycle traffic. It is likely that bicyclists traveled the wrong way in the eastbound traffic lane to avoid pedestrian blockages. Post-redesign, this blockage was removed and fewer bicyclists traveled the wrong way in the traffic lane. Alternatively, as the barriers separating the contraflow lane from the traffic lane were removed post-redesign, it is possible bicyclists were simply better able to maneuver around pedestrian-related blockages in the contraflow lane. However, as fewer pedestrians walked in the contraflow lane post-redesign, a combination of these factors is probable.

Of the total number of bicyclists that traveled the wrong way in the traffic lane, less than one percent of incidents caused conflicts. However, the number of incidents that caused traffic conflicts increased post-redesign. Pre-redesign, there were four occurrences and post-redesign there were six occurrences that caused traffic conflicts. Pre-redesign, traffic conflicts caused include four situations in which a portion of the traffic lane was blocked by a bicyclist. Post-redesign, traffic conflicts caused include one close call and seven incidents in which another road user navigated around a bicyclist that was traveling in the wrong direction. The increase in traffic conflicts post-redesign was largely caused by the presence of high volume traffic when there was slow, bumper-to-bumper automobile traffic, and streams of bicycle traffic on the right side of the traffic lane. In such situations, when bicyclists are also traveling the wrong way on the right side of the lane, toward right-way bicycle travelers, there was little space for bicyclists to maneuver around each other. In effect, traffic conflicts were caused. However, as only one close call and no collisions resulted, traffic was controlled and not dangerous.

Skateboard users

The total number of skateboard users that traveled the wrong direction in the contraflow lane increased from 14 occurrences pre-redesign to 68 occurrences post-redesign, an average increase of 253.33 percent after redesign. Of the total number skateboard users traveling the wrong way in the contraflow lane, only four occurrences caused traffic conflicts, and all happened post-redesign. These post-redesign conflicts included one close call between a skateboard user and an oncoming bicyclist and four incidents wherein another road user navigated around the skateboard user, which in some cases required moving out of the contraflow lane, into the edge of the traffic lane, for a short period of time.

The total number of skateboard users that traveled the wrong direction in the traffic lane increased from 13 occurrences pre-redesign to 15 occurrences post-redesign, an average increase of 15.38 percent after redesign. Of the total number of skateboard users traveling the wrong way in the traffic lane, only four occurrences caused traffic conflicts, and all happened post-redesign. Post-redesign traffic conflicts caused include three close calls with another bicyclist or skateboard user, two incidents wherein another road user stopped to avoid interaction, and three incidents wherein another road user navigated around the skateboard user.

The variety of traffic conflict types caused by skateboard users traveling the wrong direction in the traffic lane is more diverse than those conflict causing wrong way occurrences in the contraflow lane. This may be explained by the observation that generally skateboard users appeared to engage in more adaptive and bold use of space when traveling the wrong direction in both the contraflow and traffic lane. Since a person on a skateboard takes up less space than a bicycle does, skateboard users were better able to "squeeze" past other bicyclists or in close proximity to crossing pedestrians. In doing so, they often took more chances than bicyclists did when traveling the wrong direction in a lane. Also, during both high and low traffic volumes, in situations wherein a skateboard user was traveling the wrong direction in a lane and a bicyclist was traveling towards it, bicyclists typically swerved to avoid the skateboard user first. Since skateboard users typically move slower than bicyclists, it is possible that they have more time to judge speed and proximity of oncoming traffic and only move if necessary.

Motorist parks or turns into alley

The number of occurrences of a motorist parking or turning into the alley from East 13th Avenue decreased by almost half post-redesign, from nine incidents pre-redesign to five incidents post-redesign. Similarly, the number of resulting conflicts decreased by almost half. Pre-redesign, the traffic conflicts include seven close calls, seven occurrences in which a bicyclist or motorist stopped to avoid interaction, and just one incident in which a road user navigated around the moving vehicle. Post-redesign, the traffic conflicts include two close calls, which typically occurred when a motorist was backing into a parking stall and did not see a pedestrian or bicyclist, three occurrences in which a bicyclist or motorist stopped to wait for the moving vehicle to either turn or park, and two occurrences in which a bicyclist navigated around the moving vehicle.

