GUIDELINES FOR ROAD DIET CONVERSIONS

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ABSTRACT

Road diets, which convert four-lane highways to three-lane cross sections, are an innovative solution to address mobility and safety concerns under budgetary constraints. These improvements can assist in the development of multimodal corridors with minimal impact on automobile mobility, while retaining the original right of way. Past research has focused on evaluating road diet safety, but minimal guidance exists on determining when such conversions are appropriate from an operational perspective. The proposed guidelines focused on evaluating and comparing the operation of three- and four-lane roads at signalized intersections to provide basic guidance as to when the road diet conversion is appropriate. One of the important findings of this research is the expansion of the usable range for road diets. Prior experience has limited road diet application to roadways with ADTs less than 17,000 vehicles per day. This research identifies the importance of side street volumes and supports the utilization of road diets on roadways with volumes up to 23,000 vehicles per day. This paper provides comprehensive guidance for road diet evaluation including operational performance, correctable safety problems and identifies a list of evaluation elements that should be examined when in-depth analysis of alternatives is required.

Keywords: Road diets, safety, highway design

1. BACKGROUND

Rural and urban roadways are becoming increasingly congested throughout the US and other countries, and solutions frequently seek to improve modal options including, bike, pedestrian and transit facilities. A typical approach for solving this problem has been the addition of lanes, but this approach is an expensive and environmentally disruptive practice that frequently offers only short-term relief. The need for innovative solutions in addressing mobility and safety concerns in an environment with budgetary constraints is paramount. Such innovative solutions seek to develop multimodal corridors while retaining the original right of way and among them is the concept of road diet, where the number of travel lanes is reduced. Road diets usually involve restriping a four-lane undivided road as a three-lane road with two through lanes and a two-way left-turn lane (TWLTL). This creates surplus roadway width that can be used to widen existing lanes, create bicycle lanes, supply on street parking, widen sidewalks, or provide opportunities for landscaping and aesthetic improvements.

On roadways with high access density, the inside through lane on a four-lane undivided roadway often acts like a de facto turn-lane. This operation can block through traffic, diminishing operations, as well as introduce crash patterns such as rear end crashes and sideswipe crashes resulting from the stopped left-turn traffic. The introduction of a TWLTL can often meet the left-turn demand for both directions of travel in a single lane. This modification can then improve safety and mobility by removing turning traffic from the through lanes. Therefore, road diets are a design tool that can be used within existing right of way at a very low cost to improve mobility, and they frequently have no or few negative impacts.

Road diets have been shown to improve operating efficiency and safety for all users. Case study review has shown road diets to be effective on roads with an average daily traffic (ADT) of up to 25,000 vpd, while other studies have indicated that capacity is not affected by the elimination of the lane and often no increase in congestion is observed (Burden and Lagerway 1999; Welch 1999). Improvements in livability conditions and associated benefits are elements to be considered during road diet conversions, as review of past case studies has indicated (Rosales and Knapp 2005). Road diets make it easier for pedestrians to cross the road at both signalized and unsignalized intersections, increase feeling of a "safer and more comfortable" street, encourage an increase in pedestrian and bicyclist traffic, and encourage economic growth and redevelopment at a quicker pace (Rosales and Knapp 2005).

Past research has focused primarily on case study evaluation of road diets and on safety performance of these treatments. However, there is little literature providing guidance on the details of the designs or information as to when such conversions will work. The first attempt in defining operational guidelines for road diet conversions was completed in 2001 relying on evaluating before-after conditions on existing road diet projects completed at that time (Knapp and Giese 2001). The study recommended that a road diet conversion could be considered feasible for roads with an ADT between 15,000 and 17,500 vpd. A more recent attempt to improve on these guidelines was completed in 2006 again based on assessing existing road diets and identifying associated benefits (Rosales 2006). However, the step-by-step process developed is general in nature and does not provide specific guidance regarding volumes or left-turn percentages indicating when such a project could result in improved operational and safety conditions.

The need to identify criteria to be considered for establishing road diets is critical and should be addressed so that state and local agencies can expand their use. A review of all State DOT design manuals did not identify any guidance for road diet conversions, which can hinder their adoption. This study provides such guidance in determining the appropriateness of road diet conversions and identifies parameters to be considered during such evaluations.

