ANALYSIS OF A ROAD DIET CONVERSION AND ALTERNATIVE TRAFFIC CONTROLS

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Abstract. Safety is a prime concern of transportation engineers and safety specialists in the United States. Traffic volumes have increased tremendously over the past years. Accommodating the increased demand while improving traffic safety, has led transportation officials to utilize various lane configurations and intersection controls to operate the transportation system more efficiently and safely. The primary focus of this research is to evaluate the benefits of the Road Diet concept and the operational performance of alternative intersection controls at a site in University Place, Washington. The intersection controls studied are two-way stop control, a roundabout and traffic signals. The operation of the roadways at the intersection was videotaped and the traffic flow data collected was extracted from these tapes and analyzed using SIDRA software. The software produces many Measures Of Effectiveness (MOEs) of which six were chosen in this project for evaluating the performance of the roadways and the intersection controls. All the MOEs were statistically compared to determine which roadway configuration and intersection control performed better. For the evaluation of the operational performance of the intersection controls studied, the actual traffic volumes were incremented by 25% and 50% and the MOEs from the SIDRA output for the three intersection controls were compared for the original and the incremented volumes. This research concludes that three-lane roadway configuration can be adopted as a viable, safer alternative to the problematic undivided four-lane roadway configurations and a single-lane modern roundabout would have been the best form of intersection control at the intersection studied.

INTRODUCTION

Roadway safety is a prime concern of transportation engineers and safety specialists in the United States. Traffic volumes have increased tremendously over the past years. Accommodating the increased demand while improving traffic safety, has led transportation officials to utilize various traffic control practices. The main point of using different lane configurations and intersection controls is to operate the transportation system more efficiently and safely.

There are numerous four-lane, undivided roadways in the urban areas of the United States and some of these roadways are operating “at unacceptable levels of service and safety due to changes in volumes, traffic flow characteristics, and/or the corridor environment.” [1] Transportation engineers and safety specialists are now facing an increased challenge of improving the safety of these four-lane, undivided roadways.

Earlier “improvements to the cross-section of an urban, four-lane undivided roadway are often limited to alternatives that increase its existing curb-to-curb width”, but recently many traffic
engineers believe that the “Road Diet” concept, or conversion of four-lane, undivided roadways to a three-lane cross-section (one travel lane in each direction with a Two Way Left Turn Lane (TWLTL) in the center, can be considered a viable mitigation measure to enhance the safety and operation of these roadways. It is believed that the Road Diet concept would “have lower overall impacts than a widening option, and produce acceptable operational and improved safety results.” [1]

The term “Road Diet” is a new term used to mean a reduction in the number of travel lanes, usually from four to three.

OBJECTIVES

As mentioned earlier, since there is a problem with some of the four-lane undivided configurations, by adopting the three-lane configuration these problems can be alleviated partially or completely. Also no comparison has been made between the lane reduction concept, a roundabout and traffic signals as to which alternative would be best. This leads to the objective of this research. The two objectives of this research are:
1. To evaluate the benefits or disbenefits of the Road Diet concept at an intersection site in University Place, Washington.
2. To see if a roundabout or a signal would have been better than the “Road Diet” concept at the intersection studied.

LITERATURE REVIEW

Conversion of Four-lane to Three-lane configurations

There has been very little research done on the conversion of four-lane, undivided roadways to three-lane roadways with a center Two-Way Left Turn Lane (TWLTL) plus bike lanes on either side. Much of the research has been on the operational effects and benefits of TWLTLs. In a paper by Knapp and Welch, [1] they presented the benefits of conversion of a four-lane, undivided roadway to a three-lane roadway with a center TWLTL and presented examples of locations where successful conversions took place. These are summarized as follows [1]:

Successful conversions have taken place in Montana, Minnesota, Iowa, California and Washington. From these conversions many benefits were achieved. In Minnesota, the conversion indicated no significant increase in delay and also a significant decrease in vehicle collisions. The conversion resulted in a general reduction of congestion and vehicle speed, and improvement of safety. In Iowa the traffic flow and safety were increased. In California there was a 17% reduction of collisions due to conversions. In Washington, the total collision rate decreased by approximately 34%.

