Evaluation of Lane Reduction “Road Diet” Measures in China

Jingbo Huang1, Jun Ma1*, Duo Chen1, Yongqiang Zhao1 and Chun Gao1

1School of Traffic Management, People’s Public Security University of China, Beijing, 100038, China

*Corresponding author’s e-mail: huangjingbo1995@126.com

Abstract. Road diet measures are widely used abroad, but they have not been implemented in China. One of the important reasons is that we usually think that the reduction of the number of lanes will cause traffic congestion. In order to evaluate the impact of lane reduction “road diet” measures, we implemented road diet reform measures in Shoushan Road to Longxing Road section of Xinghai North Street, Xingcheng City. After nearly one year of adaptation, we evaluate the implementation plan from three aspects in this study: safety, operation, and subjective feeling. Then design a questionnaire to investigate the subjective feelings of drivers, bicyclists and pedestrians on road diet measures. The questionnaire data shows that 56% of drivers has been illegally occupying the non-motorized road or central yellow line area, the main reason is that the speed of the vehicle ahead is too slow and there is no illegal capture equipment. More than 70% of bicyclists believe that their number of rides has increased. More than 90% of pedestrians think it is easier to cross the street, and they used to stay in the central yellow line area. Using VISSIM and SSAM to evaluate the traffic operation and safety aspects before and after the road reform, the results show that after the reform, the average speed decreases by about 5km/h, the travel time for left turn on the road segment generally increases, and the number of conflict points decreases by about 33%.

1. Introduction

At present, there are a large number of urban two-way four-lane road sections with high roadside land development intensity, large traffic volume, large density of entrances and exits, and tight road use. Due to the limitations of existing conditions, the traffic pressure of these roads has not been alleviated by widening roads and increasing lanes. However, the concept of road diet has been fully practiced abroad, which can improve traffic safety without significantly reducing traffic capacity[1].

There are some researches on road diet, mostly focused on case studies, which compare the operational effects before and after road diet reform[2-4], and some using simulation software to study the impact of road diet reform[5-7]. Foreign research on road diet started earlier. In the 1950s and 1960s, there were some similar researches[8]. The road was designed to solve the problems of excess capacity of many two-way four-lane roads. The earliest road diet reconstruction project was recorded in 1979. In the road diet project at 17th West Street in Billings, Montana, USA, the results showed that after the road was slimmed down, the number of conflicts was reduced and no significant traffic delays were caused[9]. Recently, the US Federal Highway Administration has released the Road Diet Information Guide and adopted road diet as a two-way four-lane cross-section modification with a focus on safety. However, there were few related researches in China, most of which just introduced the concept of road diet.

In order to study the applicability of road diet in China, we had implemented a road diet transformation in Xinghai North Street, Xingcheng City. The section of Shoushan Road to Longxing...
Road in Xinghai North Street of Xingcheng City was selected as the experimental section, and the road traffic before and after the transformation were compared from three aspects of safety, operation and subjective feeling.

2. Case introduction

With the development of social economy, inevitably, the rapid growth of the number of vehicles will bring about increasingly serious traffic problems. Xinghai North Street is the main road of Xingcheng City. The road of Xinghai North Street is not wide enough, and the cross-section design is not reasonable. There are a large number of government units, commercial and residential quarters on both sides of the two streets, and there are also many entrances and exits. Because the direct traffic volume is large and left-turning vehicles will affect direct traffic, we design central directional left turn lane to reduce the impact of left-turning vehicles on direct vehicles. And the left turn of the vehicle has to cross two lanes, and there are fewer opportunities to pass through during peak hours. The disorder is not only unsafe, but also causes serious traffic congestion. In addition, the non-motorized road is narrow, resulting in a serious mixed phenomenon, and bicyclists are in an unsafe travel environment.

The left side of figure 1 is the current situation of traffic organization, which the non-motorized road is only two meters wide. But the right side of figure 1 is a more flexible cross-section design, which the width of the non-motorized road is in compliance with the standard and the left-turning vehicle enters a safe waiting area, which is safe and does not affect the normal traffic of the direct vehicle.

![Figure 1. Comparison of traffic organization schemes before and after renovation](image)

The project team did not conduct tests on the whole road. Only the section from Shoushan Road to Longxing Road of Xinghai North Street was used for the test. If the test results are good, the plan will be carried out on the whole road. The current road sections are shown in the following figures.

![Figure 2. Aerial photo of the current status of Shoushan Road to Liming Road in Xinghai North Street](image)

![Figure 3. Aerial photo of the current status of Liming Road to Youyi Road in Xinghai North Street](image)
3. Application evaluation

In July 2018, the project implemented a three-lane traffic organization plan from Shoushan Road to Longxing Road in Xinghai North Street, Xingcheng City. And we conducted the field research on June 11, 2019. Then we distributed 270 questionnaires to drivers, bicyclists and pedestrians to investigate the subjective feelings of traffic participants on the three-lane traffic organization. At the same time, the DJI Mavic2Pro model drone was used to video recording the peak period of the experimental group, then the problems existing in the current design were analyzed. Then the parameters of the VISSIM simulation modeling were adjusted by the data obtained from the survey, and the sections before and after the transformation were evaluated.