2. METHODOLOGY

Typically, road diet conversions will operate at acceptable levels as long as the signalized intersections do not present any operational problems. Therefore, this analysis focused on evaluating and comparing the operation of three- and four-lane roads at signalized intersections. In order to adequately evaluate signalized intersection operations, a full range of mainline and side street volumes, as well as left turn percentages, needed to be evaluated. Evaluation of a full range of these parameters examines a wide array of the potential operating conditions for road diet roadways. The analysis conducted through micro simulation to compare operational performance of three-lane and four-lane sections through the full range of volume combinations. A total of 480 combinations were used for the simulations, i.e. 10 volume scenarios for eight left-turn percentages and six cross street volumes. These scenarios included:

1. Mainline volumes ranging from 6,000 to 24,000 vpd with 2,000 vpd increments and assuming that 10 percent of the volume will occur during the peak hour. One directional split (50/50) was utilized.

2. Cross street volumes were varied between 3,000 to 13,000 vpd with 2,000 vpd increments. There was only one directional split (50/50) and a 10 percent estimate of left and right turns was used.

3. Left-turn percentages were used ranging between 5 to 40 percent with increments of 5 percent.

4. Right-turn percentage was set at 15 percent and not varied as right-turn volume has minimal effect on capacity of the through movement.
5. All cross-street scenarios utilized a three-lane cross-section which limited the capacity of the cross street.

Simulations were performed with the CORridor SIMulation (CORSIM) and vehicular delay was calculated for each approach independently. The data obtained from the simulation analysis was then used to develop predictive models of intersection delay that could be used in establishing potential guidelines for the implementation of road diets. The Statistical Package for the Social Sciences (SPSS) was utilized to develop these models.

3. RESULTS

The analysis completed here was used to develop prediction models that could allow for establishing guidelines and identifying the conditions under which road diets could improve the operational efficiency of the roadway. Linear regression models were used to model the delay for each condition, i.e. three- and four-lane options, and identify the variables that could predict these differences. The variables considered include the volumes of the main and side streets as well as left-turn percentage.

The model for the three-lane included all three variables of concern and had a good predictive power with an R^2 of 0.48. The model coefficients are summarized in Table 1. The four-lane model also utilized all three variables but the predictive power was lower (R^2=0.28). The variables included in the equations reflect the effect of traffic volumes on delays and their signs indicate that increasing volumes will result in greater delays. The same is true for the left-turn percentage where larger percentages will lead to greater delays.

Table 1: Coefficients for Predictive Models

Variable	Three-lane		Four-lane	
	Parameter	P value	Parameter	P value
Intercept	-29.113	0.00	-47.968	0.00
Main street volume (vph)	0.013	0.00	0.022	0.00
Side street volume (vph)	0.025	0/00	0.037	0.00
Left-turn percentage (number)	0.313	0/00	0.314	0.00

These models can be used to define the scenarios where the three- and four-lane options produce a delay difference of zero, i.e. both options will perform equally well. This will produce the line of equality which can then be used to establish the regions where road diets are advisable and those where they are not. Figure 1 presents this concept with the blue line identifying when delays are the same for both options. The combinations below the blue line indicate lower delays associated with the implementation of a road diet. The red line in the figure identifies the volume combinations where the roadway will operate under capacity with a road diet and is based on the critical lane volumes between three and four-lanes are equal. Utilizing these concepts, Figure 1 defines three areas with respect to road diet installations. The lower area called "Recommended" identifies the volume combinations where the road-diet will perform below capacity and result in operational gains. The upper area "Not-recommended" identifies the volume combinations where the roadway will operate above capacity, and will have higher delays than the four-lane alternative. Undesired congestions could be the result from a road diet operating in this range. The area between the two lines is considered as the area requiring additional investigation to determine the feasibility of a road diet conversion. A road diet in this area will operate under capacity, but may have higher delays than the four-lane section. Thus analysis should be completed to determine the impacts that would result from the road diet.

