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Evaluation of Innovative Bike-Box Application in Eugene, Oregon

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An innovative "bike box"—a right-angle extension to a bike lane (BL) at the head of the intersection—was installed with accompanying traffic signs but no extra traffic signals at a busy downtown intersection featuring two one-way streets in Eugene, Oregon, in summer 1998. The box allows bicyclists traveling to the intersection in a left side BL to get to the head of the traffic queue on a red traffic signal indication and then proceed ahead of motor vehicle traffic toward a right side BL when the traffic signal changes to green. Cyclists traveling through the intersection were videotaped before and after placement of the box. The videotapes were coded to evaluate operational behaviors and conflicts with motorists, other bicyclists, and pedestrians. Twenty-two percent of the bicyclists who approached in the left side BL and then crossed to the BL on the right side of the street (the bicyclists for whom the box was most intended) used the box. Many more bicyclists in this target group could have used the box (i.e., they had a red signal indication and enough time to move into the box). A problem with motor vehicle encroachments into the box likely diminished the frequency of use. The rate of conflicts between bicycles and motor vehicles changed little in the before and after periods. No conflicts took place while the bike box was being used as intended.

In the last few years, a variety of innovative, on-street bicycle treatments have been implemented. These include bike boxes; raised bicycle lanes; bicycle boulevards; use of paint to delineate paths through intersections, define bicycle-motor vehicle weaving areas, and highlight paved shoulders; and others. This report focuses on a bike box, a special pavement marking scheme that was pilot-tested in Eugene, Oregon.

BACKGROUND

"Bike box" is the term that has gained popularity in the United States for a European treatment usually known as the advanced stop bar (Figure 1). The box is a right angle extension to a bike lane (BL) at the head of the intersection. The box allows bicyclists to get to the head of the traffic queue on a red traffic signal indication and then proceed first, before motorized traffic, when the traffic signal changes to green. Such a movement is beneficial to bicyclists and eliminates conflicts when, for example, there are many right-turning motor vehicles next to a right-side BL. Being in the box, and thus at the front of the traffic queue, also tends to make bicyclists more visible to motorists.

In Europe, one or two traffic signals are usually part of the design. Under a single-signal design, one traffic signal is placed at the box. With a two-signal design, used in the United Kingdom, motorists are held by a red signal, while a special green signal directs bicyclists ahead to the box (*1*, *2*). Bike boxes have worked successfully on U.K. roads where up to 1,000 vehicles per hour pass through the intersections. Schemes were monitored at nine intersections (*3*, *4*). Two-thirds or more of the bicyclists used the cycle lane and the reserved waiting area. Signal violations by bicyclists were less than 20 percent. Up to 16 percent of motorists encroached into the BLs. At one intersection, more than half of all lead motorists encroached into the cyclists' reserved waiting area. The single-signal design is likely to be as effective as the two-signal design if a mandatory cycle lane and a distinctly colored road surface in the cyclist areas are used. In Denmark, recessed stop lines for motor vehicles are used to accomplish the same purpose (i.e., no bike box is used, and motor vehicles simply stop farther away from the intersection than do bicycles in a BL). This design has been found to significantly reduce the number of crashes between right-turning motorists and cyclists going straight through the intersection (*5*).

OVERVIEW OF CURRENT PROJECT

A bike box and accompanying traffic signs, but with no special traffic signals to hold motorists or direct bicyclists to the box, were installed on High Street at Seventh Avenue in Eugene, Oregon, in the summer of 1998. The application of the bike box was innovative in the sense that the intent was to give bicyclists a safer way to change from one side of the street to the other at a busy downtown intersection featuring two one-way streets (Figure 2). Before the box, the vast majority of cyclists approached on High Street in the left side BL adjacent to parked motor vehicles. The BL was left side to match with another one-way couplet and in order that creation of a right side BL next to intersections with double right-turn lanes could be avoided. Many of the cyclists approaching in the left side BL preferred to switch to the right side (through) BL on the far side of the intersection because at the next block cyclists in the left side BL had to turn left. Movement from left to right side after the intersection necessitates the crossing of three lanes of traffic. The average annual daily traffic on High Street is approximately 8,500 vehicles per day, and the peak-hour total is about 1,000 motor vehicles. When traffic was busy, bicyclists could have difficulty finding a gap large enough to allow an easy move from left to right. Some bicyclists were aggressive and used hand signals to indicate their movement from left to right. Many, however, simply stopped in the BL and waited for a suitable gap.