3.1. Subjective feelings

The driver's questionnaire was issued near the experimental section of Xinghai North Street. The local traffic police department was contacted to intercept the vehicle, then we ask these drivers some questions. A total of 151 driver questionnaires were collected. The characteristics of 151 drivers were showed in the following table.

| Characteristic   | N  | %   |
|------------------|----|-----|
| gender           |    |     |
| Male             | 111| 73.5|
| Female           | 40 | 26.5|
| Age              |    |     |
| 30               | 24 | 15.9|
| 31-40            | 67 | 44.4|
| 41-50            | 43 | 28.5|
| 50-               | 17 | 11.2|
| Travel time      |    |     |
| The peak-hour    | 86 | 57.0|
| The other time   | 65 | 43.0|

The essence of this experimental section is two-way two-lane, which has a centrally-oriented left-turn opening near the entrance and exit of the road section, while yellow lines are drawn in the center of other areas. It is observed that some vehicles occupy the central yellow line area for overtaking, turning left and so on. The questionnaire specifically designed the problem to investigate this phenomenon, and 56% of the drivers reported that they occupied the central yellow line area on the experimental section. The reason for occupying the central yellow line area is as shown in the figure 5.
Figure 5. The reason for occupying the central yellow line area

55.6% of the drivers agree that the slow vehicle ahead is one of the reasons why drivers occupy the central yellow line area, indicating that many drivers use the central yellow line area for overtaking; 43% of drivers think that no illegal capture equipment has contributed it; and 36.4% of the drivers thought that the waste of the central road resources was one of the reasons. According to the analysis, the driver lacked the understanding of the central yellow line area and there was no illegal capture equipment. Another 22.5% of drivers believe that vehicles are lined up too long, and 11.3% of drivers believe that occupying the central yellow line area does not affect traffic safety.

Due to the large number of entrances and exits in the experimental section of Xinghai North Street, the left-turning vehicles will affect the direct vehicles when they turn left in the middle of the road section. We wonder whether it is convenient for the left-turning vehicles. According to the survey, 67% of drivers think it is more convenient to enter and exit, and 66% of drivers think that it is more convenient to turn left.

The bicyclist questionnaires were also distributed on the experimental section of Xinghai North Street, and 52 samples were investigated. The characteristics of 52 bicyclists were showed in the table below.

| Characteristic          | N   | %    |
|-------------------------|-----|------|
| **gender**              |     |      |
| Male                    | 39  | 75.0 |
| Female                  | 13  | 25.0 |
| **Age**                 |     |      |
| -30                     | 10  | 19.2 |
| 31-40                   | 11  | 21.2 |
| 41-50                   | 8   | 15.4 |
| 50-                     | 23  | 44.2 |
| **Travel time**         |     |      |
| The peak-hour           | 25  | 48.1 |
| The other time          | 27  | 51.9 |

Bicyclists generally responded well, and after the non-motorized road were widened, 73% of bicyclists said their travels increased. For the number of vehicle lanes occupied by bicycles, 67% of bicyclists reported that the number of vehicle lanes occupied by bicycles was reduced. For the number of non-motorized road occupied by vehicles, 44% of bicyclists think that the number of non-motorized
road occupied by vehicles is reduced. 87% of the respondents believe that the width of the non-motorized road is sufficient, and 79% think that the ride is safe now. In general, the response is positive and positive.

We surveyed 67 pedestrians, and their characteristics were showed in the table below.

| Characteristic | N | % |
|---------------|---|---|
| gender        |   |   |
| Male          | 32| 47.8 |
| Female        | 35| 52.2 |
| Age           |   |   |
| 30            | 29| 43.3 |
| 31-40         | 16| 23.9 |
| 41-50         | 12| 17.9 |
| 50-           | 10| 14.9 |
| Travel time   |   |   |
| The peak-hour | 26| 38.8 |
| The other time| 41| 61.2 |

According to the survey, 88% of pedestrians believe that crossing the street is safer. 69% of pedestrians will choose to stay in the central yellow line area when crossing the street. 93% of pedestrians will think it is easier to cross the street. In conclusion, pedestrians are positive feedback on this retrofit plan, and we can set up a street-resident island in some yellow line areas to allow pedestrians to cross the street.