Knapp and Welch (1999) documented examples where successful conversions have taken place on roadways with Average Daily Traffic (ADT) ranges of 20,000 to 24,000 vehicles [1]. In a
study conducted by Walton and Randy, [3] they suggested that conversions to three-lane roadway configurations work well for an ADT range of 5,000 to 12,000 vehicles.

In a study conducted by Nemeth (1970), he concluded that conversion of a four-lane roadway to a three-lane roadway improved the access function of the roadway at the expense of vehicular movement because the lane reduction increased delay. He also observed that the running speeds and conflicts did not change drastically but found that vehicle braking and weaving reduced significantly after the conversion. [4]

Harwood suggested that “in some situations, with high, left turn volumes and relatively low through volumes, restriping of a four-lane undivided (4U) facility as a [three-lane] facility may promote safety without sacrificing operational efficiency.” [5]

Dan Burden and Peter Lagerway in their report “Road Diet- Fixing the Big Roads” have documented various examples where four-lane configurations have been converted to three lane configurations and are operating successfully. [9]

Hummer and Lewis of North Carolina State University produced a report that made safety comparisons of three-lane and four-lane undivided roadways. Safety data from their report indicates that the three-lane undivided roadway configurations had lower crash rates than four-lane undivided roadway configurations in the medium and high-density residential and commercial land use areas. In addition they found that, unlike the two-lane and four-lane undivided roadways, the crash rates of the three-lane roadways did not seem to increase with development density. [2]

**Bicycle and Pedestrian Safety Issues**

Four-lane roadways often tend to generate excessive speeds. As stated by Dan Burden [9]:

>“These roadways also erode the ability for transit, walking and bicycling to succeed. Pedestrians have rugged times finding gaps across four lanes. Crash rates and severity of conflicts with autos result in almost certain death (83% of pedestrians hit at 40 mph die). Many bicyclists find four-lane roads too narrow to ride comfortably”

The motorists traversing on the four-lane roadway configurations have an extra lane in their direction of travel and tend to change lanes, overtake other vehicles and travel faster than they should.

With the increased speeds the risk of conflicts also increases during the peak hours. If there are many access points on either side of the roadways, then during rush hours the through vehicles may crash into the vehicles which have slowed down to make left turns and exit the roadway. With the inclusion of separate lanes for the bicyclists, there would be greater safety for the bicyclists in the three-lane configuration with bike lanes on either side than in the four-lane configuration. [9]
In regard to pedestrian safety, the three-lane facility can occasionally provide pedestrian refuge allowing crossing pedestrians to focus on one lane of traffic at a time. In four-lane undivided roadways pedestrians need to focus on two lanes of traffic at a time, which is difficult. Though the center TWLTL is an active traffic lane, it would have a lower volume of traffic and slower vehicle speeds. Often this lane would be unoccupied by vehicles. Hence the three-lane configuration would be beneficial to bicyclists and pedestrians.

**Overview of Intersection Controls compared in this study**

Intersection controls are intended to establish which vehicles have the right-of-way through an intersection, improve traffic flow, and reduce intersection delays.

*Two Way Stop Signs as Intersection Control*

The majority of intersections in US operating under Two-Way Stop Controls (TWSC), operate with minimal delay. As stated by the Federal Highway Administration’s roundabout design guide, “the common problems associated with TWSC are congestion on the minor street caused by a demand that exceeds capacity, and queues that form on the major street because of inadequate capacity for left turning vehicles yielding to opposing traffic.” [16]

*Signals as Intersection Control*

Traffic Signals offer a great degree of control at intersections. They control the movement of traffic at intersections, “by permitting conflicting streams of traffic to share the same intersection by means of time separation. By alternately assigning right-of-way to various traffic movements, signals provide for the orderly movement of conflicting flows.” [13]

The Manual Of Uniform Traffic Control Devices (MUTCD) gives a set of warrants for the installation of signals. When the signal warrants are met, signal installation should be considered at intersections.