In addition to the crossover from left to right after the intersection that has been identified above (Figure 3, Movement 1), there were various other ways bicyclists used to negotiate this intersection.

Some would shift from the BL to the motor vehicle traffic lanes before the intersection (Figure 3, Movement 2). Others rode or walked

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FIGURE 1 European bike box.

their bicycle through the crosswalks on both High Street and Seventh Avenue as pedestrians would, a movement that delays right-turning motorists (Figure 3, Movement 3). While motorists waited for the signal to change, some bicyclists would intentionally disobey the red traffic signal at the intersection proper, move into the intersection, and then shift from left to right (Figure 3, Movement 4).

With the bike box in place, bicyclists desiring to change from the left to the right side of High Street can proceed to the head of the traffic queue on a red traffic signal indication and then cross over to the front of the second lane of traffic. The second lane is a combination through/right turn lane. The rightmost lane is right turn only. Right turn on red is not permitted; however, some motorists do not comply. The box is not meant to be used on a green traffic signal indication.

Bicyclists have the right-of-way when in the box. They are generally able to accelerate quickly through the intersection ahead of motor vehicles when the signal changes to green and then safely switch to the through BL on the right hand side of High Street such that motorists are not inconvenienced.

Several other steps were taken to help bicyclists and motorists understand the use of this innovative treatment at this intersection. A press release was prepared and stories were run in the local newspaper and the University of Oregon student newspaper. A special sign board with information about how to use the bike box was placed on a construction barricade near the intersection pedestrian crosswalk. The barricade with educational sign also had a flashing light attached. Traffic signs with orange diamond attachments added for conspicuity were placed at the intersection to indicate that traffic, except bikes, should stop before the box on a red signal indication ("Stop Here on Red," with "Except Bicycles" mounted below). A yellow diagrammatic sign that read "Bicycles Merging" was already in place.

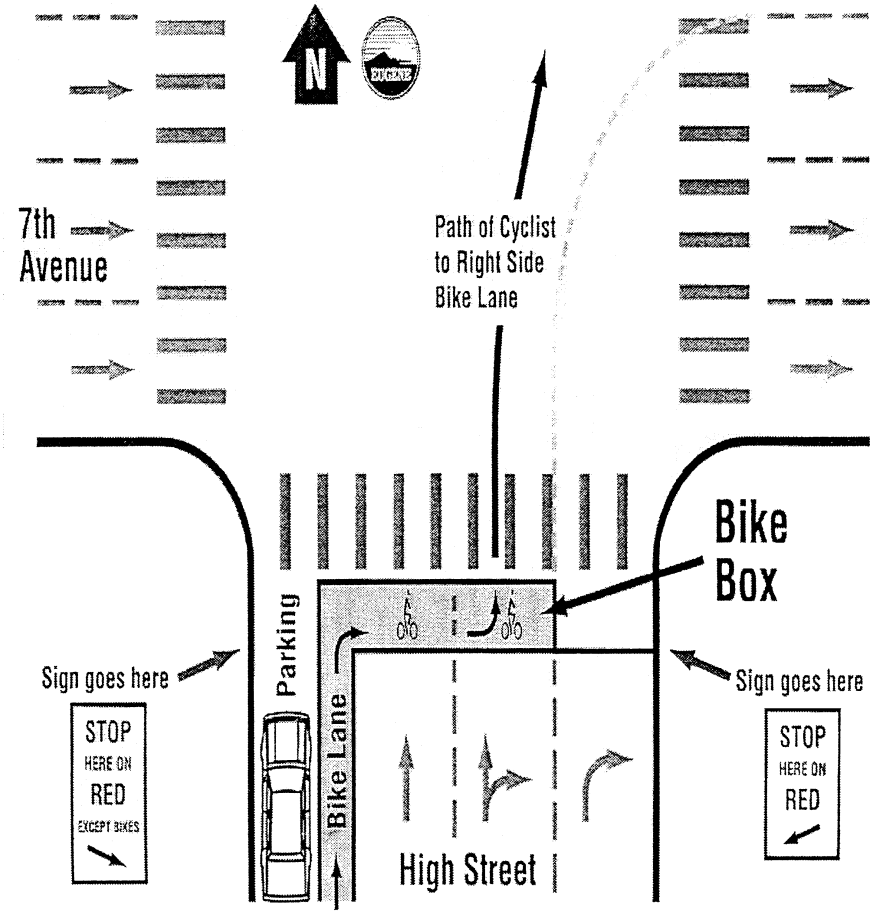

FIGURE 2 Bike box on High Street in Eugene, Oregon.

