Safety and Operational Analysis of 4-lane to 3-lane Conversions (Road Diets) in Michigan

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16. Abstract

Road diets, specifically 4-to-3 lane conversions, implemented in various locations in Michigan were studied to determine the safety- and delay-related impacts, develop crash modification factors (CMFs), and develop guidelines that would be useful in deciding when it might be desirable to implement such road diets. The results of the operational analysis support a guideline that suggests that 4-to-3 lane conversions result in significant delay when average daily traffic (ADT) exceeds 10,000 and, more importantly, when peak hour volumes exceed 1,000. A CMF of 0.91 (after adjustment for background citywide trends) for all crash types is recommended although the factor is not statistically different from 1.0. There was considerable site-to-site variation among the 24 sites studied, and this should always be considered when a road diet is contemplated. A study-by-study literature review and suggestions for implementation strategies are also included.

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EXECUTIVE SUMMARY

Priorities for the design of roadways have shifted over the years—from a primary emphasis of increasing capacity to considering the purpose of streets and roads in the context of specific settings (and often referred to as "context sensitive" design). A technique that has gained popularity in recent years is the so-called "road diet" where traditionally-designed 4-lane roads with two lanes in each direction have been converted/reduced to three lanes (often with the addition of bike lanes) with one lane in each direction and a center left-turn-only lane. Such conversions have potential impacts on both travel delay and safety.

The objectives of the study are straightforward and focused on travel delay and safety for typical 4-to-3-lane conversions in Michigan:

1. Determine the safety-related impacts of the conversions.
2. Determine the delay-related impacts of the conversions.
3. Develop a statistically sound crash modification factor for conversions.
4. Develop a guideline that addresses/incorporates the results from the above that would be of assistance to MDOT and other agencies in deciding when it might be desirable to implement such "road diets."

While the report includes a literature and state of practice review, anecdotal observations regarding pedestrian and bicyclist use of road diets, and comments regarding the successful implementation of road diets in communities, this summary is focused on the operational and safety aspects of road diet implementation.

From the operational analysis of several Michigan road diet sites—

- The operational analysis of the several sites provide reasonably consistent results and support a guideline that suggests that 4-to3-lane road diet conversions result in significant increases in delay for **ADTs over 10,000**.
- More importantly, 4-to-3-lane road diet conversions increase delay when **peak hour volumes exceed 1,000**.

- However, it is clear that "local" conditions (e.g., varying geometry, significant variation in turning movements, and variations in cross-street traffic) can have a significant impact on the viability of any proposed road diet. Thus, while an initial culling of potential road diet sites can be accomplished using the general guidelines above, in all instances a detailed operational analysis of the corridor (including operations at each intersection) for both 4- and 3-lane sections should be undertaken before the road diet conversion is implemented.

From the safety analysis of selected 4-to-3 lane road diets in Michigan—

- There is considerable site-to-site variation in the crash-related results although in almost all instances, there was a reduction in the number of crashes.
- Examination of the background (e.g., citywide, countywide) trends showed that in all cases there was a trend toward lower crash frequencies over time.
- The most appropriate methods for controlling for background trends were a simple control for citywide trends and the consideration of comparison sites.
- Average crash modification factors (CMFs), adjusted for citywide trends, were calculated across all 24 sites. The result was that the overall naïve (unadjusted) CMF was estimated as 0.63, and **0.91** after adjustment. Considering only those crash types expected to be affected by the road diet (not necessarily only reduced), the CMF was 0.90. And, finally, considering only those crash types expected to be reduced by a road diet, the adjusted CMF was 0.59. Use of the latter is problematic since there are typically offsetting changes in crash type frequencies. Only the CMF for the "correctable" crashes was statistically different from 1.0.
- While **the best estimate of a usable CMF is 0.91**, it should be noted that this is not statistically different from 1.0 and is an average across all sites. Perhaps more importantly, there is a great deal of variation from site to site.

- Considering effects of other variables on the overall CMF, it was seen that there was not much change due to controlling for other variables except for adjacent land use—residential sites tended to have a lower CMF than mixed-use or commercial sites.
- Changes in crash severity due to road diets were examined and the distributional shift over all sites was estimated (and then compared to statewide changes). The finding was that although there was a slightly more substantial shift to less severe crashes for the road diet sites, it did not seem operationally significant. Moreover, the shift could have easily been due to changes in operating speeds or enforcement rather than the road diets themselves.

Road diets are a useful tool in the traffic engineer's arsenal of making streets and roads a more integral part of the community. As a part of broader plans, they open up "traditional" roads to greater use by pedestrians and, especially, bicyclists. In general, safety benefits can be expected but vary greatly from site to site. When corrected for citywide trends, the results here indicate that only a relatively modest CMF (0.91) is appropriate. This indicates that crash/safety benefits are likely to be considerably less than what is suggested by naïve comparison of before and after crash statistics. Similarly, the results reported here also suggest that operational analyses should always be performed early on in the consideration of a road diet proposal. Moreover, the commonly-quoted threshold ADT of 20,000 for consideration of a road diet should be lower (10,000) and, more importantly, realistic peak-hour analyses (based on actual counts) are much more useful. For the sites evaluated here, the peak-hour threshold volume is estimated as 1,000 vph although this could vary with varying volumes of cross traffic at intersections.

INTRODUCTION AND STATEMENT OF THE PROBLEM

Priorities for the design of roadways have shifted over the years—from a primary emphasis of increasing capacity to considering the purpose of streets and roads in the context of specific settings (and often referred to as "context sensitive" design). Examples of this shift can be seen with the increasing popularity of traffic calming, once the bane of traffic engineers for which the efficient movement of vehicles was the principal criterion, becoming widely accepted and applied. Another technique that has gained popularity in recent years is the so-called "road diet" where traditionally-designed 4-lane roads with two lanes in each direction have been converted/reduced to three lanes (often with the addition of bike lanes) with one lane in each direction and a center left-turn-only lane. Such conversions have potential impacts on both travel delay and safety. In this context, the basic question addressed in this study is "what are the impacts of such conversions in Michigan?" The results of the study will be of use to both MDOT and local road agencies.

OBJECTIVES OF THE STUDY

The original objectives of the study are straightforward and focused on travel delay and safety for typical 4-to-3-lane conversions in Michigan:

5. Determine the safety-related impacts of the conversions.
6. Determine the delay-related impacts of the conversions.
7. Develop a statistically sound crash modification factor for conversions.
8. Develop a guideline that addresses/incorporates the results from the above that would be of assistance to MDOT and other agencies in deciding when it might be desirable to implement such "road diets."

BACKGROUND AND SIGNIFICANCE OF WORK

Lane conversions/reductions are popular with many communities as the technique is viewed as a method that puts concerns of the local community, bicyclists, and pedestrians on a par with motorists passing through neighborhoods. The impacts of such conversions can include increased motorist delay, increases and/or decreases in crashes, and better access to the transportation system for other user groups among others. Like new traffic signals, the impacts often appear to be situation-specific meaning that in some instances traffic crashes can be shown to increase while for others they decrease. The results of the study provide MDOT and other agencies with needed background information so that the outcomes of conversions in specific types of situations will be better understood.

While addressing different issues, work done under previous MDOT contracts on conversions of 2-way streets to 1-way pairs (Lyles et al. 2001) and the effect of new signals (Lyles et al. 1997) both showed that crash and operational changes varied according to the sites being considered. This same phenomenon was noted by Huang and others (2001) in a study of sites in California and Washington specifically for roads where a “road diet” was implemented. Results from several other studies showed that both crash-related and operational measures of effectiveness may vary. In the latter case, for example, if there are significant left-turn volumes on the corridor to be treated, but not particularly high through volumes, operational benefits can be accrued because of the separation of left turns into the center left-turn lane. However, if through volumes are high and the left-turning volume is not, elimination of a through lane can cause operational problems. In previous work done by Taylor for MDOT on road diets (2001), it was found that the crash reduction factor was 27.6% across all volume levels (which, at the time, compared favorably to the 25-30% reduction noted elsewhere). This included a consistent reduction in pedestrian and bicycle-related crashes. Not surprisingly, changes in delay were associated with the volumes on the treated street and the minor/side streets. When volumes were lower (e.g., in residential areas) delay increases were not significant but when major street volumes approach 2,000 vph and minor street volumes approach 200 vph, delay increases and becomes prohibitive.

One of the attractive characteristics of lane conversions is that it is a low-cost alternative—often consisting of only traffic signing and pavement marking changes. If crashes are reduced, benefit-cost ratios are very favorable. Even if there are negative operational impacts, the crash reduction potential may still trump increases in delay. The significant benefit of this project is that it provides MDOT and other agencies of a reliable source of information that can be used in determining whether to propose (or support the proposal of others) lane reduction/road diets.

ORGANIZATION OF THE REPORT

The results of the project are presented in the pages that follow. Syntheses for the several tasks that were completed are presented in the body of the report with more complete results presented in appendices. The following are the sections to the report:

- The literature review includes both traditional technical literature and more informal information from various local studies/presentations on road diets. (See also Appendix A.)
- Results from (qualitative) on-site reviews of several (Michigan) sites focusing on use by pedestrians and bicyclists. (See also Appendix B.)
- An operational analysis of several Michigan sites which focused on determining traffic volume thresholds which indicate when road diets are contraindicated from a delay perspective. (See also Appendix C.)
- A safety-related analysis of 24 sites in Michigan which focused on developing a reliable crash modification factor (CMF) that could be used in determining whether a road diet is appropriate for a given site. (See also Appendix D.)
- Suggestions related to implementation of road diets at new locations were developed based on the experience gained in completing this project and on the experiences elsewhere. (See also Appendix E.)

STUDY SITES

While the mechanism for selecting sites for inclusion in this study is addressed in more detail later in the report, Figure 1 on the next page shows the general location of the 24 sites that were analyzed plus the additional sites (in East Lansing) that were visited to observe pedestrian/bicyclist use.

