Improving Cyclist and Pedestrian Environment While Maintaining Vehicle Throughput

Before- and After-Construction Analysis

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Reallocating road space to enhance bicycle and pedestrian access is frequently a contentious issue in many American cities. This resistance to the redesign was characteristic in Eugene, Oregon, where a key street segment adjacent to a pedestrian- and bicycle-friendly university was retrofitted to accommodate nonmotorized vehicles better. The intention was to expand pedestrian and bicycle access, so a bicycle lane was actually removed in one direction in favor of implementing a shared lane, and physical barriers between an existing contraflow bicycle lane and a one-way automobile traffic lane were also removed. In addition, two-sided parallel parking stalls were replaced with single-sided, back-in angle parking stalls (a first for Eugene), and sidewalks were widened to better accommodate high pedestrian volumes. Video footage to record behavior along this block before and after the redesign was used to study traffic volume changes by mode and changes in behavior. The results demonstrated that bicycle volumes increased, pedestrian crossing volumes increased, and vehicular traffic volumes showed little change after the redesign. The integration of bicycle and vehicular traffic lanes and removal of physical barriers improved safety for nonmotorized vehicles because the rate of traffic conflicts remained low, no collisions occurred, and the redesign provided new ways for convenient navigation around blockages. Despite a perceived increase in chaos, given increased nonmotorized traffic volumes, this block became no less safe after redesign even though nonmotorized traffic volumes and adaptive use of the space greatly increased. Examination of the particular elements of this redesign provides insight into ways that other multimodal traffic streams could be improved.

This study examines a roadway redesign in Eugene, Oregon, that was constructed to improve pedestrian and bicycle conditions while maintaining existing vehicular throughput, on-street parking, and bus access. The study area, a segment of East 13th Avenue, is a gateway to the University of Oregon campus, which has approximately 24,000 students and 4,500 faculty and staff (*1*). This block is lined with food, beverage, and retail establishments that bring in significant local traffic. It functions as a hub for various transportation modes, particularly bicycles, pedestrians, automobiles, and buses. Although the individual infrastructure elements of this redesign are not unique, the combination of elements, including the removal of some bicycle facilities, is. Before the redesign, East 13th Avenue included a one-way automobile traffic lane; two-way bicycle traffic lanes, including a bicycle lane and a contraflow lane; sidewalks; and on-street parking. However, local planners and transportation officials wanted to enhance the bicycle and pedestrian facilities because of the high multimodal volumes along this corridor. Design changes included the following (see Figure 1 for before and after images of the right-of-way):

- Parallel parking on both sides of the street was changed to back-in angle parking on just the south side of the street. The number of parking stalls was reduced from 22 to 19.
- Segregated eastbound traffic and bicycle lanes were combined into a shared lane. The width of the traffic lane decreased from 15 to 12 ft.
- The westbound contraflow bicycle lane on the north side of the street was left intact, but physical barriers that previously separated bicycles from vehicles were removed and replaced with wide pavement markings. The width of the contraflow lane remained the same.
- To accommodate high pedestrian volumes, sidewalks were widened 5 ft by narrowing the roadway (curb to curb) from 44 to 39 ft.

BACKGROUND

The purpose of the redesign was to improve the conditions for nonmotorized users. The implementation of this multimodal infrastructure design falls within the complete streets policy arena. Broadly defined, the complete streets approach seeks to redesign roads that are accessible to automobiles but poorly serve nonmotorized modes, particularly pedestrians and bicyclists. Complete streets policies seek to expand street use such that they "[work] 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*).

The predominant approach toward street design of major roads in the United States is to emphasize mobility and vehicle throughput. The complete streets movement challenges some of this paradigm; the emphasis is that streets should accommodate multiple modes and should often be considered destinations themselves (*2–4*). Efforts to transform streets into complete streets from mobility-based to accessibility-based designs often face resistance from professional

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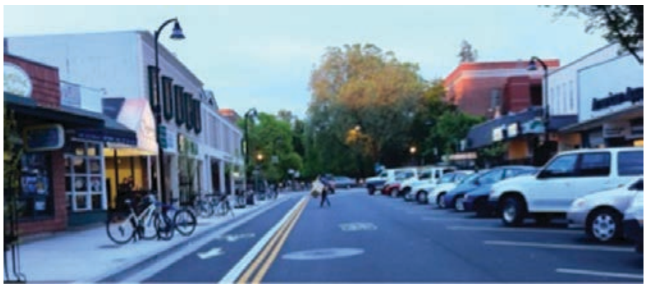
(a)



(b)

FIGURE 1 East 13th Avenue: (*a*) before redesign and (*b*) after redesign.

communities, traffic engineers, and the public, who claim that the redesign will reduce vehicular throughput and traffic flow. Yet complete streets proponents sometimes hold that vehicular throughput is not affected and that flow can improve or remain the same even when new designs create pedestrian and cycling space in areas that were previously occupied by automobiles (*4*).