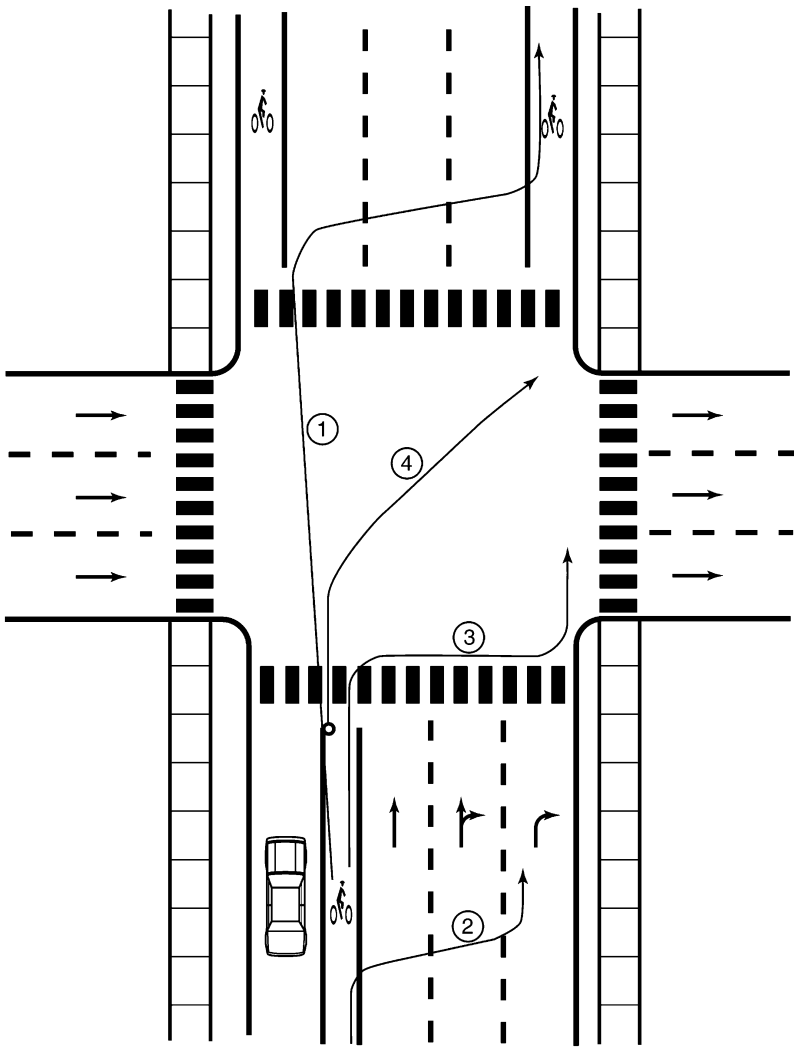

FIGURE 3 Typical bicyclist movements through intersection.

The original configuration of the bike box was relatively short in length, about 1.8 m. A standard bicycle logo was placed in the box in front of both the through lane and through/right lane.

It was determined through observation that the box should be lengthened for the purpose of promoting understanding and visibility by motorists and easier use by bicyclists. This was accomplished by removing about 1 m of the pedestrian crosswalk. The original layout by the paint crew also had traffic lane lines within the box, rather than a large rectangular box in front of two traffic lanes. This was corrected when the box was enlarged, but the result was a box that extended across all three lanes. This was not ascertained until some time later, and the decision was made to leave this configuration in place. Thus, this evaluation pertains to a bike box that extended across all three travel lanes on the street (Figure 4). While the bike box should have been extended in front of only the combination through/right-turn lane, and not in front of the right-turn-only lane, bicyclists tended to use the box correctly anyway (i.e., positioning themselves in front of the combination lane). Thus, the evaluation was not jeopardized. (Note: When the evaluation ended, the bike box was reconfigured to extend across only two traffic lanes.)