Motorist leaves parking stalls or pulls out of alley

The number of occurrences of a motorist leaving a parking stall or turning onto East 13th Avenue from the alley increased after redesign, from four incidents pre-redesign to six incidents post-redesign. The resulting conflicts caused also increased after redesign. Pre-redesign, traffic conflicts include two incidents in which a road user stopped, and one incident in which a road user navigated around a moving vehicle. Post-redesign, there were no close calls, four incidents in which another road user stopped to wait for a moving vehicle, and two incidents in which a road user navigated around a moving vehicle. The decrease in number of conflicts caused by a motorist leaving a parking stall or turning or pulling out of the alley may have been impacted by the fact that more road users waiting behind a parking motorist waited, rather than attempting to swerve around. Though motorists who backed into parking stalls post-redesign appeared to move slower and more cautiously, which allowed opportunity for bicyclists to swerve a parking vehicle.

Motorist parked in the contraflow bicycle lane

The ability for road users to move between the contraflow and traffic lane was impossible pre-redesign, when a physical buffer was present. Post-redesign the physical buffer was removed, enabling a more free-flowing right of way. However, this enabled motorists to park in the contraflow lane, effectively blocking bicycle and skateboard traffic. Post-redesign, motorists parked in the contraflow lane eight times. None of these occurrences caused close calls, but on five occasions a road user stopped to let other traffic pass before it was able to continue traveling, and on six occasions a road user needed to navigate around a parked motor vehicle. Given no close calls or collisions occurred, motorists parking in the contraflow lane did not impact safety of non-auto users, though bicycles and skateboard users were prevented from using a lane exclusively designated for them.

Motorist stopped in traffic lane

Conflicts caused by motorists stopped in the traffic lane occurred when a motorist was letting a pedestrian cross, waiting for a motorist to park or leave a parking stall, or picking up a passenger. The number of occurrences of a motorist stopping in the traffic lane increased post-redesign, from two incidents pre-redesign to twelve incidents post-redesign. The resulting conflicts increased after redesign. Pre-redesign, traffic conflicts include one close call, one incident wherein a road user stopped to wait behind a motorist and one incident when a road navigated around a stopped motorist. Post-redesign, traffic conflicts include one close call, three incidents when a road user stopped to wait behind a motorist, and six occasions when a road user navigated around a motorist. There were an equal number of close calls pre- and post-redesign and no collisions occurred. It is possible there were more conflicts caused by a motorist blocking a portion of the road post-redesign because it took motorists to back-in angle park more time than it did to parallel park. Often when motorists were parallel parking, they pulled into a stall if there was space available. Since there were commercial parking stalls dispersed between parallel parking stalls pre-redesign, pulling into parking stalls, rather than backing into them, was an option.

Motorist stopped in traffic lane to discharge a passenger

The number of occurrences of a motorist stopping in the traffic lane to discharge a passenger increased drastically post-redesign, from one incident pre-redesign to eight incidents post-redesign. The resulting conflicts also increased post-redesign. Pre-redesign, traffic conflicts caused include one incident when a road user stopped to wait for the passenger to walk across the street. Post-redesign, traffic conflicts caused include one close call, two incidents in which another road user stopped to wait for passengers to step out from a vehicle, and four incidents when a road user navigated around a vehicle and its opening car door. Typically bicyclists and skateboard users were involved in traffic conflicts related to motorists stopping in the traffic lane to discharge passengers, as opening motor vehicle doors typically occurred in or close to their path. Moreover, post-redesign non-auto users were overall more integrated with automobile traffic, so there were more opportunities, when a passenger was stepping out of a vehicle in the traffic lane, for interaction among these modes. However, as just one close call and no collisions were caused, conflict seldom occurred.