Redesigning streets to enhance pedestrian and bicycle environments broadly relates to recent policy goals for enhancing livability, a concept included in the U.S. Department of Transportation 2010 strategic plan. Ray LaHood, recent U.S. Secretary of Transportation, was a strong advocate for expanding the role of transportation and its users under the umbrella of livability. LaHood described a livable community 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" (*5*). In 2009, a collaboration between the U.S. Department of Transportation, the Environmental Protection Agency, and the Department of Housing and Urban Development formed the Partnership for Sustainable Communities to promote developing livable communities to "improve access to affordable housing, provide more transportation options, and lower transportation costs while also supporting public health and protecting the environment" (*5*).

Integral to developing livable communities is creating infrastructure and policies that support multimodal transportation, which can help decrease automobile dependency for all trips, decrease the overall cost of transportation, and make multimodal travel safer (*5*). Expanding, or in this case improving, the presence of multimodal, or complete, streets is fundamental to the overarching intent behind enhancing livable communities. Accordingly, it is critically important to understand and document the uses of specific, relatively rare or innovative street design elements like those examined in this study.

Back-In Angle Parking

Back-in angle parking requires a motorist to drive past a parking stall and reverse backward to maneuver into it, so that the front of the parked vehicle faces the street (*6*). Benefits of back-in angle parking over parallel parking include the following:

- 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 (*6*).
- Parallel parking often requires multiple forward-backward maneuvers. If, for instance, a parking stall is narrow or a driver is inexperienced, parking may require multiple attempts to successfully angle a vehicle correctly to back into a stall. Back-in angle parking only requires a motorist to angle a 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 located along a street, since automobile doors are not adjacent to the traffic lane.
- Backing into a back-in angle parking stall requires a driver to turn at a larger angle compared with parallel parking. It therefore may require other users behind a parking motorist to stop and wait. Comparatively, users behind a driver who is parallel-parking may be able to continue moving; this situation potentially creates a safety hazard (*7*).
- Users of nonmotorized vehicles are better able to steer clear of a motorist who is backing into a parking stall than one who is pulling out of one (*7*). This method also improves visibility of a driver who is exiting a parking stall (*8, 9*) since the front of the vehicle faces toward the street and the motorist has a clear view of oncoming traffic (*6*).

Contraflow Bicycle Lanes

When two-way bicycle access is desired on a one-way automobile street, a right-way contraflow lane allows bicycle travel in the opposite direction of traffic. Separation between a contraflow and traffic lane can be implemented in the form of physical buffers (cement medians, parking stalls, etc.) or pavement markings. When a physical median is present, the bicycle lane is considered a one-way protected cycle track. In either case, safety benefits to contraflow lanes include the following:

- Delineating separate areas for contraflow bicycle travel may increase user awareness and minimize conflict in a right-of-way since fewer bicyclists illegally travel the wrong way in a one-way lane (*6*),
- Contraflow lanes provide more direct access to high-use destinations (*10*), and
- These lanes 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 (*10*).

Shared Lanes

A shared lane is a bikeway that integrates automobile and bicycle travel into a single lane. In comparison with bicycle lanes, shared lanes do not delineate a portion of the road for bicyclists. Shared lanes commonly include pavement markings, or sharrows (*11*). Similar to *woonerfs,* or rights-of-way shared by pedestrians, bicyclists, and motorists, the intent of sharrows is to promote the safety and mobility of nonvehicular road use (*12*). Like *woonerfs,* sharrows affect traffic calming by improving driver awareness of nonmotorized users and decrease speeding on low-speed streets (*13*). Use of sharrows on shared lanes has the following benefits:

- Bicyclists are encouraged to ride in the right-of-way and motorists are informed where to anticipate bicyclists (*14*). These benefits are particularly important in narrow lanes, where bicyclists may need more space; sharrows are helpful because they remind motorists to give bicyclists adequate space (*13*).
- The presence of motorists and bicyclists in the same lane is known to improve spacing between modes.
- In lanes next to a curb or on-street parallel parking, sharrows are believed to help bicyclists position themselves away from swinging car doors or too close to a curb (*13*).
- For a bicyclist sharing a lane rather than riding in a separate lane alongside, sharrows allow slightly more time to react to a motorist pulling into or backing out of the lane from a side street or an adjacent stall (*15*).