METHODS

Cyclists traveling through the intersection were videotaped before and after placement of the box. The videotapes were coded to evaluate operational behaviors and conflicts with motorists, other bicyclists, and pedestrians. Other data concerning bicyclists' characteristics and experience, as well as their opinion of how the bike box functioned, were obtained through short oral surveys. These surveys were performed on days when videotaping was not being done.

RESULTS

Using the methods describe above, this section presents results of the analysis of the data. The sections that follow are descriptive and focus on bicyclist characteristics, information about movements through the intersection and use of the bike box, and conflicts.

Videotaped Bicyclist Characteristics

Several variables describing the videotaped bicyclists are presented. The variables are cross-tabulated by whether the bike box was in

FIGURE 4 Enlarged bike box extending across all three lanes of traffic.

place or not (i.e., before or after the box). Frequencies and column percentages are routinely presented. Totals differ from 747 bicyclists in the before period to 686 bicyclists in the after period, resulting from missing values.

Statistical testing of relationships was done using chi-square tests to determine if differences between before and after periods were significant or due to chance alone. When the distributions were significantly different, asterisks (**) were placed beside the name of the variable, and the level of significance, or *p*-value, is shown with the appropriate number of asterisks at the bottom of the table. As an example, a *p*-value of less than .05 means that the differences in the distributions could be due to chance less than 5 times out of 100.

Generally the tables show all levels of a variable so that more information may be conveyed to the reader; however, categories were grouped when necessary to permit appropriate statistical testing. In the text that follows, a single triangle (▼) is used to indicate a major individual cell chi-square contribution to a significant chi-square value for the overall distribution. Chi-square testing was not performed in cases in which the distributions produced zero cells because of all effects of a variable being directly related to the before or after period (i.e., presence or absence of the bike box).

Table 1 shows that slightly more than 70 percent of the bicyclists observed on the videotapes were male. There were no differences in the distributions before and after placement of the bike box.

TABLE 1 Bicyclist Gender, Before and After Bike Box

Gender	Before Bike Box	After Bike Box	Total
Male	519	504	1023
	(70.8)	(74.0)	(72.4)
Female	214	177	391
	(29.2)	(26.0)	(27.7)
Total	733	681	1414
	(51.8)	(48.2)	(100.0)

NOTE: Numbers in parentheses are percentages of the column totals; numbers in parentheses below the column totals are percentages of the overall total.

Ages of the bicyclists were estimated from observations of the videotapes and categorized into the following groups: under 16 years of age, 16 to 24 years of age, 25 to 64 years of age, and over 64 years of age. Overall, 52 percent of the bicyclists were 16 to 24 years of age, and 47 percent were 25 to 64 years of age (Table 2), and the before-and-after differences were significant. In the before period, 62 percent of the bicyclists were ages 16 to 24, versus 41 percent in the after period (▼). Conversely, 37 percent of the bicyclists were ages 25 to 64 in the before period, versus 57 percent in the after period (▼). To some extent this was probably a function of when the videotaping was done. The before data were obtained throughout the entire month of April 1998, when the University of Oregon was in session and many students were bicycling on High Street. The bike box was then installed in July 1998. The after data were collected over a longer period, from August through December of 1998. Students were much less prominent in the December data because the semester had ended. At this point, there were more commuter bicyclists using the intersection. In addition, the identification and placement of bicyclists into age groups breaking at 25 years was quite difficult, especially as the weather turned colder and the bicyclists wore more clothing.

Observed helmet use was 46 percent and did not differ before or after the bike box. None of the riders carried passengers in either period.

Characteristics of Surveyed Bicyclists

In addition to the videotapes, data concerning bicyclists' characteristics were obtained through short oral surveys administered near the intersection soon after the bike box had been installed. While these surveys provided additional data about the bicyclists using the intersection, the surveys were done mainly to see how well bicyclists thought the bike box was being understood. Results from the oral survey include the following:

- 67 percent of the bicyclists were male.
- The age distribution was 1 percent under age 16, 43 percent ages 16 to 24, 55 percent ages 25 to 64, and 2 percent over age 64. This distribution was similar to the distribution for the bicyclists who were videotaped using the intersection after the bike box was installed.