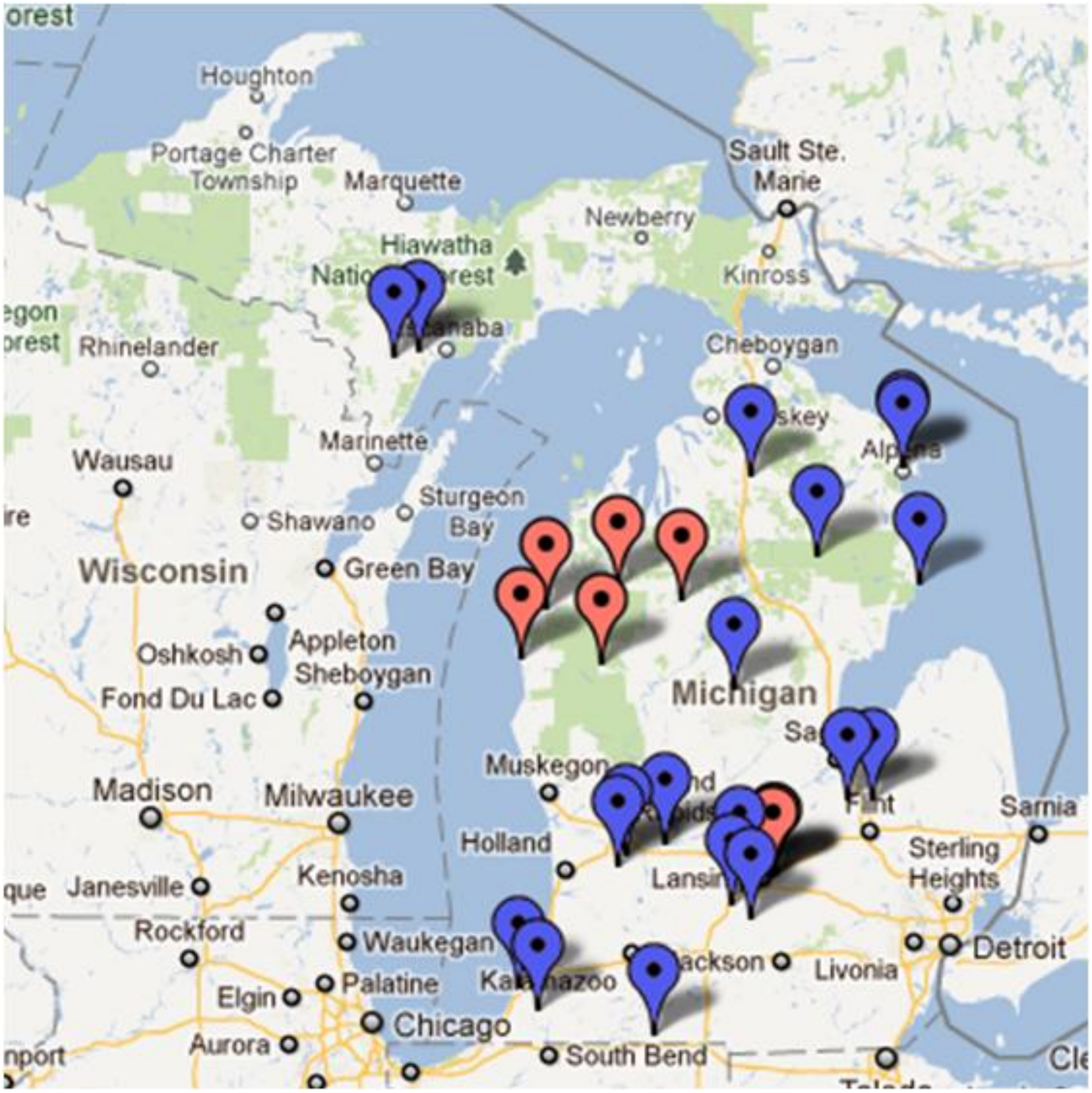


Figure 1. Study sites

The figure shows the sites that were used in the safety analysis in blue and, in red, the sites that were used in the safety analysis and visited as part of the review of pedestrian/bicyclist operations. The exception to the latter are the two (red) sites in East Lansing which were only part of the latter (the site markers overlap and are not visible in the figure). Graphical representations of each site are provided in Appendix F.

METHODS

Several different methods of analysis were utilized in this project and are briefly summarized below. Considerably more detail is provided in the appropriate section of the report.

- **Pedestrian and bicyclist operations.** These operations were qualitatively reviewed through on-site visits. Visual observations were made and recorded at several sites and some users were engaged in discussion although no formal survey instrument was used.
- **Operational analysis of road-diet sites.** Traffic operations of several road-diet sites were quantitatively assessed (using existing traffic data) to determine when potential level of service/delay issues occur when road diets are implemented. The widely-used Synchro software package was used to estimate delay and level of service for the selected sites under conditions of increasing traffic volumes. This was done to ascertain threshold values for when road diets may be contraindicated (from a delay/level of service perspective).
- **Safety-related analysis of road diet sites.** In the context of determining crash-modification factors (CMFs) for road diet implementation, before-and-after safety analyses were undertaken for several road diet sites. Both naïve and more sophisticated analyses were done including variations of case-control approaches where observed changes in overall and selected crash frequencies were controlled for background variation. Further details of these methods are presented in later sections of the report.
- **Acquisition of site information.** A straightforward survey instrument (Appendix G) was used to solicit information about tentative sites from MDOT and local agency personnel.

LITERATURE AND STATE-OF-PRACTICE REVIEW

The literature review included both a search of the traditional literature and a review of road-diet-related experiences in the field. The latter was identified from searching electronic media and following leads obtained from mailing lists and traffic professionals (several of whom could generally be perceived as "advocates" of road-diet-type projects). Some 33 different studies were reviewed for this project as well as several overarching reports. Details are provided in a study-by-study format in Appendix A.

Before discussing the literature, a point should be made about the variation in definition of various crash-related factors. Some practitioners/researchers use the term "accident modification factor" (AMF), while others simply refer to reductions in crashes or percent reductions, and still others use the now-standard "crash modification factor" (CMF). In this report, the latter terminology is used. So, in a comparison of before and after crash statistics, a CMF is correctly interpreted as that number which, when multiplied by the frequency of "before" crashes would give you the expected number of "after" crashes. Thus, the following apply:

- A typically-reported crash reduction percentage between before and after conditions (e.g., crashes were reduced by 15%) would be "converted" to a CMF as follows:

  CMF = 1 minus the percentage change.

  For example, if crashes were reduced by 15%, the CMF = 1 – 0.15 = 0.85. So, for positive improvements (crashes are reduced), the CMF < 1.0.

- If crashes increased, the percentage change (as normally reported) would be negative. In such a case the CMF > 1.0. For example, if crashes increased by 15%, the CMF is calculated as 1 – (-.15) or 1.15.

  The most interesting findings from the literature review can be summarized:

- As a general statement, crash reductions are experienced with most installations and are most typically reported as percentage changes (CMFs would be < 1.0). There is, however, significant variation in the magnitude of the reductions.

- While there appears to be significant "random variation," variation is also introduced because of the great variety in the before/after geometry and operating conditions (e.g., variation in ADT, existing left-turn driveway volumes and adjacent land uses). If the ADT is relatively low and there are few left turns, there is likely to be very little crash reduction; on the other hand, if there are many head-on/left turn crashes, crash reduction is more likely to be substantial. While head-on/left-turn and rear-end/left-turn crashes often are reduced, other crash types such as rear-end/straight in the right lane often increase because of the increased volumes in the right lane (due to the 2-to-1 lane reduction in a given direction).

- Most authors did not report estimates of CMFs per se. The most reliable estimates of CMFs are generally thought to be found on the FHWA-funded website "crash modification factors clearinghouse" maintained by the University of North Carolina Highway Safety Research Center [http://www.cmfclearinghouse.org/]. CMFs posted at this site have been vetted to some degree and a "star rating" is used as a measure of reliability. From that source, road diets are estimated to result in the following CMFs for unspecified roadway types in urban areas: all crash types/all severity levels = 0.63; all crash types/all injury crashes = 1.0; all crash types/property-damage-only (PDOs) = 0.54; angle crashes/all severity levels = 0.63-0.76; and rear-end crashes/all severity levels = 0.59. Based on another study (referenced at the same website), an estimated CMF for all crash types and all severities for minor urban arterials is 0.71.

- Many, if not most, studies were naive in that there was no control for background variation in crash trends. In virtually all areas, the general change in crashes at road diet locations must be somehow adjusted for overall decreases in crashes in the surrounding areas during the study period. Otherwise, too much of the changes in crashes may be attributed to the road diet.

- Travel speed decreases were reported for several studies as a result of road diet implementation. While this would be expected given the more restrictive geometry and a driver's inability to pass another vehicle, an unknown amount of the reduction could simply be due to lowered speed limits and/or increased enforcement.

- In addition to safety, road diets are also implemented as a part of other system changes such as an overall effort in traffic calming or as part of creating a pedestrian/bicyclist-friendly environment.

ON-SITE REVIEWS OF PEDESTRIAN AND BICYCLIST OPERATIONS

As part of the project, several road-diet sites were visited and operations were observed with primary attention being paid to pedestrian and bicyclist use/operations. The intention of this exercise was not to collect extensive quantitative information but rather to get a qualitative idea about how pedestrians and bicyclists are using road diets and their perceptions of how useful they are.

Since the goal was not necessarily to have a representative sample, the investigated road diet sites (see Figure 1 for general locations) were selected based on having "pedestrian/bicyclist safety" identified as one of the motivations for implementing the road diet project (as per responses to the data collection survey) and close proximity from site to site (so that they could be visited in a short time-frame). Five of the eight sites that were visited were located in the northwestern part of Michigan (Cadillac Transportation Service Center [TSC]) and the others were in the East Lansing area:

- M-37 in Baldwin from the US-10 junction extending approximately 200 ft. south of 9th Street;
- M-55/M-66 in Lake City from W Beeler Road to Union Street (Davis Road);
- M-37/M-115 in Mesick from the M-115/M-37 junction to Clark Street;
- US-31 in Manistee from the M-55 junction extending approximately 300 feet northeast of M-110;
- M-116 in Ludington from US-10 to approximately 500 feet north of Lowell Street;
- Burcham Road in East Lansing from Abbot Road to Timberlane Street;
- Abbot Road in East Lansing from Albert Avenue to Whitehills Drive; and
- M-43 in East Lansing from Michigan Avenue to 200 feet northwest of Audubon Road.

For the five sites located within the Cadillac TSC area, visits were conducted during a major holiday weekend (high use expected) to gain as much insight as possible regarding impressions of operations and safety. For the sites located in East Lansing, visits were done during peak usage hours during the day. The primary focus was to investigate pedestrian/bicyclist use and a secondary focus was to investigate pedestrian/bicyclist-motorist interactions. More detailed observations are provided on a site-by-site basis in Appendix B. The following remarks are based on all of the visits.