Although the use of shared lanes and sharrows has many known benefits, there is disagreement on whether they are safer for bicyclists than separately designated bicycle lanes. It has been held that separate bicycle facilities are generally safer for bicyclists, since the elderly, young children, or those with disabilities may be unable to safely navigate in mixed traffic streams (*16, 17*). Surveys have shown that people feel comfortable bicycling in a lane separate from vehicular traffic, but these findings are contextual and may not accurately indicate bicyclists' preferences in other cities or actual cycling habits (*18, 19*). Moreover, the use and safety of sharrows have not yet been extensively studied (*20*). Advocates of mixed traffic streams argue that cyclists should be in the roadway like motorists (*21*). It is acknowledged that vehicular speed affects the safety of cyclists in shared lanes, and generally low vehicular volumes are optimal in these lanes, but implementation of sharrows is recommended on streets with high bicycle volumes (*14*).

Active complete streets policies exist in most U.S. states, but there is a gap between policy adoption and actual project implementation. In professional practice, for traffic engineers, transportation planners, public policy makers, community organizations, and citizens, there is a lack of performance-based studies that provide evidence for the impacts of complete street designs or evidence showing conclusive benefits of one design over another (*22–25*). The current study aims to help fill some of this gap.

RESEARCH CONTEXT

This project studies multimodal road use on East 13th Avenue in Eugene before and after the redesign. Documentation of changes in traffic volumes, traffic conflicts (including interactions between or among modes and between modes and pedestrians crossing midblock), and unofficial midblock crossings by pedestrians was conducted. The study area is a block located between one signalized intersection, Alder Street, and one stop-sign-controlled intersection, Kincaid Street. There are no formally marked crosswalks within the study area, and therefore midblock crossings occur, including pedestrians jaywalking or crossing the street at random midblock locations rather than at intersections. Because this study examines the effects of an infrastructure design, the pedestrian midblock crossing volumes and behavior with other users within the right-of-way as opposed to sidewalk activity were analyzed; potential conflicts between pedestrians and other modes occur within the right-of-way rather than on sidewalks. The following questions guided this study:

- Did bicycle traffic volumes increase or decrease after the redesign, given the elimination of a bicycle lane and of physical barriers separating the contraflow lane and the traffic lane?
- Given that the roadway was narrowed and the sidewalks were widened, were there noticeable changes in pedestrian crossing behavior after the redesign?
- How did traffic safety or flow change after 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 nonbicycle users after the redesign, given that the physical barriers between the contraflow and traffic lanes were removed?
- Was this road segment measurably more or less safe after the redesign in terms of close calls or traffic collisions?
- Overall, how did this road segment function after the redesign in terms of mode usage and perception?

METHODS

Data Collection

Data were collected from videotape recordings and manually reviewed. A total of 54 h of video observations were collected, including 27 h before the redesign and 27 h after the redesign. Videos were recorded before the redesign during two consecutive weeks in late spring 2011, and after-redesign videos were recorded during two consecutive weeks in early fall 2011. Both before- and after-redesign recording periods occurred during academic terms, when university traffic for all modes was very active.

To ensure consistent data collection, video recording occurred three times a day on Tuesdays, Wednesdays, and Fridays from 9:15 to 10:45 a.m., 11:15 to 12:45 p.m., and 2:15 to 3:45 p.m. for two contiguous weeks before and after the redesign. All time segments started 15 min past the hour and ended 45 min past the hour to capture traffic volumes at peak and nonpeak hours as related to the ebb and flow of university student course schedules. Tuesdays, Wednesdays, and Fridays were selected as recording days to capture road users with different class and daily schedules. Video footage was recorded from a second-story roof that overlooked the study section. Weather patterns and unusual traffic patterns were noted during each time segment, but nothing out of the ordinary was observed.

Data Analysis

Traffic volumes and conflicts were documented during video review. Each observed interaction was coded by conflict type, the road users involved, their direction of travel, and the location within the study area where each incident occurred (in the traffic lane, contraflow lane, or parking area). Each 1.5-h video recording segment was divided into 15-min sections when traffic was counted to aid in detailed compilation and analysis of travel behavior. The following information was documented from video recordings for analysis:

- Number of eastbound bicyclists and automobile drivers who traveled on East 13th Avenue from Alder Street to Kincaid Street,
- Number of westbound bicyclists who traveled on East 13th Avenue from Kincaid Street to Alder Street,
- Number of pedestrians crossing midblock from the north and south sides of East 13th Avenue,
- Number of bicyclists who traveled in the wrong direction to the one a lane was intended for, and
- Descriptions of traffic conflicts, including actions that led to a conflict and resulting conflicts that occurred.