Signal timing is very important in the efficient and safe movement of traffic. If justified and properly timed, signals increase the traffic handling capacity of an intersection, and when installed under certain conditions, reduce certain type of accidents, interrupt extremely heavy flows to permit the crossing of minor movements that could not otherwise move safely through an intersection and improve the safety and efficiency of both pedestrian and vehicular traffic. If signal timing and installation is not justified they increase the overall travel times, queuing and delays by adding stops to the through traffic. This may divert the traffic to the nearby residential streets, which would be unsafe. [13]

*Roundabout as Intersection Control*

Roundabouts may be an unfamiliar type of intersection in the United States, but they're becoming more familiar as evidence of their benefits grows. Many studies have found that one of the benefits of roundabout installation is an improvement in overall safety performance. Several
studies in the U.S., Europe, and Australia have found that roundabouts perform better in terms of safety than other intersection forms [11]. Roundabouts are being implemented throughout the United States in a variety of situations. Many states are considering roundabouts as a viable alternative to two-way stop controlled intersections, and, in some cases, signals and complex freeway interchanges. [14]

In particular, single-lane roundabouts may perform better than two-way stop-controlled (TWSC) intersections in the U.S. under some conditions [12]. Although the frequency of reported crashes is not always lower at roundabouts, reduced injury rates are usually reported. Safety is better at small and medium capacity roundabouts than at large or multilane roundabouts. While overall crash frequencies have been reduced, the crash reductions are most pronounced for motor vehicles, less pronounced for pedestrians, and equivocal for bicyclists, depending on the study and bicycle design treatments. [11]

In a study conducted by Persaud, Retting, Garder and Lord, they evaluated the changes in motor vehicle crashes following conversion of 23 intersections from stop sign and traffic signal control to modern roundabouts. They conducted a before and after study using empirical Bayes procedure, and estimated highly significant reductions of 40 percent for all crash severities combined and 80 percent for all injury crashes. The reduction in number of fatal and incapacitating injury crashes were estimated to be 90 percent. [15]

The reasons for the increased safety level at roundabouts are: [11]

- Roundabouts have fewer conflict points in comparison to conventional intersections. They completely eliminate right angle crashes and left turn head on crashes.
- Roundabouts with single-lane approaches have fewer potential conflicts between vehicles and pedestrians due to short crossing distances thereby producing greater safety benefits than roundabouts with multilane approaches.
- Since the approach speeds and circulating speeds in roundabouts are low they give drivers more time to react to potential conflicts, thus helping to improve the safety performance of roundabouts.
- Due to low relative speeds, crash severity can be reduced compared to some traditionally controlled intersections.
- Pedestrians need to concentrate only on one direction of traffic at a time, at each approach as they traverse roundabouts, when compared to un-signalized intersections. Conflict points between vehicles and pedestrians are generally not affected by the presence of a roundabout.

METHODOLOGY

The research site studied is the intersection of 67th Avenue and 44th Avenue in University Place, Washington, where a four-lane, undivided roadway was physically converted to a three-lane roadway with a center TWLTL plus bike lanes on either side of the roadway. The initial lane width was 11 feet for the two through lanes in each direction. After conversion there is one 3.35 meters (11-foot) through lane in either direction, a center 3.66 meters (12-foot) TWLTL and 1.52 meters (5-foot) bike lanes on either side of the roadway, as shown in Figure 1.
Data Collection

The data collection consisted of two phases. The first phase was video data collection and the second phase was the visual data collection from the videotapes.