- Not surprisingly, a lack of pedestrian and bicyclist infrastructure along a road diet results in low levels of non-motorized use of the corridor. This was most evident at the Manistee site, which, despite listing pedestrian safety as a rationale behind conversion, did not have bike lanes or sidewalks over the length of the site.
- The two most notable characteristics of a well-functioning road diet with significant non-motorized use (besides simply having infrastructure) were the presence of pedestrian-oriented attractions and successful traffic calming:
    - Placement along corridors with commercial and pedestrian attractions:
        - The Lake City road diet was along a residential corridor of the road, just south of the city's commercial core. Despite having the infrastructure and observations being made during one of the busiest weekends of the year, there was very little pedestrian activity along the road diet, as there were no notable pedestrian-oriented attractions present; instead, all of the pedestrian activity took place north of the site, along the commercial strip of town.
        - The road diet in Baldwin ended just before reaching the main commercial district in town, therefore it had no apparent impact on pedestrian traffic.
        - While there was little activity observed during the visits to the Mesick site, it appeared (based on the signage, crosswalk locations, and proximity of a public school) that when school is in session, there is a reason for pedestrians and bicyclists to use the road diet infrastructure.
        - The Ludington site was adjacent to a public beach, which acted as a significant pedestrian generator for the road diet corridor.
        - The Burcham Road and Abbot Road sites in East Lansing both attracted a fair amount of pedestrian and bicyclist use by students from the nearby schools and Michigan State University (all of which were in session).

- Successful traffic calming:
  - Through observation and from conversations with local residents, the main cause of the increase in pedestrian usage of the Ludington site was the perception of “calmed” traffic. While the corridor has largely residential land use, the adjacent public beach had always acted as an attraction of pedestrians and bicyclists. Since the traffic was perceived to be moving more slowly (as a result of the road diet), the road was easier to cross and walk along, encouraging beachgoers to walk or bike there, rather than drive and use the parking lot.
  - Although the site in Baldwin was in a commercial area with pedestrian destinations, the road diet did not appear to be designed so that motorists perceived the need to slow down in the corridor, making it appear unsafe to cross or bike along.
  - At the Mesick site, even though the observed pedestrian traffic was low, the road diet appeared to have successfully calmed traffic—just by walking up and down the corridor, it seemed safe for pedestrian and bicyclist activity.
  - At the Burcham Road site, the local crossing guard remarked that she thought the road diet was unsuccessful at calming traffic, thus rendering the implementation somewhat of a failure.

- In several conversations with residents and in observations (both at various sites) of interactions between motorized and non-motorized traffic, it was apparent that there was an intentional lack of proper usage of the road diets by their users and/or a lack of knowledge of what usage is allowed.
  - Bicyclists were often observed riding on sidewalks rather than using the unmarked bike lanes. Pedestrians were also occasionally observed using bike lanes, even when there was an adjacent sidewalk. There appeared to be a better understanding of the purpose of bike lanes at the sites in East Lansing, where there were appropriate pavement markings.
  - There was a perceived lack of clarity regarding right-of-way at crosswalks along the road diets. Typically, motorists correctly assumed they had the right of way;

residents complained, however, that crossing was difficult when vehicles did not routinely yield to pedestrians (most notably in Ludington) even though the motorists actually had the right of way.

- Motorists occasionally used the two-way left-turn lane (TWLTL) as a waiting (or acceleration) lane in making left turns from a driveway or side-street onto the road diet.
  - On occasions when the TWLTL was used as a waiting/acceleration lane to turn into the far moving lane, motorists in the far lane appeared indecisive, perhaps thinking they were about to be cut off.
  - On a few occasions, motorists were seen making left turns from the right moving lane, rather than moving into the TWLTL and then making the left.

While generally "common sense," the following overarching comments are based on the on-site visits to (qualitatively) assess pedestrian/bicyclist use of road diet sites:

- provisions for pedestrians and bicyclists are most important when there are existing pedestrian/bicyclist generators on the site and/or when the road diet is part of a larger plan for an area;
- if pedestrian/bicyclist provisions are included in the road diet area, they need to be clearly and consistently marked; and
- there appears to be a need for additional information/education regarding appropriate use of the road and pedestrian/bicyclist facilities at road diet sites (by both pedestrians/cyclists *and* motorists), including the use of signs clearly indicating crosswalks and bike lanes at road diet sites.

OPERATIONAL ANALYSIS OF SEVERAL ROAD-DIET SITES

The objective for the operational analysis was to determine if there was a common traffic volume at which the 4-to-3 lane conversion will "fail" from a traffic operations perspective (e.g., level of service [LOS] will drop to D or below). The general rule of thumb is that a road diet should not be implemented when ADT exceeds 20,000 vehicles per day. Since the peak hour is not necessarily always the same fraction of ADT (e.g., in a tourist-oriented area, there may be a more uniform flow over the course of a day), the approach taken for this project was to look at the volume that leads to failure over the course of an hour. Examination of the limits of the traffic volume for which a road diet is appropriate is important since it is a question that typically comes up when road diets are proposed—e.g., will the lane reduction cause congestion; what happens when capacity is reduced?

The conversion of 4-lane to 3-lane sections will impact traffic operations in terms of intersection approach delay. The question is: At what volume does this degradation result in failure of the 3-lane section? To investigate this, a basic operational analysis was conducted using Synchro. The measure of effectiveness (MOE) used to evaluate and compare the operational differences between 4-lane and 3-lane sections for a given traffic volume was approach delay in sec/veh.

Nine signalized intersections from five study sites were used for analysis and are shown in Table 1. The existing data for signal timing, phases and peak hour traffic volumes, along with intersection geometry were obtained and used for the Synchro models.

Table 1. Sites/intersections used for Synchro analysis

Site #	County	City	Intersection
1	Alpena	Alpena	US-23 @ 11th Ave
8	Eaton	Charlotte	Lansing Rd @ Hall St/ Island Hwy
9	Eaton	Eaton Rapids	M-99 @ State St
			M-99 @ Knight St
			M-50 @ Canal St/Brook St
11	Genesee	Clio	M-57 @ Mill St
			M-57 @ Plaza Dr
13	Genesee	Montrose	M-57 @ Saginaw St
			M-57 @ Seymour Rd

The volumes for AM and PM peak hours were obtained, and the analysis was conducted for the worst case (i.e., the higher overall volume). In all instances, the PM peak hour was highest. The existing turning volume percentages for each approach were determined and held constant throughout the analysis. An analysis of existing conditions was done for each site and results were checked for any major issues such as high delay or queue length values (there was none). Once baseline conditions were established, each intersection was then subjected to increasing increments of mainline (road diet) volume to determine when "failure" would occur. The volume increments were 750, 1000, 1250, 1500, 1750, and 2000 vph.

The following assumptions were made:

- The volume increments were for the mainline road-diet approaches only instead of all four legs to avoid a rapid decline in intersection performance at relatively low volumes. In most instances, the non-road-diet approaches were already 3-lane sections and increasing their volumes by the same level would have made the intersection difficult to operate.
- Since it was desired to check the behavior of a 4-to-3-lane conversion at specific traffic volumes, the volume on those approaches was not increased by a fixed percentage, but rather by the same magnitude on both intersection approaches with the road diet.
- The existing signal phasing was used for the study; however, in some cases where the turning volumes were high (>100 vph) a turning bay or storage lane was provided to avoid interference with the mainline traffic. Without storage lanes, the approach delay exceeded LOS F (>80 sec/veh) at very low mainline volumes which was not realistic.
- The signal timings and splits were optimized for each mainline increment to obtain the minimum intersection delay.
- No parking was allowed on any of the intersection approaches.
- A heavy-vehicle percentage of 2% was used throughout. While in some cases this was a bit different from actual data, 2% was used for a uniform comparison.
- The upper limit of LOS D (55 sec/veh delay) was used as a threshold.

The approach delay vs. mainline volume increments (for each road-diet approach) were plotted for all intersections and visually examined to determine the critical volume associated with "failure." See the figure below for an example and Appendix C for results from all sites.

The graph below (Figure 2) shows the approach delay for both 4- and 3-lane sections (existing conditions [blue line] and road diet [red line]) as the mainline volume is varied from 750 to 2000 vph for a signalized intersection at site 9 (northbound direction). In this instance, the approach delay is less then 20 seconds/vehicle for both types of road when the mainline volume is less than 1000 but performance begins to degrade more rapidly for the 3-lane section for mainline volumes of 1250 and 1500 and very quickly beyond that. Graphs similar to this one are shown in Appendix C for each of the sites analyzed.

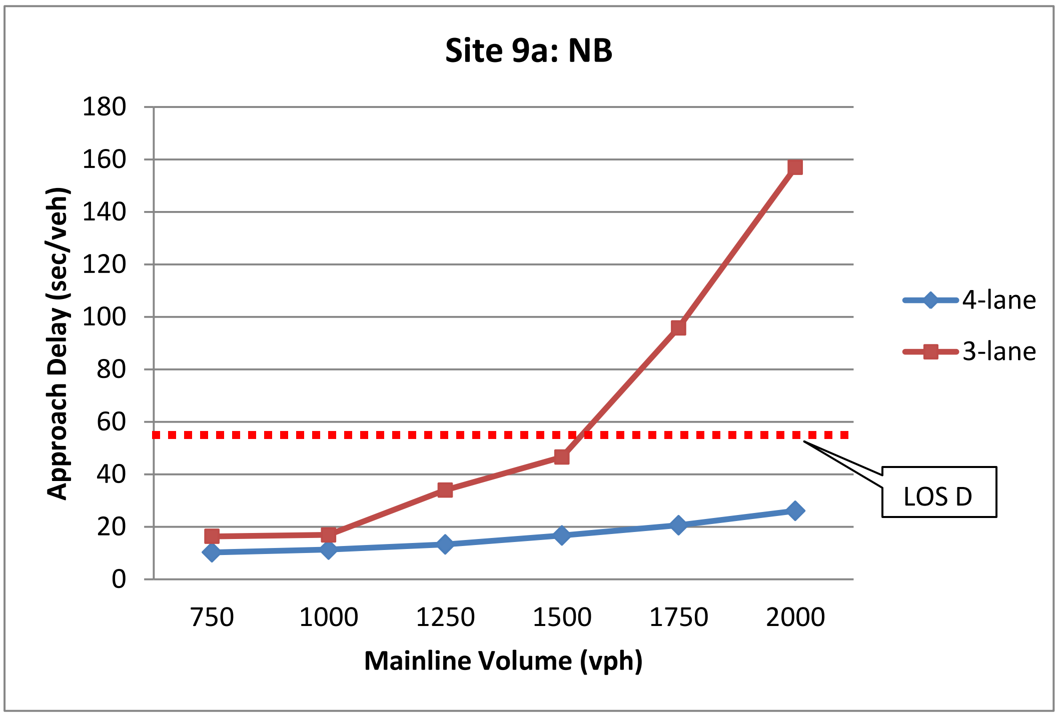


Figure 2. Typical results of approach delay versus mainline volume increments

The results (for all analyzed sites) indicate that for all cases, the approach delay for a road diet stays similar to the 4-lane section up to a mainline volume of approximately 1000 vph. When the mainline volume is increased from 1250 to 1500 vph, for most cases the approach delay for 3-lane sections increases and approached LOS D. It should be noted that the delay results for the two different approaches (e.g., NB vs. SB) for a single intersection may be different. For example, for site 9 (Eaton Rapids), the intersection of M-50 (road diet) and Canal Street/Brook Street has very different delay thresholds for the 3-lane sections for the two approaches. This is attributed to heavy left-turn volume for one approach. Notwithstanding such differences, for most cases the trends are similar for both approaches if the turning volume patterns are similar. For all the 4-lane cases, the approach delays are relatively low and typically stay below the 55 sec/veh threshold for volumes up to ~2000 vph. An obvious reason for this "better" performance for 4-lane sections is more capacity; however, another factor could be the use of turning bays at the intersections and corresponding optimized signal timings. If there are no storage or turning lanes, the approach delay would increase significantly for 4-lane sections.