Traffic Conflicts

In addition to documenting changes of use by mode, researchers examined the nature of interactions between modes. Strict crash data were not used for analysis of traffic conflicts. Instead, observed traffic conflicts and initial occurrences that regularly led to conflicts were collected from the 54 h of recording. Evaluation of safety was determined both by incidence of traffic conflicts as defined in this study and by observations that may have factored into road user interactions. Traffic conflicts were caused by eight types of actions, or encounters, taken by various road users, including those who

- Traveled the wrong way in the contraflow lane (bicyclists),
- Traveled the wrong way in the traffic lane (bicyclists),
- Parked in a stall or turned right and entered the alley along East 13th Avenue (motorists),
- Left a parking stall or left the alley and turned onto East 13th Avenue (motorists),
- Parked in the contraflow lane (motorists),
- Stopped in the traffic lane (motorists),
- Stopped in the traffic lane to discharge a passenger (motorists), and
- Caused other general pedestrian interactions (pedestrians, bicyclists, or motorists).

Traffic conflicts that resulted from the foregoing actions include road users who blocked portions of the road and caused close calls (coming in close proximity to others) and collisions. When the instigating road user blocks a portion of the road, the resulting conflict causes the affected road users to stop, to navigate around the blockage, or both. Thus a single action can cause more than one traffic conflict.

The nature of this study extends existing transportation literature and traffic studies focused on road safety. Within this literature, a traffic conflict is often considered a precursor to a potential or actual traffic collision (*26, 27*). 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]" (*28*). Here "imminent" means an anticipated result that is about to happen, and "danger of a collision" means that conflict situations are only those that result in physical contact. Within this body of literature, traffic conflicts are examined in relation to intersections (*29, 30*) or midblock locations (*31*), specific network designs (*29*), design treatments (e.g., traffic calming measures or trees close to a street) (*30*), or time of day or location (*32*).

Common in this type of study is measurement of road safety by the occurrence of traffic collisions, and whether or how a preceding traffic conflict affects the result. Motorists are typically the main actors involved in traffic conflict analyses, even if conflicts between motorists and other types of road users, such as bicyclists or pedestrians, are analyzed (*30, 31, 33*). However, in this study traffic conflicts are not considered precursors to potential or actual traffic collisions but refer to the larger variety of interactions that occur between road users that somehow impede movement, even if such interactions do not result in collision and even if a motorist is not involved.

FINDINGS

Key findings from this research include the following:

1. The volume of cyclists significantly increased, but the volume of motorists remained relatively constant. This finding shows that the redesign enhanced the bicycle environment without compromising automobile access.
2. Pedestrian midblock crossings increased and pedestrian-related conflicts decreased. This finding indicates an improved perception of safety by pedestrians.
3. Despite an increased volume of cyclists and crossing pedestrians and the removal of the physical barriers between lanes, the number of overall traffic conflicts did not increase after the redesign.

Each of these findings is delineated next.

Traffic Volumes

After the redesign, overall bicycle traffic volumes traveling east and west increased, pedestrian crossings increased, and vehicular traffic volumes slightly decreased. Figure 2 shows traffic volume changes for each road user type, separated by direction of travel, including eastbound motor vehicles and east- and westbound bicycles. In total, the number of nonpedestrian road users increased from 16,325 before the redesign to 20,464 after the redesign, a 25.4% increase after redesign. Normalizing road user types by traffic volume per hour, eastbound bicycles increased 68.5% and westbound bicycles increased 96.9% per hour after the redesign, whereas eastbound motor vehicles decreased marginally by 4.5%. Midblock pedestrian crossings also increased after redesign by 17.4%, even though no official crossing locations were installed. While midblock crossings were not intentionally encouraged or discouraged, the narrowed roadway and widened sidewalks may have prompted this increase. Overall volume changes indicate that the redesign enhanced nonmotorized modes of travel and had only a marginal effect on automobile access and throughput.

Figure 3 shows a more detailed visualization of volume changes; eastbound bicycle traffic volumes for each time segment and day of observation are represented. After the redesign, average morning traffic volumes increased by 79.5%, average afternoon traffic volumes increased by 65.5%, and average late afternoon traffic volumes increased by 53.6%. Similar representations for westbound bicycles are shown in Figure 4, where bicycle volumes after redesign are consistently higher at all times of day and days of week than the before-redesign condition. Traffic volumes for eastbound motor vehicles are shown in Figure 5, which shows that volumes generally remained constant both before and after redesign.