In terms of the location on the street where a motorist stopped to discharge a passenger, pre-redesign motorists often pulled into parking stalls to let out a pedestrian. Occasionally a motorist stopped in the middle of the traffic lane to do so. Post-redesign, seldom motorists pulled over in the contraflow lane to discharge a passenger, but usually this occurred either in the middle of a lane or on the left side, next to back-in angle parking stalls. Pulling over in the contraflow lane blocked bicyclists from using the lane designated specifically for them. Stopping in the middle of the lane to discharge a passenger was more effective because it allowed overall traffic flow to continue because it achieved the following: a) it did not block bicyclists, who, during high traffic volumes in the traffic lane, tended to the right-side of the street and b) did not block all motorists, as they were able to swerve around the stopped car, barely skimming the contraflow lane to pass. While discharging passengers in the middle of the lane typically did not cause a conflict, there were a few instances wherein streams of bicyclists and bumper-to-bumper motor vehicles were present in the traffic lane. In these situations, when the passenger opened the door of the motor vehicle to get out, it caused an oncoming bicyclist to halt suddenly or attempt to navigate around. Aside from these occasions, stopping in the middle of the traffic lane to discharge a passenger did not greatly affect other road users' travel.

Pedestrian interactions with other road users

Based on observation, of all three types of interactions, between pedestrians and bicyclists, pedestrians and motorists, and pedestrians and skateboard users, pedestrian and bicyclist interactions were most frequent. Pedestrian and bicyclist interactions occurred when a pedestrian walked in the contraflow bicycle lane where a bicyclist was traveling or swerving into, when a pedestrian crossed the contraflow or traffic lane, or when a pedestrian was discharged from a motor vehicle and came in close proximity to a passing bicyclist on the right side of the traffic lane. Pedestrian and motorist interaction occurred when a motorist was backing into a parking stall and a pedestrian was crossing the street or when a pedestrian crossed the street and a motorist waited for it to cross.

The number of occurrences of pedestrian and bicyclist interaction in the right of way decreased drastically post-redesign, from 14 incidents pre-redesign to three incidents post-redesign. Pre-redesign, pedestrians walking in the contraflow lane when the sidewalk was blocked off caused a majority of these conflicts. In these situations, since there was also a cement buffer that isolated the contraflow lane from the traffic lane, bicyclists were unable to swerve around pedestrians, like they were able to post-redesign. Pre-redesign, traffic conflicts caused include two close calls and nine incidents wherein either a pedestrian or a bicyclist stopped and yielded to the other road user, and five incidents wherein a bicyclist navigated around a pedestrian. Post-redesign, there was just one close call, two incidents when a road user stopped to avoid the other, and two incidents when a bicyclist navigated around a pedestrian, typically in the contraflow lane.

The overall number of incidents that caused traffic conflicts when there was interaction between a pedestrian and a motorist occurred four times pre-redesign and five times post-redesign, demonstrating the number of such incidents remained relatively consistent. Despite this, the resulting traffic conflicts increased post-redesign. Pre-redesign, the traffic conflicts that occurred between a motorist and a pedestrian include four incidents in which a motorist yielded to let a pedestrian cross. Post-redesign, there were three close calls, one incident when a motorist stopped to let a pedestrian cross, and three incidents when a pedestrian navigated around a motorist. In situations when a pedestrian was navigating around a motorist and a close call resulted, these occurrences caused traffic conflict(s) because the motorist was typically backing into a parking stall and did not see the pedestrian immediately. In each case this occurred, however, the motorist stopped before any serious conflict occurred.

Other observations

Based on video and on-street observation, vehicular traffic speeds appeared more varied pre-redesign and traffic jams more frequent post-redesign. The legal traffic speed on East 13th Avenue is 25 miles per hour. There were nonpeak traffic volumes time periods pre- and post-redesign. During these pockets of time, it appeared that motorists sped more frequently pre-redesign. It is possible that the narrowed roadway and the sharrow present on the traffic lane influenced motorists to drive more cautiously and at a lower speed post-redesign.