TABLE 2 Bicyclist Age, Before and After Bike Box

Age*	Before Bike Box	After Bike Box	Total
< 16	5	7	12
	(0.7)	(1.1)	(0.9)
16-24	428	270	698
	(62.1)	(40.9)	(51.7)
25-64	254	376	630
	(36.9)	(56.9)	(46.7)
> 64	2	8	10
	(0.3)	(1.2)	(0.7)
Total	689	661	1350
	(51.0)	(49.0)	(100.0)

NOTE: Numbers in parentheses are percentages of the column totals; numbers in parentheses below the column totals are percentages of the overall total.
* $p < .001$

- Helmet use was 38 percent.
- 56 percent considered themselves to be experienced bicyclists. Experienced was defined as the following: "I feel comfortable riding under most traffic conditions, including major streets with busy traffic and higher speeds."
- Just over half rode more than 25 mi (40 km) per week.
- Although 39 percent correctly indicated that the purpose of the bike box was to enable bicyclists to more easily get from the left to the right side of the street (and another 1 percent said the box was there to get bicycles to the front of traffic), another 59 percent were not sure of the purpose. This prompted the educational sign shown earlier.
- 31 percent said they had used the box.
- 35 percent said the box was large enough.
- About half of those using the box said they had encountered difficulties. Typical complaints were that motor vehicles were in the box, that drivers wanted bicycles out of the way so they could ignore the no-turn-on-red signs, and that it was uncomfortable going out in front of cars.
- 35 percent offered suggestions for improving the bike box. Typical comments were that delineation or signage should be more prominent so that cars would stay out of the box, that the box needed to be bigger and more visible, that the box should be painted, and that drivers needed more education about the box.

Maneuvers Through the Intersection and Use of the Bike Box

Table 3 shows the bicyclist maneuvers through the intersection before and after the placement of the box. Before the box was in place, 53 percent of the bicyclists approached in the left side BL, went straight through the intersection, and then crossed from left to right after the intersection. This movement was reduced to 35 percent after the installation of the bike box (Figure 5). Four percent went left to right prior to the intersection in the before period, compared with 8 percent after. Four percent went left to right in the crosswalk both before and after. Some 26 to 28 percent of riders stayed on the left side of the street before and after, such that the bike box was of no use to them. About 6 to 7 percent approached from the right side of the street on the sidewalk both before and after, while another 3 to 5 percent approached from the right side of the street in the traffic lanes. The vast majority of the "other" category involved bicyclists shifting from the left side BL to the through-traffic lane prior to the intersection and then crossing the other two traffic lanes after the intersection. Of all the bicyclists coming through the intersection in the after period, 11 percent used the bike box as intended (i.e., approaching from the left-side BL and then moving in front of traffic and into the box on a red traffic signal).

TABLE 3 Bicyclist Maneuvers Through Intersection, Before and After Bike Box

Maneuver	Before Bike Box	After Bike Box	Total
Left to right before the intersection*	31 (4.2)	55 (8.0)	86 (6.0)
Left to right after the intersection	392 (52.6)	238 (34.7)	630 (44.1)
Left to right in pedestrian crosswalk	34 (4.6)	30 (4.4)	64 (4.5)
Used bike box after approaching from left side bike lane	0 (0.0)	74 (10.8)	74 (5.2)
Stayed on left side of street	197 (26.4)	192 (28.0)	389 (27.2)
Approached on right side of street in the traffic lane*	25 (3.4)	35 (5.1)	60 (4.2)
Approached on right side of street in the sidewalk*	48 (6.4)	46 (6.7)	94 (6.6)
Other	18 (2.4)	15 (2.2)	33 (2.3)
Total	745 (52.1)	685 (47.9)	1430 (100.0)

NOTE: Numbers in parentheses are percentages of column totals; numbers in parentheses below the column totals are percentages of the overall total.
*Some bicyclists used the bike box from these non-standard approach maneuvers.