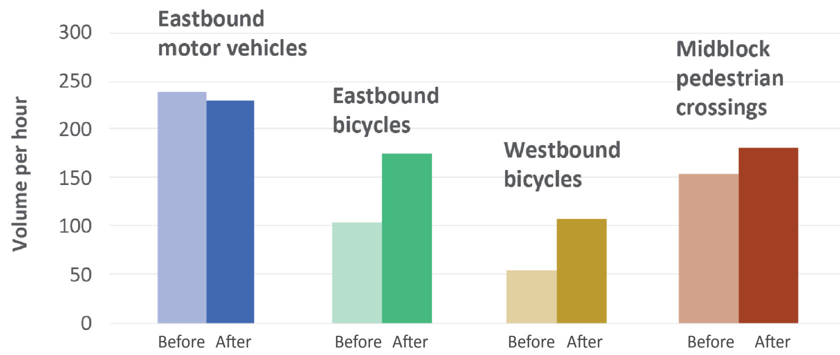


FIGURE 2 Traffic volume changes before and after redesign for eastbound motor vehicles and bicycles, westbound bicycles, and midblock pedestrian crossings.

FIGURE 3 Changes in volume of eastbound bicycle traffic per time segment and per day.

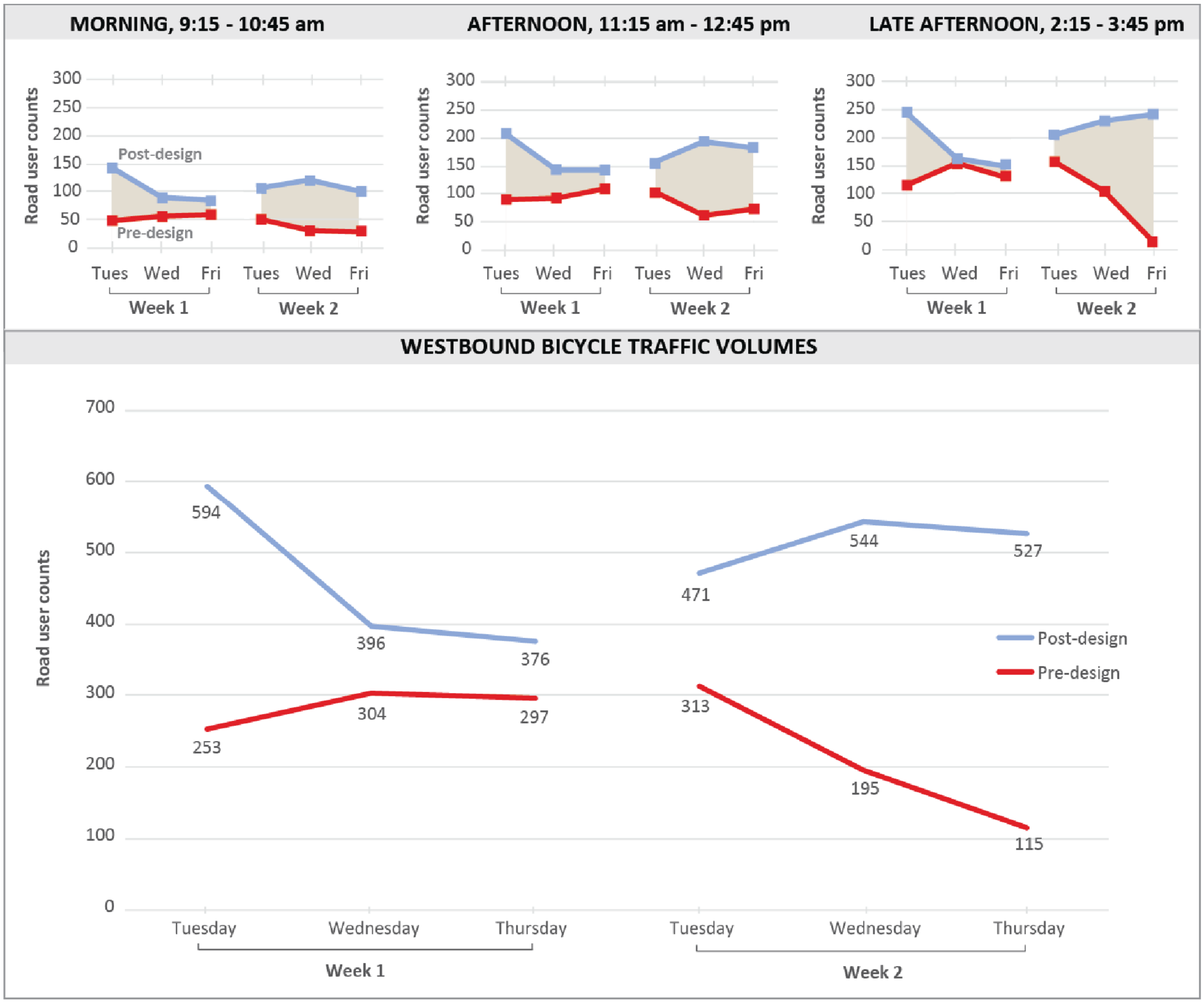


FIGURE 4 Changes in volume of westbound bicycle traffic per time segment and per day.