Table 2 shows a summary gleaned from the results of the Synchro analysis (over all six sites). In general, if the mainline volume increased beyond an interpolated value of 1000-1100 vph for these sites (consistent with the other assumption showed above), the conversion from 4-lane to 3-lane sections will typically have a negative impact on the traffic operations in terms of approach delays. Using a K factor of 0.10 for conversion from peak hour to ADT yields an ADT of 10-11,000 veh/day. This is considerably lower than the 20,000 ADT which appears to be a widely used rule of thumb. The results here suggest that an ADT of greater than 10,000 would be a better figure to use as a critical ADT where a road-diet conversion for a particular site requires detailed operational evaluation. For all of the 3-lane study sections, the average mainline volume was 1500 vph (corresponding ADT of 15,000 vpd) at which the approach delay reached the threshold of 55 sec/veh.

A corridor-level operational analysis study using microscopic simulation models (e.g., VISSIM) would provide an even more detailed evaluation of the operational impacts of a proposed road diet. More detained operational analysis can incorporate multiple factors (e.g., varying levels of heavy traffic volumes, turning movements at the intersection).

Table 2. Interpolated mainline volumes (vph) when approach delay ≥ 55 sec/veh (≥LOS D)

Site #	County	City	Intersection	Interpolated Mainline Volume at Threshold Delay (≥ 55 sec/veh)			
				4-lane		3-lane	
1	Alpena	Alpena	US-23 @ 11th Ave	SB		SB	
				-		1750	
8	Eaton	Charlotte	Lansing Rd @ Hall Street/ Island Highway	NE	SW	NE	SW
				-	-	1600	1550
9	Eaton	Eaton Rapids	M-99 @ State Street	NB	SB	NB	SB
				-	-	1550	1550
			M-99 @ Knight Street	NB	SB	NB	SB
				-	-	1350	1350
			M-50 @ Canal Street/Brook Street	SE	NW	SE	NW
				-	1750	1850	1100
11	Genesee	Clio	M-57 @ Mill Street	EB	WB	EB	WB
				-	-	1150	1300
			M-57 @ Plaza Drive	EB	WB	EB	WB
				-	-	1300	1800
13	Genesee	Montrose	M-57 @ Saginaw Street	EB	WB	EB	WB
				-	-	1350	1650
			M-57 @ Seymour Road	EB	WB	EB	WB
				-	-	1700	1650

The important summary points from the operational analysis include the following:

- The operational analysis of the several sites provide reasonably consistent results and support guidelines that suggest that 4-to-3-lane road diet conversions become problematic for **ADTs greater than 10,000**.
- More importantly, 4-to-3-lane road diet conversions result in increased delay for **peak hour volumes between 1,000 and 1,500**.
- However, it is clear that "local" conditions (e.g., varying geometry, variation in turning movements, and variations in cross-street traffic) can have a significant impact on the viability of any proposed road diet. Thus, while an initial culling for potential road diet sites can be accomplished using the general guidelines above, in all instances a detailed operational analysis of the corridor (including operations at each intersection) for both

4- and 3-lane sections should be undertaken before the proposed road diet conversion is implemented.

A SAFETY-RELATED ANALYSIS FOR SELECTED 4-TO-3 LANE ROAD DIETS

The overarching purpose of the project was to estimate a crash modification factor (CMF or CMFs) that could be used to estimate crash savings that result from the implementation of 4-to-3-lane road diets in Michigan. From the outset it needs to be clear that road diets can have any of the following results (or combinations of results):

- decreases in crashes since, for example, left-turning vehicles are moved out of a through lane and into the reserved turning lane (the TWLTL) at mid-block non-intersection locations;
- increases in crashes since two lanes of through vehicles are moved into a single through lane (e.g., rear-end crashes in the right-hand lane become more likely simply due to higher volumes in the lane);
- decreases in pedestrian and bicyclist crashes because of the provision of better infrastructure for these users; and
- increases in pedestrian and bicyclist crashes since such users/trips are attracted to the improved infrastructure.

In addition, crash increases or decreases can vary substantially given the prevailing ADTs, road usage patterns, adjacent land uses (e.g., are there pedestrian/bicyclist attractors adjacent to the road diet site), turning volumes (especially mid-block), peak hour characteristics, and type of area (e.g., tourist area, university campus, small town) among others. Finally, background variation in crash frequencies (e.g., all crashes are steadily decreasing in a particular city) must be considered when trying to isolate the effect of a road diet.

The point is that there is likely to be significant variation in existing conditions prior to the implementation of a road diet. Crash savings (if there are any) are, likewise, likely to vary substantially with all of these variables.

In this section, the development of a crash modification factor (CMF) for selected 4-to-3 lane road diet sites in Michigan is documented:

- first, site selection is reviewed;
- next, data collection and reduction (e.g., reclassification of crash types) are discussed;
- then, the data analysis is presented including consideration of various methods for controlling for background trends in crash history; and,
- finally, a general CMF for road diets in Michigan is presented.

SITE SELECTION

Site selection for this project was developed through a general solicitation of sites from various MDOT personnel (e.g., TSC and/or regional traffic engineers) and local agencies. MDOT personnel had developed a tentative contact list which was supplemented with suggestions from others. A survey (see Appendix F) was sent to the list with the purpose of identifying potential sites, locations of the road diets, basic information about the site (e.g., type of road diet such as 4-to-3 lane reductions), the reasons for implementing the road diet, start and end dates for the actual implementation, and other basic data. Some 43 initial sites were eventually identified via the survey. Although it had originally been envisioned that different types of road diets might be included in the study, review (with MDOT) of the set of sites that emerged from the survey led to the conclusion that the study be limited to the "standard" 4-to-3 lane road diet conversions.

Some sites were eliminated because they were too recent to have adequate (three years) "after-implementation" data. Other sites were too old to have crash data that were consistent with data for all other sites. Other reasons for eliminating sites included: length too short, other recent site changes, inconsistent or no ADT data, and on-street parking allowed. For the final analysis, a total of 24 sites were generally used. For some of the analysis (e.g., on-site visits to observe pedestrian/bicyclist operations) some older sites were used while for other parts of the analysis, some of the 24 were not used. The latter is discussed in more detail below. Locations of all of the sites (including some that were only visited) were shown earlier in Figure 1. A copy of the spreadsheet for each of the 24 sites used in the crash analysis is in Appendix D.

DATA COLLECTION AND REDUCTION

Once the sites had been identified and agreed-upon, crash data were retrieved for each site (both for the mainline and cross streets near the intersections) as were ADT and other traffic data (e.g., turning data for some sites for the operational analysis). In addition to the electronic crash records, the "hard copies" of all of the relevant UD-10s were retrieved so that the actual crash diagram and narrative could be examined for each crash. This allowed, for example, for a determination of whether cross-street crashes were correctly assigned to the intersection or the cross street itself (and back from the intersection)—i.e., were these crashes at all associated with the road diet.

In addition, crashes were "reclassified" using a more-detailed assignment so that the effects of the road diets could be more accurately assessed. An example of this "reclassification" is assigning a rear-end/straight crash to the right or left lane during the "before" period. Further, crash categories were classified as whether they were expected to be: 1) "correctable" by a road diet (e.g., a rear-end left-turn crash in the left lane which should be corrected with a road diet since the turning vehicle would be out of the regular travel lane as a result of the road diet); or 2) affected by the road diet (e.g., rear-end crashes in the curb lane might increase). Note that while "correctable" crashes are a benefit, the affected crashes might either increase or decrease. Details of the reclassification scheme can be seen in Appendix G.

During the review of the crash data, some crashes were eliminated from consideration in the subsequent analysis. For example, if the crash didn't have anything to do with the roadway or its geometry, it was eliminated. Examples of such an elimination include a crash where a driverless vehicle rolled out of a driveway and crossed the entire roadway before crashing; and another where a police traffic stop resulted in the admission by the (inebriated) driver that she had been involved in a crash "somewhere" within the preceding hour or so, and the crash was coded to the street where the stop occurred. Other crashes that were eliminated included those with animals, those that occurred during (any) construction, and those that occurred on (or were otherwise attributable to) the side streets.

DATA ANALYSIS

Once all of the data had been prepared and reconciled, the analysis was relatively straightforward except for the control for background trends. The data used for any site is illustrated in the spreadsheet on the next page (site 11). Copies of the spreadsheets for all 24 sites are in Appendix D.

With reference to the information shown on the next page, the top section contains a summary of the basic **site characteristics** for site 11 (e.g., county, city, road name). The next section contains the **descriptive statistics** which include the basic crash frequencies by before and after period (and further broken down by year) as well as all of the crash information for background trends (e.g., crashes for the city and county over the same time period). The third section shows a **naïve before/after crash analysis** (no correction for trends) including a graphical representation of the crash frequency by year for the site. The fourth section shows the **before/after crash analysis with a simple adjustment for various background trends**. The final section (only available for some sites) shows the **before/after crash analysis adjusted for trends of an untreated comparison group**. Each of these sections is discussed in more detail in the following paragraphs.

Site characteristics, in addition to simple identification of the site, are also used for grouping similar types of sites when the CMF is developed—for example, the number of driveways, intersections, and average daily traffic (ADT).