Summary of Findings

General Trends

Traffic volumes and road user behavior were significantly impacted by infrastructure changes. The redesign of East 13th Avenue reshaped the roadway, changing it from a restricted design that segregated modes to a fluid and free-flowing design. Prior to redesign, separation of space within the roadway was paramount; a row of parallel parking stalls, parking meters, and cement medians separated the contraflow lane and the vehicular traffic lane. Post redesign, the vehicular traffic lane and bicycle lane were integrated into a shared lane and pavement markings delineating separation between the contraflow lane and the traffic lane replaced physical buffers.

Traffic Volumes

After redesign, the volume of east and westbound bicyclists, east and westbound skateboard users and pedestrian crossings increased. Increased traffic volumes for these modes suggest that the road became easier or more comfortable to use after redesign. In comparison, motor vehicle usage decreased slightly after redesign, but did not drastically change. The combination of these trends suggests that the redesign helped balance alternate mode usage and did not greatly affect motor vehicle usage.

Westbound bicycle traffic volumes in the morning and early afternoon drastically increased, more so than eastbound bicycle traffic volumes after redesign. Also bicyclists traveling the wrong direction in the traffic lane decreased substantially after redesign. Given the amount of wrong way eastbound bicycle travel in the contraflow lane increased the amount of westbound bicycle travel in the traffic lane decreased, the following theories are possible:

- When the right of way became more open post-redesign, given physical barriers were removed, bicyclists were usually able to swerve around blockages in the contraflow lane.
- Pre-redesign, pedestrians often walked in the contraflow lane because there was sidewalk construction, which typically blocked bicycle traffic. It is possible that there were more westbound bicyclists that traveled the wrong direction in the traffic lane pre-redesign because pedestrians often blocked the contraflow lane. When sidewalk construction was finished post-redesign, fewer pedestrians blocked the lane, better enabling bicycle travel.

Traffic Encounters and Conflicts

East 13th Avenue was a chaotic street pre-redesign and remained chaotic post-redesign. To an uncritical eye, the removal of physical barriers and the integration of eastbound bicycle and vehicular traffic may appear to have created a more chaotic and unsafe street post-redesign, since there became more opportunities for improper lane use. However, no traffic collisions occurred and the amount of close calls remained the same post-redesign. The openness of the street enabled more free-form uses, and had many positive impacts. The ability to make more free-form use of the right of way post-redesign caused the following:

- Overall, more encounters that caused traffic conflicts, but no collisions and no change in the number of resulting close calls. While the right of way became less restrictive, overall it was no less safe.
- New ‘rule-breaking’ encounters; the ability of motorists to park in the contraflow lane, which blocked non-auto traffic, and the ability to move or swerve between lanes going different directions, which made wrong way travel easier because a wrong way traveler could swerve back into the correct lane.
- More conflicts caused by wrong way travel. Though in comparison to the total number of wrong way occurrences, encounters that caused conflict were infrequent, and the level of danger of such conflicts was low, given only one close call and no collisions resulted. Conflict causing occurrences were largely instigated by the presence of high bicycle and vehicular traffic volumes in the traffic lane, because this restricted space for navigation.
- Fewer conflicts caused by pedestrians blocking bicycle traffic by walking in the contraflow lane. Removal of physical barriers between the traffic and contraflow lanes better enabled bicyclists to navigate around blockages, and slightly veer into the traffic lane to avoid obstruction. While this means bicyclists did not stay in the correct lane, it also means that navigation in the contraflow lane improved, increasing the ability of bicyclists to use the space.

- Improved visibility for all road users in the right of way. With fewer physical barriers, particularly without a second row of parking stalls between the traffic and contraflow lane, bicyclists, skateboard users and pedestrians had a wider field of vision and were better able to navigate around oncoming traffic or blockages. Also the installation of back-in angle parking allowed motorists parked in stalls to clearly see oncoming traffic when pulling out.
- Fewer traffic conflicts caused while a motorist was parking. The use of back-in angle parking caused fewer conflicts than the use of parallel parking. This is likely impacted by the fact that other motorists behind a motorist who was parking often waited rather than navigating around, which commonly occurred pre-redesign.
- More traffic conflicts caused by motorists stopping to discharge passengers in the traffic lane. Use of the shared lane integrated mixed traffic streams, but when a car door was opened to discharge a passenger and a bicyclist was present, often the bicyclist had to swerve in avoidance. However, dangerous conflict was infrequent, as no collisions and just one close call resulted.