Traffic Conflicts

As mentioned, observed traffic conflicts occurred when an initial action, or encounter, taken by a road user caused a negative tangible outcome with one or more other road users. Resulting conflicts include blocking portions of the road, causing close calls (approaching in close proximity), and causing actual collisions. Table 1 delineates the types and number of conflict-causing actions and resulting traffic conflicts that occurred before and after redesign. Figure 6 shows the street locations of conflicts before (*top*) and after (*bottom*) redesign.

East 13th Avenue was chaotic before the redesign and remained so after the redesign because of high multimodal use. After redesign, new opportunities for improper lane use increased. The removal of physical barriers between the contraflow bicycle lane and the traffic lane enabled free-form use of the roadway, or adaptive behavior that created new ways for navigation. These free-form uses gave the outward appearance of increased chaos, since multiple modes sharing the same space may be viewed as more chaotic than when modes are segregated. However, no collisions occurred and the rate of close calls remained the same after redesign. Free-form uses of the roadway and its impacts after redesign include the following:

- The overall occurrence of actions that typically led to conflicts increased, but no collisions occurred and close calls did not increase. These findings indicate that a less restrictive right-of-way is not less safe.
- New rule-breaking actions arose. After redesign, motorists were able to park in the contraflow lane, blocking nonmotorized traffic, and wrong-way travel became easier as bicyclists were able to move or swerve between lanes going in different directions.
- Wrong-way travel overall increased, but such actions that led to conflicts (in comparison with the total number that occurred) were infrequent before and after redesign. Conflict-causing occurrences were largely instigated by the presence of high bicycle and vehicular traffic volumes in the traffic lane, which restricted space for navigation.
- Pedestrians walking in the contraflow lane decreased after redesign, reducing conflicts caused by blockage of westbound bicycle traffic. Further, the lack of physical barriers between the traffic