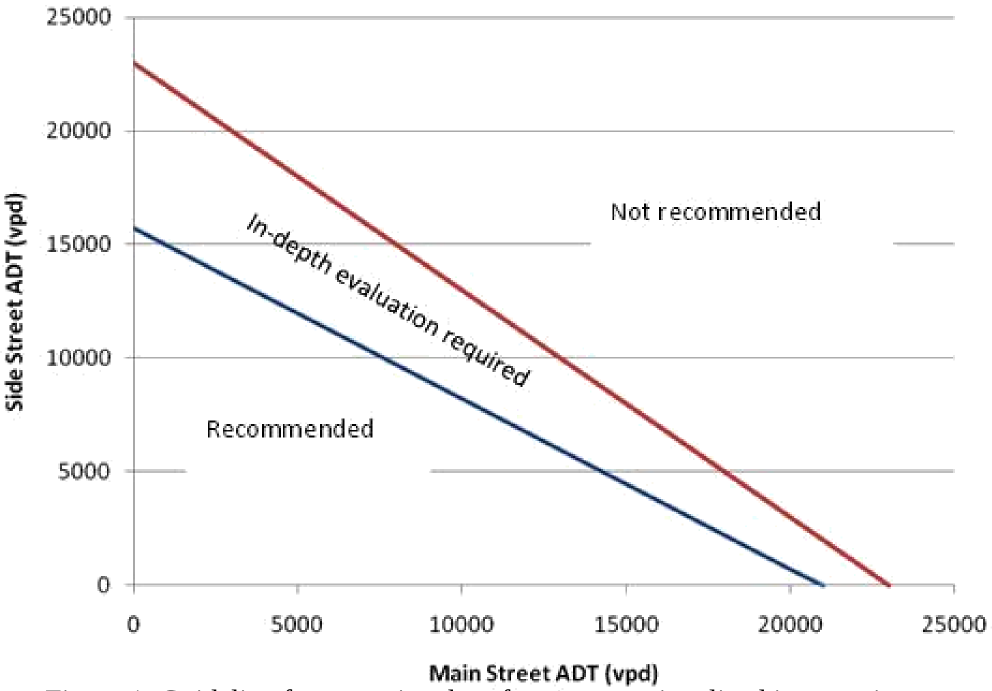

Figure 1: Guideline for operational performance at signalized intersections

The operational guidance developed is based only on main and side street volumes, since it was determined that the operation of the signalized intersection is the critical aspect for a road diet conversion based on the analysis conducted here and since road diets will result in improved conditions at unsignalized intersections. While left-turn percentage was shown to be a significant parameter for the capacity and delay of an intersection, it has the same effect for both the four-lane and three-lane sections and therefore provides no differentiation between the alternatives, i.e., the left-turn percentage does not contribute any additional delay to the difference between the two options.

The evaluation of the unsignalized intersections indicated that for all scenarios evaluated, the road diet results in lower delays along the side street, which could outweigh the minor increases along the main street. It was therefore deemed appropriate to not develop a similar guidance as the one shown in Figure 1 for unsignalized intersections. Therefore, unsignalized intersections or access points are not a significant determinant of the success or failure or a road diet project. Even unsignalized access points with high volumes of left turn traffic on the major street will continue to operate at acceptable levels of service while signalized intersections may fail due to the reduced mainline capacity. The primary concern for unsignalized access points is overlapping left turn movements within the two-way left turn lane, which is avoided with the four-lane section. The existing KYTC auxiliary turn lane policy currently addresses this concern by recommending against the use of TWLTLs for access point densities greater than 85 access points per mile (KYTC 2009).

4. GUIDELINES

The data analyzed here was utilized to develop guidelines for road diet conversions. The guidelines have been developed as a standalone document and they can be used to determine the steps required for a road diet conversion (Stamatiadis et al. 2011). A brief description of the guidelines is provided here.

4.1 Road Diet Conversions

The guidelines focus on the determination of whether a road diet application is appropriate considering operational, safety, and other factors that could have a bearing on the decision to implement a road diet conversion. To achieve this, a flow chart was developed that identifies the various steps to be taken when such decision is evaluated (Figure 2).