Bicyclists sometimes used the bike box in nonstandard ways, such as (*a*) moving from left to right prior to the intersection and then maneuvering into the box, (*b*) approaching from the right side of High Street and then moving forward into the box, or (*c*) even approaching from the right sidewalk and then moving into the box. An additional 5 percent of the bicyclists used the box in these three nonstandard ways. When these are added to the standard bike box users, 16 percent of all bicyclists coming through the intersection used the box. Eliminating the bicyclists who stayed on the left side of the street (and thus had no need for a bike box to help them cross over to the right side of the street), 29 percent of the bicyclists who went through the intersection used the bike box.

The bike box was targeted for bicyclists who approached in the left side BL and then crossed to the right side of the street. Use of the box by this group in the after period amounted to 22 percent.

Another 105 bicyclists (or 15 percent of the total in the after period) who made the left-to-right shift could have used the box but chose not to. Had all of these bicyclists used the box, the use rate would have been 52 percent of the targeted group, perhaps approaching the practical upper limit for this situation. However, for 38 of these 105 bicyclists (36 percent), a motor vehicle was encroaching into the box from either the far left through lane or middle combination lane on High Street. The extent to which this affected use of the bike box is unknown, but it is logical to assume that motor vehicle encroachment diminishes use.

Motor Vehicle Encroachments

A separate set of motor vehicle data pertaining to encroachment into the bike box on a red traffic signal was gathered on 3 days in December 1998, some 5 months after the box had been installed. Times of data collection were varied and included midday, early afternoon, and late afternoon. The camera was positioned at a right angle to the side of the intersection such that motor vehicles would be unaware of videotaping. Encroachments on a red traffic signal indication were coded as minor (up to one-fourth of a motor vehicle in the bike box), moderate (one-fourth to one-half of a motor vehicle in the box), and severe (over one-half of a motor vehicle in the box). Results were the following:

Level of Encroachment	*n*	*%*
No encroachments	97	48.0
No encroachments	97	48.0
Minor encroachments	41	20.3
Moderate encroachments	32	15.8
Severe encroachments	32	15.8
Total	202	100.0