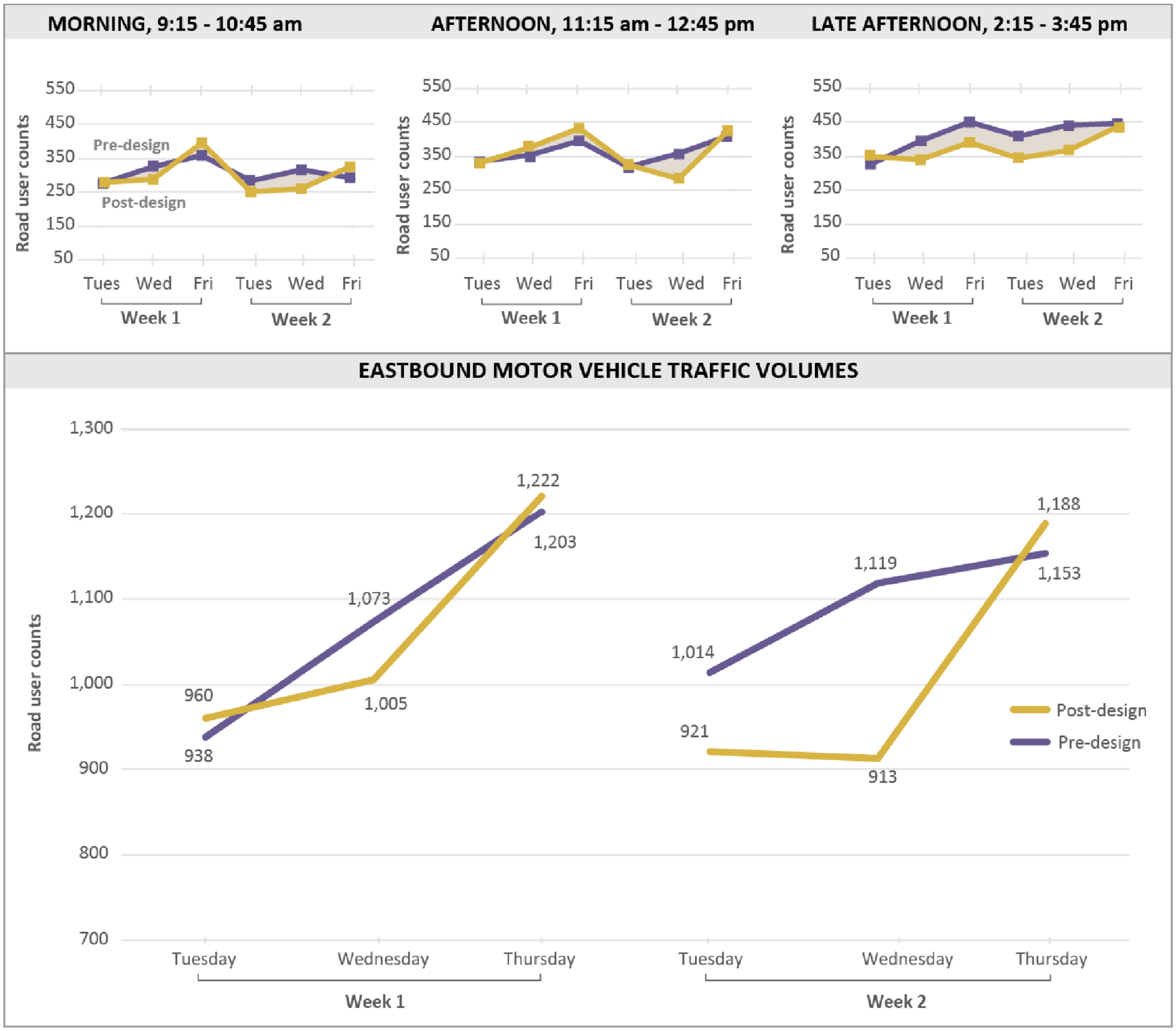


FIGURE 5 Changes in volume of eastbound motor vehicle traffic per time segment and per day.

and contraflow lanes enabled bicyclists to move around pedestrian blockages more easily.

- The installation of back-in angle parking allowed motorists parked in stalls to clearly see oncoming traffic when they pulled out; this feature led to fewer traffic conflicts while a motorist was parking. The use of back-in angle parking after redesign caused fewer conflicts than the use of parallel parking before redesign. This finding is likely affected by the fact that other motorists behind a motorist who was parking often waited rather than navigating around, which commonly occurred before redesign.
- More traffic conflicts were caused by motorists stopping to discharge passengers in the traffic lane after redesign. Use of the shared lane integrated mixed traffic streams, but when an automobile door was opened to discharge a passenger in the traffic lane while a bicyclist was present, often the bicyclist maneuvered around the potential conflict. That said, no collisions and just one close call resulted; this finding shows that the street redesign allowed road users to negotiate unpredictable behavior quickly and safely.

CONCLUSIONS AND RECOMMENDATIONS

This study examined transportation infrastructure changes designed to enhance the pedestrian and bicycle environments of a busy street adjacent to a university while maintaining access to automobile throughput and on-street parking. Somewhat counterintuitively to the goal of enhancing bicycle facilities, the redesign involved removing an eastbound bicycle lane in favor of implementing a shared travel lane and removing physical barriers separating the westbound contraflow lane and eastbound traffic lane. The redesign increased sidewalk widths and altered the on-street parking method from two-sided parallel parking to single-sided back-in angle parking.

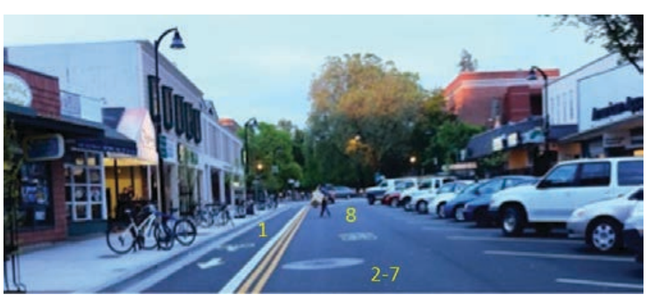
Overall, the redesign successfully improved facilities for bicyclists and pedestrians without compromising vehicular use. Modal use increased for nonmotorized vehicles and changed little for motorists after the redesign. Safety improved for nonmotorized vehicles, as bicycle volumes significantly increased in both directions;

TABLE 1 Conflict-Causing Actions and Resulting Traffic Conflicts

Action Type	Number of Conflict-Causing Actions: Before Redesign	Number of Conflict-Causing Actions: After Redesign	Number of Traffic Conflicts — Portion of Road Is Blocked — Road User Stops: Before Redesign	Road User Stops: After Redesign	Road User Navigates Around: Before Redesign	Road User Navigates Around: After Redesign	Close Call Occurred: Before Redesign	Close Call Occurred: After Redesign
Traveling wrong way in contraflow lane (bicyclist)	1	5	0	4	0	2	1	0
Traveling wrong way in traffic lane (bicyclist)	4	6	0	0	3	7	0	1
Parking in stall or turning into alley (motorist)	9	5	7	3	1	2	7	2
Leaving parking stall or alley (motorist)	4	6	2	4	1	2	2	0
Parking in contraflow lane (motorist)	na	8	na	5	na	6	0	0
Stopping in traffic lane (motorist)	2	12	1	3	1	6	1	1
Stopping in traffic lane to discharged passenger (motorist)	1	8	0	2	1	4	0	1
Pedestrian interaction with other road user(s)								
Bicyclist	14	3	9	2	5	2	2	1
Motorist	4	5	4	1	0	3	0	3

NOTE: All numbers are total number of occurrences. No collisions occurred before or after redesign. na = not applicable.