Phase 1: Video Data Collection

The benefit of using this method for data collection is that all the data is recorded on video tapes and can be accessed and retrieved at a later time. In this method, all the information recorded on the tapes can be accessed for evaluation at any time and serves as a permanent record for reverification of results. A specially designed 360° omnidirectional video camera and videocassette recorder were used for data collection. Two cameras were used in the study. One camera was placed near the intersection and the other on one of the approaches. This was done to see the traffic flow coming and leaving the intersection. The cameras were installed on existing poles, mounted perpendicular to the ground. The cameras were mounted approximately 6 meters (20 feet) above the ground. The camera feed went into a TV/VCR unit placed in a recycled traffic signal controller cabinet placed on the same pole as the camera. The video images were recorded on standard VHS videotapes. [8]

Data from the intersection was collected before the roadway was re-striped and after re-striping the roadway. The traffic counts from the intersection were video taped for two six hour sessions from 7:00AM-1:00PM and from 1:00PM-7:00PM. The traffic was videotaped for five days in the before (four-lane) condition and for five days in after (three-lane) condition.

Phase 2: Visual Data Collection

In this phase the data was visually collected from the videotapes. Traffic counts; traffic conflicts, and queuing at the intersection were recorded. The counts were recorded for fifteen-minute intervals. Hourly counts were used as input data for analysis using the computer program aaSIDRA (Signalized and Un-signalized Intersection Design and Research Aid). The tapes were also watched for conflicts and queuing separately for each fifteen-minute interval. For this research purpose traffic conflicts are defined as

“a traffic event involving two or more road users, in which one user performs some atypical or unusual action, such as a change in direction or speed, that places another user in jeopardy of a collision unless an evasive maneuver is undertaken.” [5]

SIDRA Software

The software used for data analysis is aaSIDRA, Version 1.0. The Australian Road Research Board (ARRB), Transport Research Ltd., developed the SIDRA package as an aid for design and evaluation of intersections such as signalized intersections; roundabouts, two-way stop control, and yield-sign control intersections.
In a roundabout performance evaluation study conducted by Sisiopiku and Un-Oh using SIDRA they found that:

“In evaluating and computing the performance of intersection controls there are some advantages that the SIDRA model has over any other software model. The SIDRA method emphasizes the consistency of capacity and performance analysis methods for roundabouts, sign-controlled, and signalized intersections through the use of an integrated modeling framework. This software provides reliable estimates of geometric delays and related slowdown effects for the various intersection types. Another strength of SIDRA is that it is based on the US Highway Capacity Manual (HCM) as well as Australian Road Research Board (ARRB) research results. Therefore SIDRA provides the same level of service (LOS) criteria for roundabouts and traffic signals under the assumption that the performance of roundabouts is expected to be close to that of traffic signals for a wide range of flow conditions.” [10]

The input to the software includes the road geometry, traffic counts, turning movements, and speed of the vehicles. The SIDRA software analyzes the data and the output provides measures of effectiveness from which the performance of the roadway can be determined. There are 19 measures of effectiveness given in SIDRA output but only six of them were considered relevant to the project. The six measures of effectiveness used in evaluating the performance are: [6]

“Average Queue Length: The average queue length represents the value below which 50 per cent of all observed cycle queue lengths fall. By using this value we were able to clearly show the change in queue length for the two roadway configurations. This measure was checked for both the major and minor approaches.
Degree Of Saturation: This measure gives us a measure of the congestion on the roadway that is being used by the traffic. It is the ratio of volume to capacity. Here the volume of the vehicles is input and the capacity is calculated by SIDRA.
Average Intersection Delay: This measure gives the average vehicle delay for all the vehicles entering the intersection.
Maximum approach Delay: This measure gives the average vehicle delay for the approach with the highest average delay.
Proportion Of Vehicles Stopped: This measure gives the proportion of vehicles that are approaching the intersection and are required to stop due to the vehicles already present in the intersection.
Maximum Proportion Of Vehicles Stopped: This measure gives the highest proportion of vehicles that are stopped on one approach due to the vehicles already present in the intersection.”