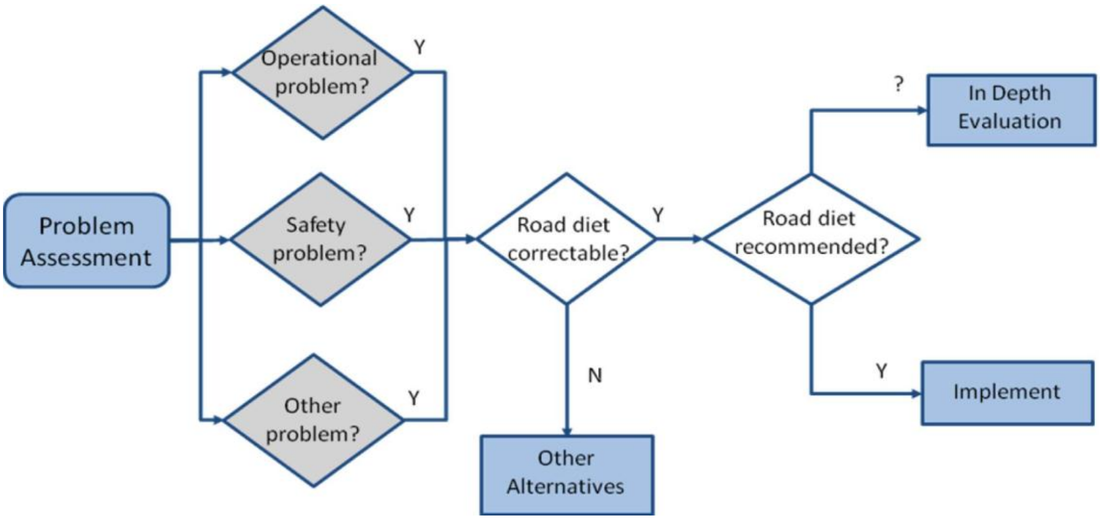

Figure 2: Decision-Action Flow Chart for Road Diet Evaluations

The flow chart allows the user to identify the appropriate action to be undertaken to determine whether the road diet will improve the operations, safety or other performance issues. To address this, lists of possible problems correctable by a road diet implementation are identified (Table 2). In addition to these lists, the required items for conducting an in-depth evaluation are also identified in order to allow for a complete evaluation of the implications from a road diet implementation.

Table 2: Road Diet Correctable Problems

Category	Problem	Rationale
Operational	Delays associated with left-turning traffic	Separation of left-turning traffic have shown to improve delays at signalized intersections
	High side street delays at unsignalized intersections	Side street traffic requires shorter gaps due to the consolidation of left-turns into one lane
	Other operational problems	Potential inclusion of bicycle lane could reduce delays
Safety	Rear end crashes with left-turning traffic	Removal of stopped turning vehicles from the through lane could reduce rear end crashes
	Sideswipe crashes	Elimination of need to change lanes to avoid delays behind a left-turning vehicle in the inside through lane reduces sideswipe crashes

	Left-turn crashes due to offset left turns	Elimination of the negative offset between opposing left-turn vehicles and increase of available sight distance reduces left-turn crashes
	Bicycle and pedestrian crashes	Bicycle lane separates bicycles from traffic; pedestrians have shorter distance to cross and can use a refuge area (if one provided)
Other	Bicycle/pedestrian accommodation due to lack of facilities	Opportunity to provide appropriate or required facilities increasing use by such users
	Aesthetics	Provision for landscaped medians and other treatments as see fit
	Traffic calming	Potential for uniform speeds and consistency; opportunity to encourage pedestrian activity

4.2 Road Diet Considerations

Typical considerations for road diet conversions include traffic volumes of the main and side streets and main street left-turn percentages. However, compatibility of the treatment with roadway functional classification, access frequency and land use should also be considered when determining the feasibility of a road.

Road diets may be proposed to address both safety and operational issues on roadways. The guidelines provide criteria to be considered in determining whether a road diet conversion is appropriate. These criteria include operational performance ranges that would support a road diet project as well as safety considerations that need to be evaluated. The operational performance identifies three ranges: 1) Volume combinations where the road diet is recommended because it will improve the operational performance (i.e. delays will be lower with the road diet), 2) Volume combinations where the road diet is not recommended because the operational performance deteriorates (i.e. delays will increase), and 3) Volume combinations where an in-depth evaluation is needed. The last range identifies cases where the road diet will operate under capacity, but may have higher delays than the four-lane section. Thus analysis should be completed to determine the impacts that would result from the road diet.

The crashes that could be affected by a road diet implementation were also identified. These included:

- Sideswipe crashes, which can result from vehicles changing lanes to avoid delays behind a left-turning vehicle in the inside through lane. These types of crashes can occur at midblock access points and major intersections. Road diets eliminate these types of crashes by removing the turning vehicle from the through lane. Sideswipes can also occur between vehicles traveling on the two-way left-turn lane and those attempting to enter it but these crashes are not a frequent occurrence as prior research and case studies indicate.

- Rear end crashes, which can be the result of vehicles traveling in the inside through lane behind a stopping or stopped left-turning vehicle. A road diet reduces these types of crashes by removing the stopped turning vehicle from the through lane. Road diets are anticipated to reduce rear end crashes on roadways with high volumes of left-turn traffic; however, increased congestion resulting from the lane reduction may increase rear end crashes on the main street under other conditions.

- Left-turn crashes, which can result from restricted sight distance caused by opposing turning traffic. Road diets address these types of crashes by providing a dedicated left turn lane and correcting the negative offset between opposing left-turn vehicles.