Descriptive statistics include all of the basic crash information for the site. For each site, three-year before and after windows are shown. While, in most, if not all, instances the construction duration was short-lived, the crash data for the entire year during which the construction/implementation of the road diet occurred are eliminated from the analysis. Thus, each year in the before-after window for every site is a full calendar year and all before-after comparisons are based on three full years before and after the construction year. This eliminates any issues with one site being completed in the spring while another is completed in the fall. In addition to the overall crash frequencies, crash data are also broken down by

Site Characteristics

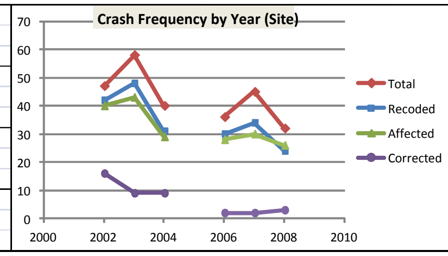
Site No.	11	Length (mi)	1.46
County	Genesee	Land Use	Mixed commercial-residential
City	Clio	No. of Driveways/Intersections	80/12
Route/Road Name	M-57	Treatment Type	Repaving within existing curbs with new markings
PR/CS No.	1494503/25101		
BMP	9.400	Nearest Cross Street	Washington St.
EMP	10.856	Nearest Cross Street	Liberty St.

Descriptive Statistics

	Before Period			After Period		
Year	2002	2003	2004	2006	2007	2008
ADT	14628	14614	14892	13726	13466	16108
Crash Frequency (Total)	47	58	40	36	45	32
Crash Rate	6.05	7.47	5.05	4.94	6.29	3.74
Crash Frequency (Recoded)	42	48	31	30	34	24
Crash Frequency (Intersection-related)	5	8	3	5	5	6
Crash Frequency (Driveway-related)	10	5	7	2	6	0
Crash Frequency (Affected by Road Diet)	40	43	29	28	30	26
Crash Frequency (Corrected by Road Diet)	16	9	9	2	2	3
Crash Frequency (Background, Countywide)	14306	14066	13285	10458	10701	10180
Crash Frequency (Background, Citywide)	44	63	46	43	44	43
Crash Frequency (Background, Trunklines-Countywide)	1854	1854	1752	1400	1321	1218
Crash Frequency (Background, Trunklines-Citywide)	33	39	24	18	30	20

Crash Analysis Method: Simple (Naïve) Before/After Analysis

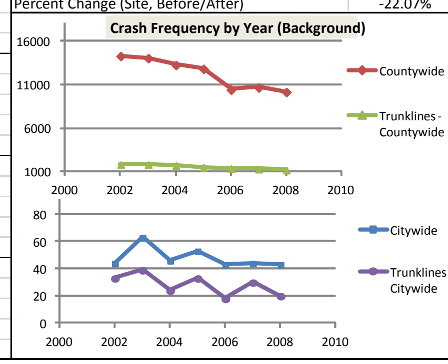
Average Crashes per Year (Before)	48.33
Average Crashes per Year (After)	37.67
Percentage Change	-22.07%
Average Crashes per Year (Recoded, Before)	40.33
Average Crashes per Year (Recoded, After)	29.33
Percentage Change	-27.27%
Average Crashes per Year (Affected, Before)	37.33
Average Crashes per Year (Affected, After)	28.00
Percentage Change	-25.00%
Average Crashes per Year (Corrected, Before)	11.33
Average Crashes per Year (Corrected, After)	2.33
Percentage Change	-79.41%



Crash Analysis Method: Before/After Comparison with Background Trends

Background Area Location (County, City)	
Average Crashes per Year (Countywide, Before)	41657
Average Crashes per Year (Countywide, After)	31339
Percentage Change Overall Countywide	-24.77%
Projected Average Crashes per Year using Countywide Background (Site, After)	36.36
Percent Change for Site Adjusted for Countywide Background	2.70%
Average Crashes per Year (Citywide, Before)	153
Average Crashes per Year (Citywide, After)	130
Percentage Change Overall Citywide	-15.03%
Projected Average Crashes per Year using Citywide Background (Site, After)	41.07
Percent Change for Site Adjusted for Citywide Background	-7.04%
Average Crashes per Year (Trunklines-Countywide, Before)	5460
Average Crashes per Year (Trunklines-Countywide, After)	3939
Percentage Change Overall Trunkline-Countywide	-27.86%
Projected Average Crashes per Year using Trunklines-Countywide Background (Site, After)	34.87
Percent Change for Site Adjusted for Trunklines-Countywide Background	5.79%
Average Crashes per Year (Trunklines-Citywide, Before)	96
Average Crashes per Year (Trunklines-Citywide, After)	68
Percentage Change Overall Trunkline-Citywide	-29.17%
Projected Average Crashes per Year using Trunklines-Citywide Background (Site, After)	34.24
Percent Change for Site Adjusted for Trunklines-Citywide Background	7.10%

Average Crashes per Year (Site, Before)	48.33
Average Crashes per Year (Site, After)	37.67
Percent Change (Site, Before/After)	-22.07%



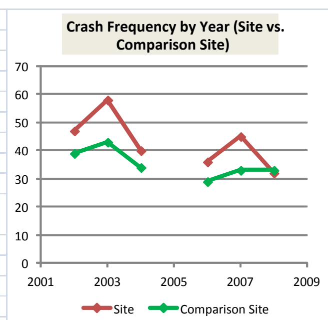
Crash Analysis Method: Before/After with Comparison Group

Comparison Site Location (County, City)	Shiawassee, Owosso	Route/Road Name	M-52
PR/CS No.	551706		
BMP	16.299	Nearest Cross Street	Main St.
EMP	17.759	Nearest Cross Street	Laura Ln.

Descriptive Statistics	Before Period			After Period		
Year	2002	2003	2004	2006	2007	2008
Crash Frequency (Total)	39	43	34	29	33	33

Crash Modification Factor Computation

Sample Odds Ratio (year 1-2)	0.86	
Sample Odds Ratio (year 2-3)	1.09	
Mean of Sample Odds Ratios	0.98	
Standard Error of the Sample Odds Ratios	0.17	
95% Confidence Interval of the Sample Odds Ratio [LL, UL]	0.65	1.30
N-observed,T,B [total observed no. of crashes in before period for treatment group]	145.00	
N-observed,T,A [total observed no. of crashes in after period for treatment group]	113.00	
N-observed,C,B [total observed no. of crashes in before period for comparison group]	116.00	
N-observed,C,A [total observed no. of crashes in after period for comparison group]	95.00	
N-expected,T,A [expected no. of crashes that would have occurred in after period w/out treatment]	118.75	
Variance of N-expected,T,A	367.25	
Crash Modification Factor (CMF)	0.93	
Variance of CMF	0.03	
Standard Error of CMF	0.17	
95% Confidence Interval of the CMF [LL, UL]	0.60	1.26



whether they are intersection- or driveway-related and whether they are correctable or affected. Background data for assessing citywide and countywide trends are also shown. Finally, citywide-trunkline and countywide-trunkline trends are also shown. These can be used to "adjust" the basic before-after comparisons for background trends/variation (addressed below).

The **naïve before/after crash analysis** is a simple comparison of the three-year before and after crash frequencies. (Again, note that percentage reductions [in crashes] are discussed here—the percentage reductions in crashes can be converted to CMFs using the formula where the CMF = 1 – [percent reduction].) A percentage change (based on the before period) is also shown. In addition, similar numbers are shown using recoded crashes and then limiting the crash types to those that are presumed to be affected or correctable by the road diet. A graphical comparison of before and after frequencies is also shown (for total crashes, recoded crashes, affected crashes, and correctable crashes). It should be noted that the results shown for site 11 are fairly typical:

- Considerable year-to-year variation in crash frequencies are noted during both the before and after periods.
- In general, the crash frequencies are lower in the after period than during the before period. If there was no background variation, this would suggest that road diets result in significant crash reductions, regardless of which general group of crashes is examined.
- Crash reductions for "correctable" (by a road diet) crashes are the most substantial—a not-unexpected outcome.

The **before/after crash analysis with a simple adjustment for various background trends** is a consideration of the proposition that some of the observed reduction in crash frequencies is not because of the road diet but rather due to other causes (which may not be known). Background trends are shown for the county in which the road diet is located, for the city, and considering trends in only trunkline crashes for both the county and city. The trunkline trends were added since most of the road diets to be analyzed were on trunklines.

Various arguments can be made for which background trend "best" represents the overall environment for the road diet. After considering all of the sites, it was decided that the citywide trend is the most reasonable and realistic to use as the indicator of what else is occurring in the background of the implementation of the various road diets. The county level includes many roads that are quite different (in design and use) from those being "dieted" and, in some instances, may even include other larger urban areas. For this reason, the countywide data are not considered as representative as the citywide data. In addition, for some sites (in smaller cities), the trunkline category may primarily consist of the road diet site. Thus, the following analysis is based on using the "city trend" as indicative of the environment in which the road diet is undertaken. In each instance, the adjusted percentage change is also shown. That is, what is the effect of the road diet after considering (subtracting out) the background trend. Again, what is shown for site 11 is fairly typical of other results (see Appendix D for all sites):

- There is some year-to-year variation in background trends (i.e., the trend lines shown are not flat or monotonically increasing or decreasing).
- Notwithstanding year-to-year variations, the overarching background trends are that crash frequencies are decreasing.
- The simple (naïve) before-after trends associated with road diet implementation need to be adjusted for the general downward trend in crash frequency being experienced in the various cities where road diets were implemented.
- A considerable portion of the reduction in crash frequency that would be attributed to the road diet under a naïve scenario is accounted for by the background trend. For example (considering site 11 as shown), the average number of crashes per year is reduced from 48.3 to 37.7 or ~22% for the road diet site; but citywide crashes decreased from 153 to 130 or ~15%. Thus, much of the reduction on the road diet site is presumably attributable to the background trend—the modified crash reduction due to the road diet is reduced to ~7% (which corresponds to an adjusted CMF of 0.93).

The **before/after crash analysis adjusted for trends of an untreated comparison group** (last section in the example shown) is another attempt at controlling crash reduction for background trends. In the narrative here, the term CMF is used. As noted earlier, a CMF is used to estimate the number of crashes expected at a site following the implementation of a countermeasure or treatment. In addition to the naïve before/after analysis and comparison with background crash trends, the CMFs for each of the 24 project sites were computed. FHWA's 'A Guide to Developing Quality Crash Modification Factors' (Gross et al., 2010) provides several methods to compute crash modification factors and functions including before/after with comparison sites, empirical Bayes, and full-Bayes studies. While these (and other) methods differ primarily in statistical approach to modeling the crash data, a fundamental requirement for most methods is the availability of data for a group of "comparison sites" which are very similar to the "treatment sites" in physical and operational aspects.

To conduct a before/after analysis with a comparison group, comparison sites were identified using various characteristics such as length of road diet, area type (residential, commercial, or mixed), driveway and intersection density, number of lanes in the before period (including similar bike/pedestrian facilities), treatment year, and ADT. Given the practical difficulties in achieving ideal pairs of comparison and treatment sites, this exercise resulted in the identification of 17 potential comparison sites for 9 of the 24 treatment sites (multiple comparison sites were identified for six treatment sites). Crash data for comparison sites in the before period were then extracted to ascertain suitable matches with specific treatment sites.