Data Analysis

The data collected from videotapes for the AM and PM periods was recorded manually in 15-minute periods, and hourly data was then input to the SIDRA software for analysis. All the
Measures of Effectiveness (MOEs) were statistically compared using the standard statistical procedures as described below. The data analysis was done separately for the AM and PM hourly volumes but the procedure followed was the same for both sets of data. This was done to see whether the results differed due to the differences in before and after traffic volumes for both AM and PM traffic counts, as there was more traffic during the PM period than during the AM period.

**Conflict Analysis**

Crashes are statistically rare events and in order to make valid conclusions several years of data should be used. In the absence of sufficient crash data, conflict analysis techniques can be used as a surrogate to evaluate the safety of the roadway. The first step is to observe the number of conflict points for the roadway condition. From Figure 2, it can be seen that there are fewer conflict points in the case of a three-lane roadway configuration. Since the number of conflict points has decreased, the roadway should be operating with less risk in that condition. “The three-lane configuration basically reduces the risk of rear end collisions and sideswipe collisions.” [1] The types of conflicts that might not decrease, and could possibly increase, are those between the through vehicles and the right turning vehicles. The conflicts data was visually collected from watching the tapes. Very few conflicts occurred in the AM period. Almost all the conflicts occurred in the PM period. The conflicts were observed for every 15-minute interval for the AM and PM periods and the Northbound and Southbound vehicles were tabulated separately. Dividing the total number of observed conflicts with the respective approach volumes and then multiplying the obtained values by 100,000 gives a standard conflict rate. The multiplication by 100,000 results in convenient numbers. [7] See Tables 1 and 2 for conflict rates.

**RESULTS FOR ROAD DIET CONCEPT**

Statistical analysis techniques were used to compare the outputs from the SIDRA. The statistical analysis of the MOEs helps determine if and how the four-lane and three-lane roadway conditions differed in operation. The analysis provides information to assess characteristics of the three-lane roadway configuration and the four-lane roadway configuration. The statistical testing was done separately for the AM and PM periods in order to find out the operation of the roadway during these separate periods. Statistical tests were not run to compare the statistical significance of the conflicts for the before and after condition as the number of conflicts observed was very few and a meaningful statistical inference is not possible from the small sample. The overall results of statistical testing and conflict analysis are given in Table 3.

**DISCUSSION OF RESULTS FOR ROAD DIET CONCEPT (FOR BOTH AM AND PM PERIODS)**

- The Average Intersection Delay (Seconds/Vehicle) increased by 25% for the three-lane condition during the AM period. The increase in the delay was anticipated because the three-lane condition had only one through lane for the through vehicles and the right turning
vehicles. However, Statistical tests showed that the increased delay is not statistically different from the delay that occurred in the four-lane condition. For the PM period there was no change.

- The Maximum Approach Delay (Seconds/Vehicle) on the 44th Avenue was 61% higher during AM period and 25% higher during PM period in the three-lane condition. The Maximum Approach Delay (Seconds/Vehicle) is due to the unavailability of sufficient gaps for the vehicles that are approaching the intersection from the minor approach (44th Avenue). The major approach (67th Avenue) had one through lane dropped in each direction in the three-lane condition and it would be difficult to find more vehicular gaps in this condition than in the four-lane condition. Hence, there is an increase in Maximum Approach Delay (Seconds/Vehicle). Statistical tests showed that this increase is significantly higher than the delay that occurred in the four-lane condition for the AM period only.

- There was a 77% increase during the AM period and a 36% increase during the PM period, in the Average Queue Length (ft) on the minor approach (44th Avenue) in the three-lane condition. This increase on the minor approach (44th Avenue) is likely due to the unavailability of sufficient gaps for the vehicles approaching the intersection from this minor approach (44th Avenue). Statistical tests showed that this increase is significantly higher from the average queuing that occurred in the four-lane condition for AM and PM periods.