3.2. Video analysis

By collecting the drone video, we found that the road traffic is running smoothly, but there were some vehicles occupying the non-motorized road or the central yellow line area. The vehicle trajectory analysis found that the vehicle occupied the central yellow line for the following reasons:

Two-way two-lane does not allow direct vehicles to overtake. We took a 15-minute peak video of three experimental sections and found that 16 cars occupy the central yellow line area for overtaking. The front car speed of such vehicles is counted as follows, and most vehicles are found to be below 30km/h. The average speed is 22.2km/h. If there is only one direct vehicle lane in one direction and no overtaking lane in the center, it is easy to cause illegal overtaking behavior.

| Sequence numbers | speed (km/h) |
|------------------|--------------|
| 1                | 27.1         |
| 2                | 20.1         |
| 3                | 23.7         |
| 4                | 28.3         |
| 5                | 16.1         |
| 6                | 22.5         |
| 7                | 17.2         |
| 8                | 28.5         |

Direct lined up too long, causing left-turning vehicles to illegally occupy the central yellow line area to enter the left-turning lane. We took a 15-minute peak video of three experimental sections and found that 10 cars occupied the central yellow line to enter the left-turning lane. We found that part of the central yellow line area in front of the intersection is a waste.

Turning left from the entrance and exiting of the road section need temporarily occupy the central yellow line area. The video was found to have 15 cars occupying the central yellow line area from the section access port within 15 minutes. The central yellow line area of such section did not fully consider the traffic demand of the entrance and exit, and needs to be improved in the future.
3.3. Simulation evaluation

The experimental section of the simulation is shown below. Use VISSIM to evaluate the road before and after improvement, and select the travel time and average speed as the evaluation indicators. The travel time is shown in the following table.

![Figure 6. Simulation process](image)

| Turn left into the access port | Turn left to exit the access | Turn right into the access port |
|-------------------------------|-----------------------------|-------------------------------|
| Status quo                   | After transforming          | Status quo                   | After transforming  |
| 12.7                         | 17.4                        | 2.7                          | 2.8  |
| 20.8                         | 15.3                        | 5.9                          | 2.3  |
| 9.4                          | 24.1                        | 2.5                          | 13   |
| 7.6                          | 26.9                        | 4.3                          | 5.2  |

As shown in the table, after the transformation, the travel time of the left turn into or exit the access port is mostly increased, and the travel time of the right turn into or exit the access port remains almost unchanged.

The average speed of cars decreased from 50km/h to 45km/h, and the average speed of buses decreased from 37.4km/h to 31.7km/h. Overall, traffic efficiency has declined after road diet reform, but it is not very obvious.

Using SSAM to evaluate the road safety, the distribution of conflict points before and after the transformation is shown in the following figure. The number of conflict points before the transformation is 218, and the number of conflict points after the transformation is reduced to 145. The number of conflict points decreases by about 33%.

![Figure 7. Conflict point distribution before the transformation](image)

![Figure 8. Conflict point distribution after the transformation](image)
4. Conclusion
The lane reduction “road diet” measures can bring great benefit, though it may cause some problems in China. The traffic management department needs to fully consider the traffic volume, travel demand and people's feelings before the road cross-section reconstruction. In general, the speed of the vehicle after the transformation is reduced. The traffic operation efficiency has not been significantly reduced, but the traffic safety level has improved significantly. The overall evaluation of this program should be positive. However, the experimental section of Xinghai North Street in Xingcheng City has problems such as illegally occupying the non-motorized road or the central yellow line area. Illegally overtaking behavior is the drawback of a single direct lane. In the future, we need to add a passing lane or expand the left-turning lane. In addition, it is necessary to consider the addition of illegal capture equipment. For some existing central yellow line areas, measures such as adding guardrails or setting up pedestrian islands may also be considered.

References
[1] Knapp K, Chandler B, Atkinson J, et al.e. (2014) Road Diet Informational Guide. Federal Highway Administration. Washington DC.
[2] Welch, T. (1999) The Conversion of Four-Lane Undivided Urban Roadways to Three-Lane Facilities. Institute of Transportation Engineers Urban Street Symposium. Dallas.
[3] Huang, H., Stewart, J., and Zegeer, C. (2002) Evaluation of Lane Reduction ‘RoadDiet’ Measures on Crashes and Injuries. Transportation Research Record, 1784: 80–90.
[4] Squires CA, Parsonson PS. (1989) Accident comparison of raised median and two-Way left-turn lane median treatments. Transportation Research Board, No. 1239: 30–40.
[5] Robert B. Noland, Dong Gao, Eric J. Gonzales, Charles Brown. (2015) Costs and benefits of a road diet conversion. Case Studies on Transport Policy. 83: 5-6.
[6] MaWanjing, LiLi, WuZhizhou. (2014) Investigation of the performance of two-way left-turn lane on roads with staggered intersections. Canadian Journal of Civil Engineering, 41(12): 1005-1018(14).
[7] Lyon C, Persaud B, Lefler N, Carter D, Eccles KA. (2008) Safety evaluation of installing center two-Way left-turn lanes on two-lane roads. Journal of the Transportation Research Board, Transportation Research Board of the National Academies, No. 2075: 34–41.
[8] Nemeth, Z.A. (1978) Two-Way Left-Turn Lanes: State-of-the-Art Overview and Implementation Guide. Transportation Research Record 681: 62-69.
[9] Harwood D W. (1986) Multilane Design Alternatives for Improving Suburban Highways. Transportation Research Board. Washington DC.