In order to determine the suitability of the treatment-comparison pairs, sample odds ratios were computed using the crash data in the before period. The mean, standard error, and 95% confidence intervals of the sample odds ratios were computed to determine if crash frequencies at the comparison site were statistically similar to the treatment site in the before period. This crash data comparison further reduced the number of suitable comparison sites to five to match with the following treatment sites: 1, 3, 8, 11 (shown above), and 13.

For the five treatment sites for which the sample odds ratios resulted in viable comparison sites, the expected number of crashes that would have occurred in the after period without treatment (N-expected,T,A) was computed. The CMF was then computed based on the observed number of crashes in the after period for treatment sites (N-observed,T,A) N-expected,T,A, and the variance of N-expected,T,A (Gross et al., 2010). The variance, standard error, and 95% confidence interval of the CMF were also computed.

The CMF for site 11 (see above) was computed to be 0.93 with a 95% confidence interval of 0.60-1.26. Since the confidence interval includes the value of 1.0, it cannot be stated with 95% confidence that the true value of the CMF is not 1.0. In other words, the treatment did not have a statistically significant effect in reducing the crashes at this site. By way of comparison, the naïve before/after analysis shows a decrease of ~22%, and comparison with background crashes shows a range from a **~7% reduction** when adjusted for citywide crashes to an **increase of ~7%** when adjusted for citywide trunk line crashes. A graphical illustration of the crash trends for site 11 and the comparison site is also shown.

For site 1 (see Appendix D), the CMF was computed as 0.98 with a 95% confidence interval of 0.62 and 1.35. Again, since the confidence interval contains the value of 1.0, it cannot be stated with 95% confidence that the true value of the CMF is not 1.0. In other words, the treatment did not have a statistically significant effect in reducing the crashes at this site. While the naïve before/after analysis shows a decrease of 15.6%, the uncertainly of the treatment effect is somewhat evident from the comparison with background crashes where the effect of treatment yields a reduction of 6.11% when adjusted for countywide crashes, and shows an increase of 6.07% when adjusted for citywide crashes.

For site 3 (see Appendix D), the CMF was computed to be 0.83 with a 95% confidence interval of 0.58 and 1.07. The results relative to the confidence interval are the same as above. The naïve before/after analysis shows a decrease of 34.03%, and comparison with background crashes shows a wide range from 20.58% reduction when adjusted for countywide crashes, and a reduction of only 2.34% when adjusted for citywide trunk line crashes.

The CMF for site 8 (see Appendix D) was computed to be 0.97 with a 95% confidence interval of 0.61 and 1.33. Again, these results are similar to those noted above. The CMF for site 13 (see Appendix D) was computed to be 0.80 with a 95% confidence interval of 0.48 and

1.12, so the results are similar. Overall, the CMFs computed using the before/after analysis with comparison groups were not found to be significant for any site.

The outcome of the exercise using comparison sites to adjust the percentage of crash reductions and/or the CMFs was somewhat disheartening. While it seems intuitively clear that there is some reduction in crashes due to road diets, the results of the most-detailed analysis indicated that it was not statistically significant. However, that analysis is highly dependent on the comparison sites that were selected. It was impossible to find sites that were an exact match for the road diets studied, notwithstanding some measure of statistical fit. Roadway segments upstream and downstream from the road diets were considered as were parallel routes; all to no avail. Sites in different locations were considered and those chosen were the "best possible," but far from perfect. The dilemma was whether to go forward with developing recommended CMFs which may not be statistically defensible. The decision was to go forward and, to the extent possible, develop CMFs based on citywide trends in crashes during the before and after periods. The caveat regarding the suitability of comparison groups being noted.

ESTIMATION OF CMFs AND DISCUSSION

As noted, the site-by-site results (as discussed above) for all 24 sites are presented in Appendix D. These results were synthesized to get a general result that could be used by MDOT as a guideline for what might be expected to result from a road diet implementation. Further work was also done to examine trends in crash severity.

The tasks below were completed to develop CMFs; the results are shown in the summary spreadsheets in the appendix. An abbreviated version of that spreadsheet (showing CMFs) is shown on the next page (Table 3). These spreadsheets contain the results from the following tasks:

- Site-by-site calculations were done as described above.
- A summary of selected site characteristics was prepared for each site and included:
    - site number,

Table 3. Abbreviated summary of CMF-related data

Summary/synthesis for crash analysis (CMFs)

							CMF correction factors											
site	~ADT	length (miles)	~avg annual crash	# of drivwys	# of intersecs	type	based on county trend	based on city trend	based on trunkline county trend	based on trunkline city trend	**basic CMF**	basic CMF corrected by city trend	**CMF based on recoded crashes**	recoded CMF corrected by city trend	**CMF for affected crashes**	affected CMF corrected by city trend	**CMF for corrected crashes**	corrected CMF corrected by city trend
1	13442	0.37	34	19	4	com	0.91	0.78	1.07	0.84	0.84	1.06	n/a	n/a	n/a	n/a	n/a	n/a
2	13261	1.44	41	26	17	com	0.98	0.56	0.88	0.47	0.47	0.91	0.47	0.91	0.39	0.83	0.13	0.56
3	10965	4.33	53	100	35	res	0.87	0.73	0.87	0.68	0.66	0.93	0.62	0.90	0.59	0.86	0.30	0.57
4	11062	0.53	3	16	8	com	0.78	0.63	0.83	0.72	0.36	0.72	0.18	0.55	0.22	0.59	1.00	1.37
8	14328	0.81	39	49	7	com	0.81	0.68	0.79	0.66	0.79	1.11	0.79	1.10	0.81	1.12	0.21	0.53
9	17020	0.43	38	16	8	com	0.81	0.60	0.78	0.54	0.46	0.86	0.45	0.86	0.52	0.92	0.33	0.74
11	14572	1.46	43	80	12	mix	0.75	0.85	0.72	0.71	0.78	0.93	0.73	0.88	0.75	0.90	0.21	0.36
13	9016	1.31	25	97	11	mix	0.84	0.64	0.83	0.51	0.61	0.98	0.56	0.92	0.50	0.86	0.15	0.51
16	12342	0.87	24	58	8	res	0.84	0.84	0.83	0.90	0.49	0.65	0.31	0.47	0.30	0.46	0.27	0.43
18	7137	0.96	5	55	6	res	0.76	0.80	0.71	10.43	0.80	1.00	0.77	0.97	0.83	1.04	0.17	0.37
20	12639	0.68	7	34	9	res	0.80	0.69	0.75	0.79	0.60	0.91	0.69	1.00	1.43	1.74	0.40	0.71
22	7663	0.22	6	12	3	com	0.93	0.47	0.77	0.41	0.52	1.05	n/a	n/a	n/a	n/a	n/a	n/a
23	14652	0.50	20	23	9	com	0.72	0.76	0.78	0.93	0.69	0.93	0.75	0.99	0.86	1.10	0.36	0.60
25	6512	0.79	10	38	4	res	0.81	0.71	0.89	0.72	0.59	0.88	0.58	0.87	0.88	1.16	0.80	1.09
26	10855	0.58	4	39	5	res	0.95	0.87	0.97	0.96	0.44	0.57	0.11	0.24	0.22	0.35	0.00	0.13
29	10747	0.49	7	30	4	res	0.78	0.79	0.86	0.83	0.32	0.53	0.40	0.61	0.24	0.44	0.00	0.21
30	7676	0.38	10	25	8	mix	0.76	0.76	0.80	0.90	0.76	1.00	1.50	1.74	0.69	0.93	0.30	0.54
33	7049	0.69	10	19	6	mix	0.81	0.53	0.87	0.67	0.51	0.98	0.59	1.06	0.67	1.13	0.33	0.80
34	7719	0.46	6	22	2	com	0.79	0.67	0.76	0.29	0.64	0.97	0.56	0.89	0.62	0.95	0.20	0.53
36	4995	0.86	5	42	5	mix	0.76	0.72	0.69	0.00	0.52	0.80	0.43	0.70	0.42	0.69	0.13	0.40
37	14164	0.30	10	4	4	com	0.87	0.88	0.81	0.91	0.49	0.61	0.68	0.80	0.50	0.62	0.33	0.46
39	n/a	0.39	19	14	5	res	0.81	0.69	0.91	0.77	0.48	0.79	0.81	1.13	0.92	1.23	0.24	0.55
40	3510	0.50	6	31	7	com	0.65	0.71	0.62	0.68	1.40	1.69	2.00	2.29	0.60	0.89	0.67	0.96
43	13660	0.62	46	27	11	mix	0.97	0.94	0.91	0.78	0.89	0.95	n/a	n/a	n/a	n/a	n/a	n/a
average	10652	1	20	37	8		0.824	0.721	0.821	1.088	**0.630**	**0.91**	**0.67**	**0.95**	**0.62**	**0.90**	**0.31**	**0.59**
std dev	3587.02	0.82	16.09	25.54	6.62		0.080	0.115	0.096	2.002	0.225	0.23	0.42	0.42	0.29	0.31	0.25	0.28
max	17020	4	53	100	35		0.978	0.936	1.073	10.429	1.400	1.69	2.00	2.29	1.43	1.74	1.00	1.37
min	3510	0	3	4	2		0.648	0.467	0.616	0.000	0.323	0.53	0.11	0.24	0.22	0.35	0.00	0.13
										n	24	24		21		21		21
										95% conf	0.090	0.092		0.182		0.134		0.122
										μ-95%	0.540	0.817		0.765		0.762		0.469
										μ+95%	0.720	1.001		1.128		1.030		0.712

- crashes,
- length of road diet,
- approximate average annual crash frequency (over all years—used later to divide sites into high and low accident frequencies), and
- type of site (residential, mixed and commercial—used later to divide sites).

- Percentage changes for the county trends, city trends, and trunklines were calculated for each site (as above) and transferred to the summary spreadsheet—these are used as alternative corrections for considering background variation.
- The percentage reductions (or increases) between the before and after period were calculated for all, recoded, affected, and correctable crashes and transferred to the summary sheet.
- Each of the basic reductions was then "adjusted" using the various corrections for city, county, and other trends (the abbreviated summary below shows only the corrections for city trends; the sheet in Appendix D shows all of the corrections).
- Once the above information was all transferred to the summary sheet, averages (and other statistics) were calculated over all sites with usable data. Confidence intervals for the relevant average CMFs were also calculated.
- All of the percent changes were converted to CMFs (a separate worksheet in the appendix which is shown in abbreviated form below).
- The sites were sorted by relatively high and low "before" crash frequencies (>19 crashes/year vs. 10 or fewer crashes/year), type of adjacent land use (residential, mixed residential and commercial, and commercial), number of driveways (>32 and <32), and number of intersections (8 or less, 9 or more).