- There was a 91% decrease for AM and PM periods in the Average Queue Length (ft) on the major approach (67th Avenue) in the three-lane condition. This decrease on the major approach (67th Avenue) is likely due to the separation of the left-turning vehicles from the through and right-turning vehicles. Statistical tests have shown that this decrease is significantly lower than the average queuing that occurred in the four-lane condition.

- There was a 37% increase during AM period and 26% increase during PM period, in the Degree Of Saturation (v/c) in the three-lane condition. This measure gives us the amount of capacity that is consumed by the existing traffic loading, and thus, is a measure of congestion. This factor is very important as we can decide whether the three-lane condition is handling the traffic as well as the four-lane condition or not. Statistical tests show that this increase is not significantly different from the Degree Of Saturation (v/c) in the four-lane condition. Hence the three-lane condition is handling the traffic as well as the four-lane condition.

- There was a 66% decrease during AM period and 71% decrease during PM period, in Proportion Of Vehicles Stopped (%) in the three-lane condition. Statistical tests showed that this decrease is significantly lower from the Proportion Of Vehicles Stopped (%) in the four-lane condition.

- There was a 2% increase during AM period and 4% increase during PM period, in Maximum Proportion Of Vehicles Stopped (%) in the three-lane condition. The reasons for insufficient gaps have been explained earlier. Statistical tests showed that this increase is not significantly different from the Maximum Proportion Of Vehicles Stopped (%) in the four-lane condition.
COMPARISON OF OPERATIONAL PERFORMANCE OF ROAD DIET CONCEPT, MODERN ROUNDBOSS ABOUT AND TRAFFIC SIGNAL

The second objective of this research is to see if a modern roundabout or a traffic signal would have been better than the “Road Diet” concept that was implemented at the intersection studied. The intersection of 67th Avenue and 44th street has Two Way Stop Signs as intersection traffic control. In order to test the second objective, the traffic volumes obtained in the after condition were used. The traffic volumes were incremented by 25% and 50% and the operational performance of the intersection traffic controls was evaluated. This was done to observe the performance of Road Diet concept, modern roundabout and traffic signal for various levels of traffic volumes. The traffic signals were compared only with the incremented volume data sets. This was done because the original volume set does not meet the signal warrants and hence traffic signals were not used in comparison for this volume set.

Roundabout Design

A single-lane roundabout was designed based on the Federal Highway Administration’s roundabout design guide [16], for the existing intersection geometry and traffic conditions. The selected design has the following properties:
- A Single-Lane Roundabout,
- The Inscribed Circle Diameter is 115 feet,
- The Circulating Width is 16 feet (This value is taken because SIDRA has fixed upper and lower limits for circulating lane widths and 16 is the lower limit),
- The truck apron is 9 feet (This was based on the design vehicle requirements a WB-50, which requires a minimum of 25 feet for maneuvering the roundabout. Since the circulating lane is 16 feet wide the remaining 9 feet is provided using a truck apron.

Traffic Signal Design

After incrementing the traffic volumes by 25%, the signal warrants in the MUTCD are met. The intersection of 67th avenue and 44th Street has a major and a minor approach (67th Avenue- Major approach, 44th Street- Minor Approach). Hence a semi-actuated signal system had been selected for the intersection. Also SIDRA gives the option of specifying individual approach movements as coordinated or non-coordinated which helps in better handling of semi-actuated type of signals. In this case all the movements were specified as coordinated movements. For this type of signal system, the green split, priority method applies. SIDRA will set all coordinated movements as high priority movements for the purpose of green split calculations.