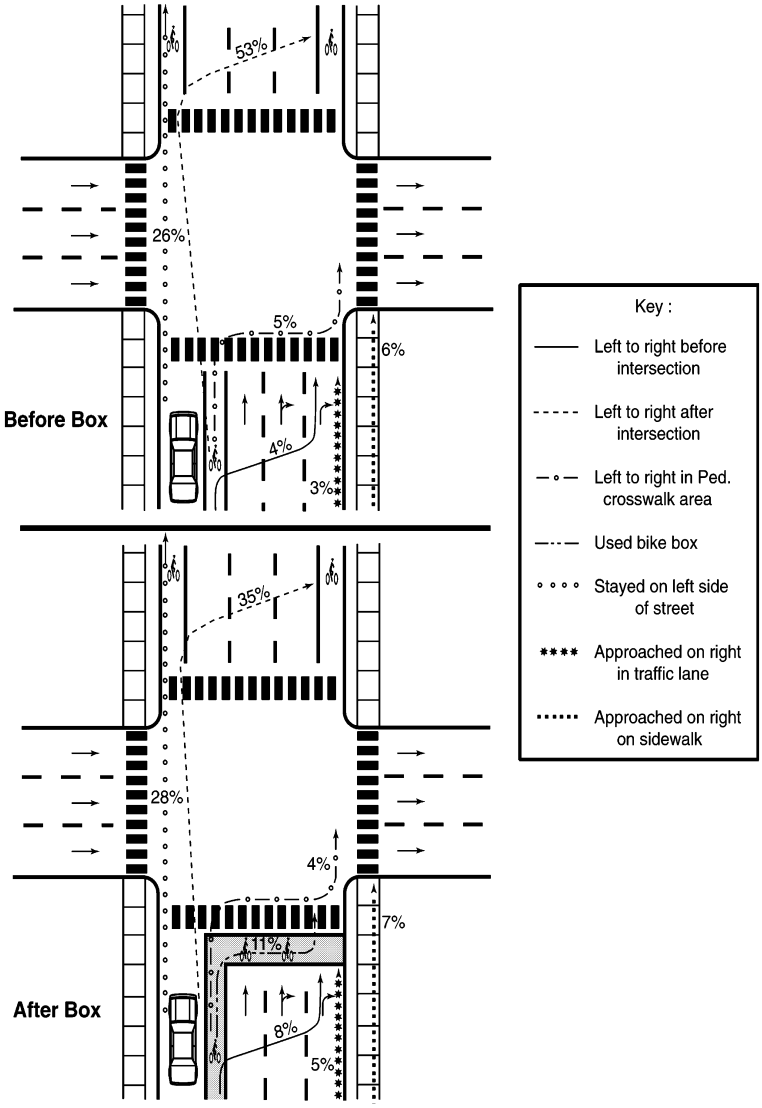

FIGURE 5 Bicyclist maneuvers through the intersection before the installation of the bike box (*upper*) and after the installation of the bike box (*lower*).

There was some variability across the three time periods. It appeared that severe encroachments were somewhat related to the amount of traffic volume. During heavier traffic, vehicles near the end of the signal cycle that were unable to get through the signal tended to encroach well into the box.

Totaling of all three data collection periods (202 total signal cycles) shows that vehicles were encroaching into the box in slightly more than half of the signal cycles. Sixteen percent of the encroachments were severe, meaning more than half of the vehicle was in the box. These percentages are similar to those reported earlier in the United Kingdom.

Signal Violations

Bicyclist signal violations were coded in the before and after periods (Table 4). Overall, no signal violations occurred 88 percent of the time a bicyclist approached the intersection. In the before period, bicyclists would occasionally run the red signal to make the move from right to left across the intersection. It was thought that having the box in place might reduce the frequency with which bicyclists either (*a*) ran the red signal indication, or (*b*) anticipated the signal change and started moving forward shortly before the red signal changed to green to get ahead of traffic and cross to the right side of the street. However, this was not the case. There were no differences in the before and after distributions.

Conflicts

A conflict between a bicycle and a motor vehicle or another bicycle was defined as an interaction such that at least one of the parties had to make a sudden change in speed or direction in order to avoid the other. Conflicts were infrequent, and there were no differences in the before and after distributions (Table 5). Conflict rates were quite similar—1.3 per 100 entering bicyclists before, and 1.5 after. One of the 10 conflicts in the before period was a bike–bike conflict, while all other conflicts in both periods were bike–motor vehicle conflicts.

TABLE 4 Bicyclist Traffic Signal Violations, Before and After Bike Box

Signal Violations	Before Bike Box	After Bike Box	Total
None	658 (88.3)	595 (87.1)	1253 (87.8)
Ran the red signal	47 (6.3)	49 (7.2)	96 (6.7)
Red signal at start up	40 (5.4)	39 (5.7)	79 (5.5)
Total	745 (52.2)	683 (47.8)	1428 (100.0)

NOTE: Numbers in parentheses are percentages of the column totals; numbers in parentheses below the column totals are percentages of the overall total.

In addition, one of the 10 before conflicts was coded as serious, while all other before and after conflicts were coded as minor.

The location of the conflict was also coded. In the before period, two conflicts occurred within the intersection proper (one while bicyclists were crossing from left to right in the crosswalk and one while bicyclists were approaching from the right in the road) and eight after the intersection. The eight conflicts after the intersection involved the bicyclist crossing from left side to right side BL. In the after period, two occurred before the box, six within the intersection proper, and two after the intersection. No conflicts occurred while bicyclists were using the bike box as intended (i.e., approaching from left side BL and then moving into the box). It appeared that the bicyclists were able to gauge the timing of the signal quite well. One conflict in the after period occurred when a bicyclist was crossing from left to right in the crosswalk and the signal changed from red to green. Three of the after period conflicts resulted from bicyclists approaching from the sidewalk on the right hand side of the street, continuing straight ahead, and then crossing in the Seventh Avenue pedestrian crosswalk. This placed the bicyclist in a position where he or she was difficult to be seen by motor vehicles making a right turn, particularly motor vehicles turning right from the combination through/right lane in the middle (Figure 6).

FIGURE 6 Conflict when bicyclist comes off right sidewalk and onto street.