The important CMFs in Table 3 are those in bold red. These are: the basic (unadjusted) CMF referred to earlier as the "naïve" CMF and based solely on the overall change in crash frequency between the before and after periods; the basic CMF adjusted for the citywide trend;

and the CMFs for recoded crashes, affected crashes, and correctable crashes. Similar CMFs were calculated considering different stratifications of the sites (e.g., by high and low frequencies of before crashes). (Details on these variations are not shown in the abbreviated version of the spreadsheet but are provided in Appendix D.)

The 95% confidence intervals for the mean values of the CMFs are also shown in the following spreadsheet. Note that in every instance (save for the "correctable" crashes) the confidence interval for the trend-corrected CMF contains the value of 1.0—therefore, the average CMFs are not statistically different from zero. This result is actually similar to that obtained from the more detailed analysis involving comparison sites discussed in the last section.

The relevant CMFs are further summarized in Table 4 below. The naïve CMF is 0.63—that is, if all of the reduction in crashes was attributed to the implementation of the road diets the "after" crashes would be 63% of the "before" crashes. However, it was argued above that the naïve CMFs needed to be adjusted for the background citywide trend in crash frequency. In all instances (see detailed results), the citywide trend over the seven-year period (3 years before, 1 year for construction, and 3 years after) studied was toward decreasing crashes. Thus, the "uncorrected CMF" is adjusted for that (average) trend with the result that the basic CMF (shown in bold green in the table) is estimated as 0.91. That is to say that after the adjustment for the background trend, the "after" crashes on road diet sites would be 91% of the "before" crashes (only a 9% reduction after adjustment). Looking at the recoded crashes and only affected crashes, it is seen that the CMF varies by only a few points. For the crashes expected to be "corrected" by a road diet, the CMF is 0.59—that is, for those crashes expected to be reduced by road diets the "after" crashes would be only 59% of the "before" crashes.

The basic CMF is the one that is suggested for general estimates for proposed road diet projects. This is with the strong caveat that there is significant variation among sites. For example, the results in Table 3 show that the (citywide-trend-adjusted) CMFs for the 24 sites studied varied from 0.53 to 1.69 although most sites had CMFs less than 1.0. It should be noted that the site with the highest CMF had a low number of crashes so that a large percentage

Table 4. Comparison of mean values of CMFs

type of CMF	un-corrected CMF	CMFs corrected for city trend: basic CMF	CMF for recoded crashes	CMF for affected crashes	CMF for corrected crashes
average over all sites	**0.63**	**0.91**	**0.95**	**0.90**	**0.59**
potential adjustments for different characteristics					
high crash	0.65	0.92	0.91	0.92	0.54
low crash	0.61	0.90	0.98	0.88	0.63
res	0.55	0.78	0.77	0.91	0.51
mix	0.68	0.94	1.06	0.90	0.52
com	0.67	0.99	1.05	0.88	0.72
low driveway density (<32)	0.63	0.93	1.07	0.87	0.66
high driveway density (>32)	0.63	0.88	0.81	0.92	0.51
low number of intersections (8 or less)	0.61	0.90	0.95	0.83	0.61
high number of intersection (9 or more)	0.67	0.93	0.93	1.05	0.55

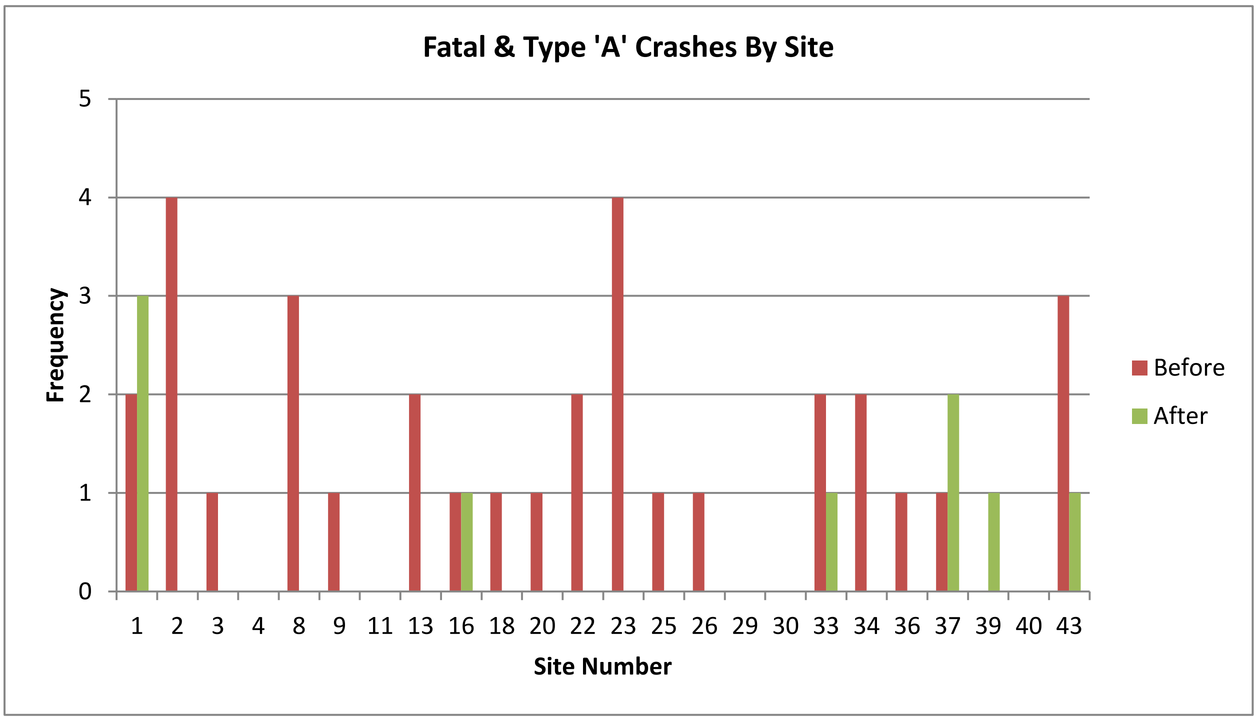
change was relatively easy to achieve. For such reasons, the sites were disaggregated by crash frequency (and other factors) as seen in Table 4—this was to illustrate how the CMF might vary from one grouping to another. For example, the basic (adjusted) CMF is seen to be 0.92 for "high" crash sites and 0.90 for "low" frequency sites. Looking at the "basic CMF" column, it is noted that most of the groupings don't make much difference—with only a couple of points of difference from one grouping to another. The most notable exception is the grouping by type of adjacent land use. The results here suggest that the CMF for "residential" sites might result in more crash savings (CMF = 0.78) than for commercial or mixed-use sites (CMFs = 0.99 and 0.94, respectively). The way the "potential adjustments" should be interpreted is, for example: while the overarching CMF for all sites is expected to be around 0.91, a residential site might result in a lower CMF than would be achieved at a mixed-use or primarily commercial site.

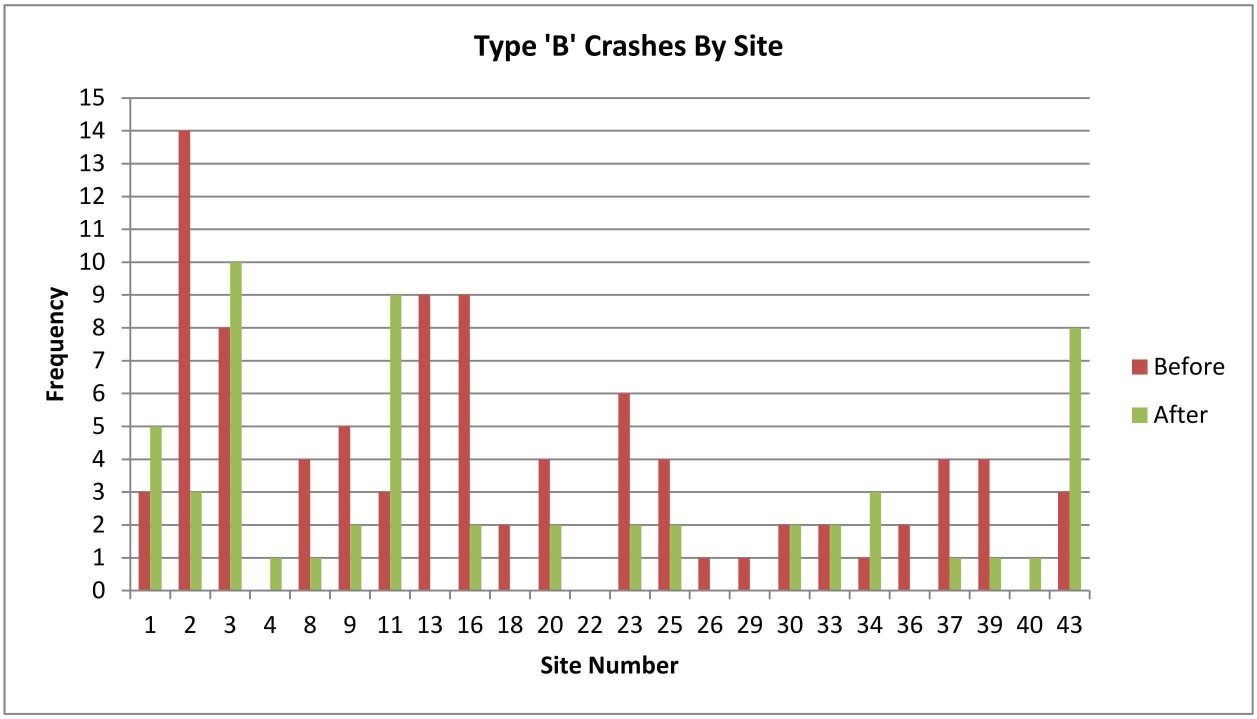
The exception to the above is the collection of those crash types that are expected to be "corrected" by a road diet. The overall CMF is estimated at 0.59 and (as shown in the detailed results) is statistically different from zero. So, while there is more confidence in this result, it should be noted that there are some offsetting changes in the frequencies of other crash types.