There are additional elements that should be considered when road diets are evaluated including:

- multimodal operations, which can be improved with the implementation of a road diet,
- pedestrian safety, which can be improved with the addition of the refuge within the two-way left-turn lane,
- operational consistency where more uniform speeds along the corridor can be achieved, and
- livability, which can be improved by increasing opportunities for residential and commercial growth with a road diet.

4.3 Design Considerations

Various design aspects of the road diet conversion have been identified including recommended cross sections (dimensions of elements and possible components) along with methods to properly transition to and from the road diet to the existing roadway cross section. Transitions are recommended to occur at major change points, such as intersections, since they could allow for a more appropriate accommodation of turning movements. However, if necessary, transitions can occur at midblock sections, where it is recommended to place this away from intersections and/or high volume access points that would place stopped turning traffic in the through lanes of the merging traffic.

If not designed properly, these transitions can increase crashes removing any safety benefit of the road diet. All transitions should follow AASHTO's Policy on Geometric Design for Highways and Streets and MUTCD guidance for the reduction of through lanes.

An additional design issue of concern is the potential of high access densities to increase the likelihood of conflicts between traffic turning into and exiting the access point. This could affect safety along the corridor, since there is the potential for rear end crashes from vehicles slowing down to negotiate entering the access point and overlapping of left-turns between the main street and adjacent access points. According to KTC Auxiliary Turn Lane Policy, a non-traversable median and turn restrictions are recommended when a corridor exceeds 85 access points per mile (based on number of access points on both sides of the street).

Prior to the implementation of a road diet, it is recommended that a capacity analysis be completed for the major signalized intersections on the corridor to ensure that they would operate acceptably with a revised lane configuration. Analysis based on Highway Capacity Manual (HCM) methodologies is sufficient to check intersection capacities. For special cases, such as closely spaced intersections, coordinated signal systems, or corridors with at-grade rail crossings, micro-simulation is recommended to adequately evaluate arrival patterns and queue formation and dissipation.

4.4 Road Diet Not Recommended

The guidelines provide a list of conditions when a road diet may not be appropriate. These conditions include corridors where the operational efficiency may degrade as a result of the road diet, corridors where at-grade rail crossings or other conditions exists that may create queues that require a long time to dissipate; and high crash rates resulting from conditions not correctable by road diets. The latter condition reflects cases where crashes such as right angles are a problem. The use of a road diet will not address such crashes. Other scenarios include cases where adequate transitions cannot be developed or if left-turn lanes already exist on the corridor.

The expert panel analysis was the next safety analysis performed for each case study using all the information and analyses conducted as input. The expert panel reviewed each documented crash after the completion of the given project and determined the potential influence of project design features on crash. This approach utilized specific crash data (including location, crash type, environmental conditions, etc.) and the expertise of panelists, who first examined the potential influence of the driver, roadway, environmental, and vehicular factors on crash occurrence. The second examination determined the likelihood of the crash being associated with the project design and to each design element. The expertise of the panel included highway safety, highway design, planning, project development, crash reconstruction, traffic operations, and human factors.

5. CONCLUSIONS

This paper provides the background and process used to develop a set of guidelines to determine when road diet conversions are feasible. A structured approach was followed that considered the operational evaluation of three- and four-lane roads and identified parameters significant to the successful operation of road diets.

An important aspect of the work completed here is the extension of the usable range of volumes where road diets could be beneficial. Past work recommended their application for roads with an ADT up to 17,500 vpd. The current research indicates that such conversions could work for roads with greater volumes, up to 23,000 vpd. Moreover, the findings here identify the effect of the side street volume, indicating that both volumes need to be considered when determining whether such a conversion should be considered.

Road diets may also improve the operational efficiency of signalized and unsignalized intersections on a corridor. Operational improvements are typically seen when high ADTs and high left-turn percentages are present on the primary and cross-street. Typically road diets are shown to have reduced delays and reduced queues when high left-turn percentages AND high volumes are present.

The data analysis focused on the safety and operational characteristics of each case study and is based on the before and after crash analysis, the crash type expectation analysis, the speed comparisons, and the expert panel analysis. The overall results for each case study are presented in Table 2, where the safety, operational, and expert panel analyses are summarized. The safety and operational results are assessed relative to their influence on safety with a designation of an algebraic sign (+ or -) to denote the differences between the after and before conditions of the project and statewide differences. The negative numbers indicate an improvement in safety or a lower operating speed than the design speed. The positive cells are also shaded to highlight the cases where deterioration in safety was noted or the operating speeds were higher than the design speed. Finally, the expert panel scores are presented for each case study (scoring range 0: no influence, 1: least influence, 5: most influence).

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