Cycle time can be specified for the program to determine green splits. For program determined cycle times the user can have the program calculate the cycle times by specifying a lower limit (cL) and an upper limit (cU) and a cycle increment (Δc). The program determines a list of cycle times as provided the lower limit is greater than the minimum cycle time (cL > cmin). If the lower limit is less then the minimum cycle time calculated by the program (cL < cmin), then cL = cmin is set. The upper limit is set to 60 seconds, as this low value generally minimizes delays. [6]
Since Program option “P” is chosen for the cycle time setting, the program itself also calculates phasing.

RESULTS OF STATISTICAL ANALYSIS-COMPARISON OF OPERATIONAL PERFORMANCE OF ROAD DIET CONCEPT, MODERN ROUNDABOUT AND TRAFFIC SIGNAL

The statistical analysis of the MOEs helps determine if and how the Road Diet Concept (with Two Way Stop Signs as intersection control), Modern Roundabout and Traffic Signal would have differed in operation for the various increased levels of traffic. The analysis provides information to assess the advantages/disadvantages of adopting Road “Dieting”, Modern Roundabout or Traffic Signals. The statistical testing of the SIDRA output for each alternative was done separately for the AM and PM period as was done in the earlier chapters. The overall results of statistical testing for the comparisons are given in Table 9.1 and 9.2. If the data sets are not statistically similar then, based on the average values of the data sets, a ranking of the alternatives is given and a relationship is established. The data set with the “best” value (the one with the least average value) is given the best rank and the values are arranged in an ascending order starting from the least value to the highest value.

Discussion Of Results for the Comparison of operational performance of Road Diet Concept, Modern Roundabout and Traffic Signal

Discussion for AM period

- The Average Intersection Delay (seconds/vehicle) is statistically similar for the original volumes for all alternatives. For the incremented volumes the roundabout gives the least delay when compared to the others. It gives a statistically significant difference in delays from the other options for the incremented traffic volumes.
- The Maximum Approach Delay (seconds/vehicle) is least when a modern roundabout is used for the original and the incremented volumes. The signal delay values are close to the roundabout delay values. The roundabout and traffic signals give statistically significant differences in delay when compared to road diet for the original and incremented traffic volumes.
- The 95% Queue Length is least for the 4-Lane configuration in the case of original volume, least for the 3-Lane configuration in the case of 25% incremented volume and least for roundabout in the case of 50% incremented volume. The differences are statistically significant for the original and incremented traffic volumes.
- The Degree Of Saturation (v/c) is statistically similar for the original volumes. For the incremented volumes the roundabout gives the least value, which is statistically significant when compared to the others.
- The Proportion Of Vehicles Stopped (%) is least when the 3-Lane configuration is adopted for the original and the incremented volumes. The 3-Lane configuration gives values, which
are considerably better than the others. The differences are statistically significant for the original and incremented traffic volumes.

- The Maximum Proportion Of Vehicles Stopped (%) is least when a modern roundabout is used for the original volume. For the 25% incremented volume the results are statistically similar. For the 50% incremented volume the signal gives the best result. The differences are statistically significant for the original and incremented traffic volumes.

Discussion for PM period

- The Average Intersection Delay (seconds/vehicle) is least when a modern roundabout is used for the original and the incremented volumes. The values given by the roundabout are very less compared to the others. The differences are statistically significant for the original and incremented traffic volumes.
- The Maximum Approach Delay (seconds/vehicle) is least when a modern roundabout is used for the original and the 25% incremented volume. For the 50% incremented volume the signals give the least value. The signal delay values are close to the roundabout delay values. The differences are statistically significant for the original and incremented traffic volumes.
- The 95% Queue Length is least for the 4-Lane configuration in the case of the original traffic volume, least for the 3-Lane configuration and 4-Lane configuration (same result) in the case of the 25% incremented volume and statistically similar in the case of 50% incremented volume. The differences are statistically significant for the original and incremented traffic volumes.
- The Degree Of Saturation (v/c) is least for the modern roundabout for the original and incremented volumes. The differences are statistically significant for the original and incremented traffic volumes.
- The Proportion Of Vehicles Stopped (%) is least when the 3-Lane configuration is adopted for the original and for the incremented volumes. The 3-Lane configuration gives values, which are considerably better than the others. The differences are statistically significant for the original and incremented traffic volumes.
- The Maximum Proportion Of Vehicles Stopped (%) is least when a modern roundabout is used for the original and incremented volumes. The differences are statistically significant for the original and the 50% incremented traffic volumes. For 25% incremented volumes they are statistically similar.