Recommendations

While this study examined infrastructure changes that occurred on just one block of a larger street network, the changes that resulted provide insight into whether a similar street design could be used elsewhere. The implementation of the redesign successfully rebalanced the street, enabling accommodation for more bicyclists, skateboard, and pedestrian users without compromising vehicular use. The street transformed from a chaotic design to a more chaotic design. In effect, the roadway became no less safe and overall functionality of the space improved.

Implementing a narrowed roadway and a sharrow on a multimodal street should be considered as a method for creating traffic-calming effects and increase pedestrian usage. Results show that variations in vehicular traffic speed appeared to decrease post-redesign. Even during low traffic volumes, when few road users were present, fewer motorists appeared to speed. It is likely the narrowed roadway and the presence of the sharrow may have caused motorists to proceed more cautiously. Moreover, pedestrians appeared more comfortable crossing the street after redesign, considering midblock pedestrian crossings increased post-redesign.

Implementing back-in angle parking and a shared traffic lane on one-way, low speed streets with multimodal traffic should be considered as a safe, viable option. Results show that back-in angle parking method improved road safety, provided it increased driver visibility of oncoming traffic, increased driver awareness of bicycle movement while parking, and commonly caused motorists to wait behind a vehicle that was back-in angle parking, rather than attempting to swerve around it.

Implementing a shared lane on a one-way, multimodal street should be considered as a way to improve safety and make functional use of a lane. While there is disagreement among transportation planners and engineers regarding the safety and comfort of bicyclists riding in a shared lane, this study shows that both safety improved and bicycle traffic volumes in the shared lane substantially increased. The implementation of a shared traffic lane in replacement of a separate vehicular traffic and bicycle lane eliminated the danger of passing bicyclists being hit by opening vehicle doors, parked in stalls along the roadway. This was known to have occurred prior to the redesign, though it was not observed firsthand. The presence of the shared traffic lane also effectively encouraged bicyclists to ride in the right of way, closer to the center of the lane rather than the side. Vehicular traffic volumes also appeared to remain consistently low post-redesign, given the presence of a sharrow and a narrowed roadway, which may indicate motorists proceeded more cautiously post-redesign, which improved overall safety. Moreover, while parallel parking stalls were removed post-redesign and replaced with back-in angle parking, after observing the behavior of bicyclists in the lane, it is apparent that a shared lane on a street with parallel parking stalls would effectively improve bicycle safety.

Redesigning project for multimodal traffic on low speed, high volume street with two-way bicycle traffic and one-way vehicular traffic should consider excluding a physical barrier between the vehicular traffic and contraflow lane. This study demonstrates that fewer barriers do not decrease safety or increase traffic conflict and delay, and are not detrimental to the ability of road users to use the space. Rather, they create new opportunities for more convenient navigation and increase road user awareness of other modes, given vehicular traffic speeds decreased. Specifically, the implementation of a shared lane led to integrated bicycle and motor vehicle traffic, wherein motorists generally became more aware of the presence of bicyclists, and bicyclists appeared more careful when or if navigating around a motorist who was parking or leaving a parking stall. In the cases where conflict did increase after redesign, as it did for wrong way travel in the traffic lane, none of the conflicts were severe, as no close calls or collisions resulted. This shows that it may actually be beneficial to exclude physical barriers between lanes on a low speed street intended for multimodal traffic.