(a)



(b)

FIGURE 6 Street locations of traffic conflicts: (*a*) before redesign and (*b*) after redesign (numbers refer to action types in Table 1).

this finding indicates that the environment became a preferred location for entering and exiting the university area. The rate of bicycle conflicts decreased while volumes increased; this finding indicates that safety improved after redesign. It is unclear whether such volumes increased or whether cyclists simply changed their routes, but the increased volumes after redesign indicate that travel along this street segment was safe, comfortable, and offered direct routes east and westbound.

Pedestrians also seemed to experience an increased level of safety and comfort, given that midblock crossing volumes increased and pedestrian-related traffic conflicts decreased after redesign; this finding shows that the rate of such conflicts decreased. Pedestrians observed while crossing the street appeared to display an improved perception of caution for oncoming traffic. Given that no official crosswalks were installed after redesign nor did they exist before the redesign, an increase in midblock pedestrian crossing volumes could be perceived as an increase in potentially dangerous activity. However, in areas where pedestrian volumes are high, automobile traffic speeds are low and such users have priority, as on East 13th Avenue, so an increase in midblock crossings is likely due to an improved perception of safety by pedestrians and an appropriate and positive effect of this street redesign. Specifically, the removal of physical barriers separating the contraflow lane from the traffic lane, the decreased width of the roadway (curb to curb), and the widened sidewalks created fewer barriers for pedestrians to cross, a wider view of oncoming traffic within the roadway, and a reduced crossing distance.

Considering these positive changes, communities with locales near universities, thriving city centers, or main streets that are seeking to accommodate multiple modes in a busy area with high pedestrian or bicycle volumes could consider aspects of this redesign. Implementing back-in angle parking and a shared traffic lane on one-way, low-speed street is a safe, viable option. Results show that back-in angle parking improved road safety, since 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 backing in to park rather than their attempting to swerve around it.

Implementing a shared lane on a one-way, multimodal street could be considered as a way to improve safety and make functional use of a lane, depending on the location of the potential bicycle lane, the type of on-street parking, and the speed of traffic that exists. On East 13th Avenue, the bicycle lane was removed and replaced with a shared lane, and the on-street parking method was changed from parallel to back-in angle parking. The implementation of back-in angle parking removed the risk of bicyclists' getting "doored" by a parallel-parked driver's opening his or her driver-side door as a bicycle approaches. Considering parallel parking, it is possible that a shared lane is preferred, which gives cyclists some flexibility in maneuvering. However, implementing back-in angle parking and separate bicycle and traffic lanes may yield a similar increase in bicycle volumes as the implementation of a shared lane and back-in angle parking did in this study. A separate research study investigating the differences in these types of adjacent facilities could provide more nuanced insight.

Redesigning streets for multimodal traffic on low-speed, commercial streets with high bicycle and pedestrian volumes could consider excluding a physical barrier between a vehicular traffic lane and a contraflow lane, although 2 or 3 ft of striping or pavement markings between the contraflow and travel lane may be important. This study demonstrated that fewer physical barriers between such lanes did not decrease safety or increase traffic conflicts. Rather, this change created new opportunities for more convenient and flexible navigation. The implementation of a shared lane appeared to also increase motorists' awareness of the presence of bicyclists, and bicyclists appeared more careful when navigating around motorists parking or leaving a parking stall. When conflict did increase after the redesign, as it did for wrong-way travel in the traffic lane, none of the conflicts were severe, since no close calls or collisions resulted. This finding shows that it may be beneficial to exclude physical barriers between lanes on low-speed streets 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 could be considered in areas with overall high traffic volumes and frequent pedestrian crossings. The effects of the redesign have demonstrated that increasing the use and chaos of shared space does not decrease safety within the right-of-way. During high-volume traffic periods, which occurred regularly, there was often bumper-to-bumper vehicular traffic, bicyclists weaving between automobiles and between the shared traffic and contraflow lanes, heavy bicycle traffic in the traffic lane, bicyclists traveling the wrong way in the traffic or contraflow lane, and frequent pedestrian crossings. To some, this high level of activity may have appeared disorganized, unsafe, and confusing. Yet this study showed that the redesign improved visibility, caution, and comfort of nonmotorized users while the traffic volumes of such users significantly increased and the traffic volumes of motorized users showed little change. Overall, this redesign improved an already complete street and enhanced livability of this area, thereby helping to meet national transportation goals through specific redesigns of space for local users.

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