CONCLUSION

Conclusions from the research for the Road Diet Concept

- The total numbers of vehicle conflicts were reduced.
- Based on the videotape data analysis, there was a decrease in the conflict rate for the three-lane configuration. Conflicts have long been considered a valid surrogate for crashes; therefore, the three-lane configuration should experience less crashes.
- There is an increase in the Average Intersection Delay (Seconds/Vehicle) in the three-lane condition. However, this increase was observed only for the AM period and the increase was
not statistically significant. There was no change for the PM period, i.e., results were statistically similar.

- There was an increase in the Maximum Approach Delay (Seconds/Vehicle) in the three-lane condition for both the AM and PM periods but the increase was statistically significant only for the AM period and not statistically significant for the PM period.
- There was an increase in the Average Queue Length (feet) in the three-lane condition on the minor approach (44th Avenue) for both the AM and PM periods but neither increase was statistically significant.
- There was a decrease in the Average Queue Length on the major approach (67th Avenue) for both AM and PM periods and the decrease was statistically significant for both the AM and PM periods.
- There was an increase in the Degree Of Saturation (v/c) for the three-lane condition in both the AM and PM periods. The increase was statistically significant for the PM period but not statistically significant for the AM period.
- There was a decrease in Proportion Of Vehicles Stopped (%) at the intersection in the after condition for both AM and PM periods and the decrease was statistically significant for both the AM and PM periods.
- There was an increase in the Maximum Proportion Of Vehicles Stopped (%) on the minor approach (44th Avenue) for both AM and PM periods. The increase was statistically significant for the PM period but not statistically significant for the AM period.

Conclusions from the comparisons of Road Diet Concept, Modern Roundabout and Traffic Signals

- For the original traffic volumes the single-lane modern roundabouts’ performance is better compared to the road diet concept for four out of six MOEs. Of the remaining two the 4-Lane configuration works better for one and the 3-Lane configuration for the other. So for the original traffic volumes a single-lane modern roundabout would have performed best.
- As the traffic volumes increase by 25% and 50% the modern roundabout performs better than the others in most of the cases except for the Proportion of Vehicles Stopped and Maximum Proportion of Vehicles Stopped. For the Proportion of Vehicles Stopped the Road Diet Concept would have performed best for both 25% and 50% incremented traffic volumes. The results for Maximum Proportion of Vehicles Stopped for the 25% incremented traffic volumes are statistically similar and for 50% incremented traffic volumes the Signal would have performed best.
- From the comparison it can be concluded that a modern roundabout would have given the best results at this intersection, when compared to the Road Diet Concept and traffic signals.

Overall Conclusion

The conclusions of this research are based on the data collected from one location and may not apply to all situations. This research demonstrates a methodology to demonstrate the benefits of a three-lane roadway configuration vs. a four-lane roadway configuration and operational
performance of two other types of Intersection Control; namely a single-lane modern roundabout and traffic signals.

The decrease in conflict rate, likely enhancement of pedestrian and bicycle safety (due to decrease in number of conflict points and separate bike lanes in each direction), and the effective or almost equal operational performance of the three-lane configuration compared to the four-lane configuration, all suggest that the three-lane roadway configuration can be adopted as a viable, safer alternative to the problematic undivided four-lane roadway configurations.

The study suggests that modern roundabouts may be a better alternative when compared to Road Diet Concept and traffic signals, at intersection with conditions and traffic loading similar to those at the intersection in this study.

REFERENCES


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