DISCUSSION OF RESULTS

The use of a bike box to facilitate the movement of bicyclists from a left side BL, through an intersection, and across several lanes of a one-way street to a right side BL was an innovative approach. During periods of busy traffic, movement from the left to the right side of the roadway after the intersection can be difficult for bicyclists to negotiate. The use of the box is so recent in the United States that at present no official design standards are in place. Thus, this pilot effort was a valuable learning experience in many ways.

The data indicated that the use of the box was reasonably good. Usage can be examined in the following ways:

- For all bicyclists coming through this intersection, 11 percent used the box as intended (i.e., approaching from the left side BL and then moving into the box on a red traffic signal indication).
- Including bicyclists who used the box through other maneuvers, such as crossing from left to right before the intersection and then moving into the box, 16 percent of all bicyclists used the box.
- Of the bicyclists who approached in the left side BL and then crossed to the right side of the street (the bicyclists for whom the box was most intended), 22 percent used the box.
- Many more bicyclists in this target group could have used the box (i.e., they had a red signal indication and enough time to move into the box). Had these bicyclists done so, then some 52 percent would have used the box. This last percentage thus approximates the upper limit of bike box use for this pilot location and left-to-right maneuver during this time period.

TABLE 5 Conflicts, Before and After Bike Box

Conflict Occurrence	Before Bike Box	After Bike Box	Total
No	737 (98.7)	676 (98.5)	1413 (98.6)
Yes	10 (1.3)	10 (1.5)	20 (1.4)
Total	747 (52.1)	686 (47.9)	1433 (100.0)

NOTE: Numbers in parentheses are percentages of the column totals; numbers in parentheses below the column totals are percentages of the overall total.

A problem with motor vehicle encroachments into the box likely diminished the amount of use. Overall, encroachments occurred in 52 percent of the red traffic signal indications after the box had been in place for 5 months. While this is not uncommon even in Europe where the design has been in place for some time, it is troubling, and remedies should be sought. Bicyclists surveyed about the pilot location tended to frequently complain about the encroachment problem.

The bike box had no effect on signal violations. Some 6 to 7 percent of bicyclists violated a red signal indication both before and after placement of the box.

The rate of conflicts between bicycles and motor vehicles changed little in the before and after periods. The rate was 1.3 conflicts per 100 entering bicyclists before the bike box and 1.5 conflicts per 100 entering bicyclists after. However, the pattern of the conflicts did change. Eight of the 10 conflicts in the before period involved a bicyclist

moving from left to right across the travel lanes after the intersection. Two of the 10 conflicts in the after period were of this type. Six after conflicts took place within the intersection proper, but three of these involved bicyclists coming off the right sidewalk and conflicting with right-turning motor vehicles. No conflicts took place while bicyclists were using the bike box in the normal sense.

CONCLUSIONS AND RECOMMENDATIONS

Use of the bike box to help bicyclists negotiate a difficult maneuver at this intersection was considered to be a rigorous test. All things considered, the innovative treatment worked reasonably well. More evaluations should be conducted in other settings and for other maneuvers so that how well this design works in the United States and how it might be improved might be further understood. For upcoming evaluations, a number of recommendations can be made.

- Education of both bicyclists and drivers as to the proper use of the box is important. This can be accomplished through newspaper stories, radio and television public service announcements, brochures in bike shops, and so forth. The education sign posted at the Eugene intersection came about after the oral survey of bicyclists revealed that the box was not well understood. One of the bicyclists participating in the oral survey suggested use of a banner across the roadway. This would be an excellent way of drawing attention to the presence of the box and the expected movements, especially for motorists.
- Use of bold demarcation of the box is vital. This could involve wider striping than the norm or perhaps painting the box a bright color.
- Steps should be taken to limit motor vehicle encroachment. Setting stop bars back a short distance from the box might lessen encroachment. Offset (or staggered) stop bars would also be beneficial, not only for encroachment purposes but also to help motorists see bicyclists moving into the box. Some police presence may also be necessary to instruct, warn, or ticket motorists about improper encroachment.

In summary, the bike box is a promising tool to help bicyclists and motorists avoid conflicts in certain kinds of intersection movements. More boxes need to be installed and evaluated so that their effectiveness in different settings may be further understood. Pilot testing the Danish treatment of recessed stop bars for motor vehicles is also recommended.

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