Finally, the combination of back-in angle parking, a shared traffic lane, removal of physical barriers between the traffic and contraflow lane, and a narrowed roadway is recommended in areas with overall high traffic volumes and frequent pedestrian crossings. The effects of the redesign on East 13th Avenue have demonstrated that increased chaos does not imply decreased safety within the right of way. During high volume traffic periods, which occurred regularly, concurrently there was bumper-to-bumper vehicular traffic, bicyclists weaving between motor vehicles, skateboard users swerving between the shared traffic and contraflow lane, heavy bicycle traffic in the traffic lane, bicyclists traveling the wrong way in the traffic or contraflow lane, and frequent pedestrian crossings. To an outsider, the high level of activity that occurred on just one block would likely appear disorganized, and unsafe, and confusing. Despite this perception, functionality and safety of the street became more balanced. The redesign improved visibility, caution, and comfort of non-auto users while the traffic volumes of bicyclists, skateboard users and pedestrian crossings significantly increased.

(1) Rue, H., and K. Rooney. Creating Livable Communities: How the transportation decision making process can support more livable community outcomes. Publication FHWA-HEP-12-003. FHWA, U.S. Department of Transportation, 2011.

(2) McCann, B. Complete the Streets! *Planning*, Vol. 71, No. 5, 2005, pp. 18-23.

(3) City of Eugene, *Alder Street and University District Streetscape Improvements*, Public Works Planning Project, Oregon. http://www.eugene-or.gov/portal/server.pt?open=514&objID=4300&parentname=Gateway&parentid=None&mode=2&in_hi_userid=2&cached=true. Accessed August 3, 2011.

(4) Oregon University System, *Campus Profile*, Office of Admissions, University of Oregon, Eugene. http://admissions.uoregon.edu/profile.html. Accessed August 27, 2011.

(5) *Back-in/Head-out Angle Parking*. Nelson/Nygaard Consulting Associates, San Francisco, CA, 2005, pp. 1-8. http://lda.ucdavis.edu/LDA191/Course%20Handoutes%20%26%20Readings/05-Back_in_Diagonal_Parking.pdf, Accessed August 27, 2011.

(6) City of Seattle. Crown Hill Walking Tour Answers, http://mayormcginn.seattle.gov/crown-hill-walking-tour-answers/. Accessed May 15, 2012.

(7) Nawn, J.A., Back-in Angle Parking in the Central Business District, URS Corporation, Pottstown, PA, undated.

(8) Pedestrian and Bicycle Information Center. *Back-in angle parking: what is it, and when and where is it most effective?* http://www.walkinginfo.org/faqs/answer.cfm?id=3974. Accessed May 15, 2012.

(9) Transportation and Parking Commission, *Back-in Angle Parking Test*, Northhampton, MA, http://www.northamptonma.gov/tpc/BackIn_Angle_Parking_Test/. Accessed June 10, 2012.

(*10*) Williams, J. *Wisconsin Design Facility Design Handbook*. Wisconsin Department of Transportation, Wisconsin, 2004.

(*11*) Baltimore Bike Community Blog, November 2010, http://www.bmorebikes.com/want-more-bike-lanes-tell-the-city/. Accessed June 10, 2012 and NACTO Urban Bikeway Design Guide, April 2011, http://bikeped.rutgers.edu/ImageFolio43_files/gallery/Bike-

Ped_Facilities/Documents/NACTO_2011_UrbanBikeway_DesignGuide.pdf. Accessed June 10, 2012.

(*12*) Hughes, B. *Call to bring Dutch 'woonerf' model of safer streets to Wales*. WalesOnline, Cardiff, Wales. http://www.walesonline.co.uk/news/wales-news/2012/03/12/call-to-bring-dutch-woonerf-model-of-safer-streets-to-wales-91466-30510606/. Accessed June 12, 2012.

(*13*) Matwie, C.T. and J. F. Morrall. Guidelines for a safety audit of bikeway systems. *World Transport Policy and Practice*, Vol. 7, No. 3, 2001.

(*14*) Oregon Bicycle and Pedestrian Program. *Oregon Bicycle and Pedestrian Design Guide*. Oregon Department of Transportation, Oregon. http://www.oregon.gov/ODOT/HWY/BIKEPED/planproc.shtml. Accessed June 10, 2012.

(*15*) Hunter, W. W., L. Thomas, R. Srinivasan, and C. A. Martell. *Evaluation of Shared Lane Markings*. Publication FHWA-HRT-10-044. FHWA, U.S Department of Transportation, 2010.

(*16*) Harkey, D.L., and S. Stewart. Evaluation of Shared-use facilities for Bicyclists and Motor Vehicles. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1578, Transportation Research Board of the National Academies, Chapel Hill, N.C., 1997, pp. 111-118.

(*17*) Sherman, W. Cityphile, June 14, 2011, http://cityphile.com/photo/sharrow-2/. Accessed June 10, 2011.

(*18*) Pucher, J. Cycling Safety on Bikeways vs. Roads. *Transportation Quarterly*, Vol. 55, No. 4, 2001, pp. 9-11.

(*19*) Hartell, D. *Dedicated bike lanes or shared-use markings?* The Morning Call, Lehigh Valley, NJ. http://articles.mcall.com/2012-03-13/news/mc-bicycle-lanes-point-counterpoint-20120309_1_bike-lanes-sharrows-motor-vehicle-lane. Accessed June 10, 2012.

(*20*) Moynihan, C. *Bike Lanes, Intended for Safety, Become Traffic Battlegrounds*. New York Times, New York, NY. http://www.nytimes.com/2008/05/04/nyregion/04bikes.html?pagewanted=all. Accessed June 10, 2012.

(*21*) Garrad, J., G. Rose, and S. Kai Lo. Promoting transportation cycling for women: The role of bicycle infrastructure, Victoria, Australia. *Preventative Medicine*, Vol. 46, 2008, pp. 55-59.

(*22*) Schramm, A., and A. Rakotonirainy. The effect of road lane width on cyclists safety in urban areas. Presented at Policing and Education Conference, Australasian Road Safety Research, Sydney, New South Wales, 2009.

(*23*) Forester, J., The Bikeway Controversy. *Transportation Quarterly*, Vol. 55, No. 2, 2001.

(*24*) Oregon Bicycle and Pedestrian Program. *Oregon Bicycle and Pedestrian Design Guide*. Oregon Department of Transportation, Oregon. http://www.oregon.gov/ODOT/HWY/BIKEPED/planproc.shtml. Accessed June 10, 2012.

(*25*) Williams, M. J. Validity of the traffic conflicts technique. *Accident Analysis and Prevention*, Vol. 13, No. 2, 1981, pp. 133-145.

(*26*) Tiwari, G., D. Mohan., and J. Fazio. Conflict Analysis for Prediction of Fatal Crash Locations in Mixed Traffic Streams. *Accident Analysis and Prevention*, Vol. 30, No. 2, 1998, pp. 207-215.

(*27*) Kieliszewski, C. A. Twisted Metal: An Investigation into Observable Factors that Lead to Critical Traffic Events. Ph.D. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA, 2005.

(*28*) Parker, M.R., Jr., and C.V. Zeeger. *Traffic conflict techniques for safety and operations: Operations Manual*. Publication FHWA-IP-88-027. FHWA, U.S. Department of Transportation, 1989.

(*29*) Sayed, T. and S. Zein. Traffic conflict standards for intersections. *Transportation Planning and Technology*, Vol. 22, No. 4, 1999, pp. 309-323.

(*30*) Marshall, W. E., and N.W. Garrick. Does street network design affect traffic safety? *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 769-781.

(*31*) Ewing, R., and E. Dumbaugh. The Built Environment and Traffic Safety: A Review of Empirical Evidence. *Journal of Planning Literature*, Vol. 23, No. 4, 2009, pp. 347-367.

(*32*) Spicer, B.R. *A traffic conflict study at an intersection on the Andoversford by-pass*. Transport and Road Research Laboratory, Berkshire, 1974.

(*33*) Räsänen M. and H. Summala. Attention and expectation problems in bicycle-car collisions: an in depth study. *Accident Analysis and Prevention*, Vol. 30 No. 5, 1998, pp. 657-666.