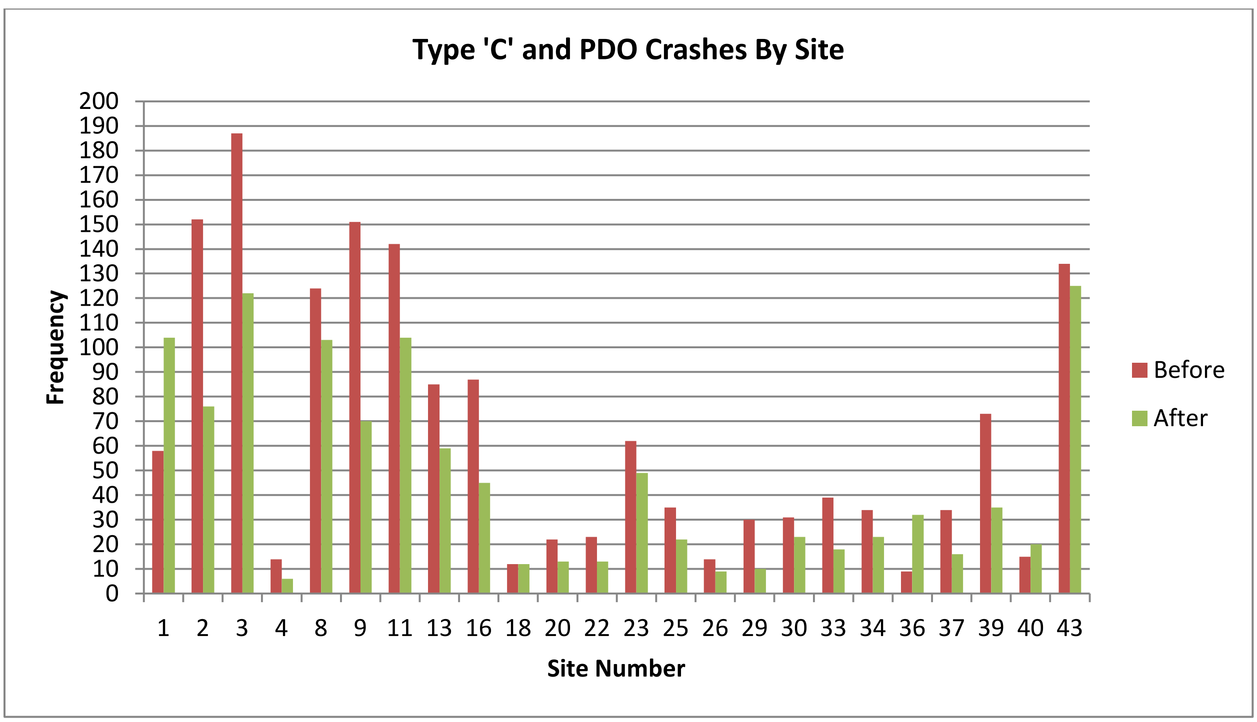
So, used only for selected crash types, this CMF has utility but it is not necessarily good for estimating overall changes.

CRASH SEVERITY

Changes in crash severity might also be expected as a result of the implementation of road diets. Changes in severity must be handled with care as there are many factors in play—e.g., changes in speed limits and/or operating speeds can shift severity distributions regardless of whether road diets are being implemented. The overarching trends in Michigan are that the total number of crashes and all types of severity are decreasing over time (from 1996 through 2010) although not without some year-to-year fluctuation. The three graphs below show the before and after frequency of three severity classifications (fatal + A crashes, B crashes, and C +







PDO crashes) by site. As can be seen, and has been repeatedly noted, there is considerable variation by site although the trend is for an overall reduction (which was noted earlier for all crashes over all sites). Perhaps the best indication for severity effects is the shift in the distribution of severity for the sites studied. This overall trend (all sites combined) is shown in Table 5.

Table 5. Shift in crash severity for all sites

crash type	**before**	**after**
fatal + A	33 (2%)	9 (1%)
B	91 (5.4%)	57 (4.9%)
C + PDO	1567 (92.7%)	1109 (94.4%)

It would appear that there is a slight trend toward less severe crashes on the road diet sites. For rough comparison purposes, an examination of overall statewide trends in severity (using the same severity groupings as for Table 5) is shown below from 2001 to 2010.

Table 6. Shift in statewide crash severity between 2001 and 2010

crash type	**2001**	**2004**	**2007**	**2010**
fatal + A	2.4%	2.4%	2.3%	2.0%
B	5.2%	4.8%	4.7%	4.8%
C + PDO	92.4%	92.8%	93.1%	93.2%

One issue in comparing the severity shift for the sites is that the actual time periods for the before and after windows varies by site (for example, before-after for site 1 compares 1997-1999 with 2001-2003 while the before-after for site 2 compares 2004-2006 with 2008-2010). That notwithstanding, there are distributional shifts in overall statewide severity over the 10-year period of: a 0.4 percentage point decrease in fatal+A crashes, a 0.4 percentage point decrease in B crashes, and a 0.8 percentage point increase in C+PDO crashes. This compares to a 1 point decrease in fatal+A, a 0.5 point decrease in B, and a 1.7 point increase in C+PDO for the road diet sites. This suggests that the road diet shifts are slightly larger and more positive (from a safety perspective) than overall statewide trends would suggest over the last 10 years or so. Such small differences do not seem operationally significant and could easily be attributable to things like changes in operating speeds, changes in enforcement, or just random variation.

SUMMARY AND DISCUSSION

The development of a crash modification factor (or factors) for road diets in Michigan was the primary objective of this study. In all, 24 separate sites were studied with this goal in mind. Overall changes in crash experience before and after the implementation of the 4-to-3 lane road diets were evaluated and then controlled for background variation. The latter was done through examining citywide and countywide trends (trends on trunklines were also examined) and through consideration of comparison sites (i.e., untreated “control” sites). Changes in crash severity were also examined. The following is a summary of the results of those analyses.

- There is considerable site-to-site variation in the crash-related results although in almost all instances, there was a reduction in the number of crashes.
- Examination of the background (e.g., citywide, countywide) trends showed that in all cases there was a trend toward lower crash frequencies over time. This is a clear indication that before-to-after comparisons of road diet implementations (or any other change to the road system infrastructure) must be evaluated with explicit control for the background trends.
- Several approaches for controlling for background variation were pursued. The most appropriate were deemed to be a simple control for citywide trends and the consideration of comparison sites.
- Good/acceptable comparison sites could be identified for only a few of the 24 sites and none of the eventual comparisons gave statistically significant results—that is, the calculated CMFs for specific sites were not statistically different from 1.0.
- Average CMFs, adjusted for citywide trends, were calculated across all 24 sites. The result was that the overall naïve (unadjusted) CMF was estimated as 0.63 and **0.91** after adjustment. Considering only those crash types expected to be affected by the road diet (not necessarily only reduced), the CMF was 0.90. And, finally, considering only those crash types expected to be reduced by a road diet, the adjusted CMF was 0.59.

Use of the latter is problematic since there are typically offsetting changes in crash type frequencies. Only the CMF for the "correctable" crashes was statistically different from 1.0.

- While the best estimate of a usable CMF is 0.91, it should be noted that this is not statistically different from 1.0 and is an average across all sites. Perhaps more importantly, there is a great deal of variation from site to site.
- Considering effects of other variables on the overall CMF, it was seen that there was not much change due to high vs. low overall crash frequency sites, nor was there much difference due to driveway or intersection density. However, sites where the land use adjacent to the road diet was primarily residential tended to have a lower CMF than mixed-use or commercial sites.
- Changes in crash severity due to road diets were also examined. The question was whether the distribution of severity changed—i.e., do crashes tend to be more or less severe after road diets are put in place. Again, it was noted that there was considerable variation from site to site (and often the numbers of crashes, especially the more serious, were quite small). The distributional shift over all sites was estimated and compared to statewide shifts over the general analysis period. The finding was that although there was a slightly more substantial shift to less severe crashes for the road diet sites, it did not seem operationally significant. Moreover, the shift could have easily been due to changes in operating speeds, enforcement, or simply random variation rather than the road diets themselves.

IMPLEMENTATION OF ROAD DIETS

One of the issues with road diets (and, really, any street or road improvement) is how and when to engage the public if the action is being initiated by MDOT or other agency. Road diets in Michigan are typically perceived as a safety improvement although there may also be upkeep and maintenance savings as well. A more-detailed implementation guide is presented in Appendix E but summary comments are presented below.

Historically, traffic engineers (and the public agencies they work for) have been perceived as being primarily concerned with expanding or at least maintaining street and road capacity and enhancing traffic flow. However, over the last decade or so, there has been increasing interest in how streets and roads "fit" into the adjacent environment—conversations about complete streets, traffic calming, green design, accommodating pedestrians and bicyclists, and so forth have become much more common. The road diet concept has gained considerable traction with various agencies, and road diets are often proposed by traffic engineers as being better for non-motorized users and having safety benefits. Ironically, some communities resist proposals for road diets because they can reduce capacity in some situations. Regardless of why a road diet is being proposed (e.g., a single stand-alone project, part of a pedestrian/bicyclist plan, part of a complete streets program), there needs to be engagement of the local community if the project is to be smoothly implemented.

ROAD DIET IMPLEMENTATION

Road diets have been implemented in many states including California, Washington, Iowa, Minnesota, Florida, and, of course, Michigan. For the purpose of developing an implementation guide, studies that present information on the process of implementing a road diet were further reviewed. These studies included advantages and disadvantages of a road diet, motivating factors for conversion, and lessons learned following the project (e.g., Gallagher 2007).

The apprehension regarding (or overt dislike of) road diets stems from the counter-intuitiveness of reducing the capacity of the roadway while maintaining an acceptable level of service. To challenge the general thinking, many agencies implementing road diets have experienced success by utilizing techniques that both educate and involve the community.

An implementation guide encompasses all aspects of the project in a beginning-to-end fashion. Continuous community involvement should be maintained through each phase of the road diet conversion. There are three basic phases: pre-construction (phase I), construction (phase II), and post-construction (phase III) with the following objectives for each phase:

- phase I—community education and acceptance for the road diet project;
- phase II (which can be very short if the project is primarily re-striping)—mitigate any negative effects associated with construction and roadway operations; and
- phase III—demonstrate how the road diet fulfilled community objectives while highlighting the benefits of the new corridor.

Success of a road diet project can be measured on several levels, however, when a road diet fulfills the needs of a community while maintaining the necessary function of the corridor, success is generally recognized.

In **phase I, community education and acceptance**, it is essential to promote community involvement and a sense of ownership from the outset. Many agencies implementing road diets have involved the public through town hall meetings, workshops, and newspaper postings which detail the road diet project specifically (Gallagher 2007). Others have found success by implementing road diet projects through city master plans or other citywide initiatives such as Complete Streets or a community bicycle plan. For example, Michigan's Genesee County Metropolitan Alliance adopted a "Complete Streets" approach where "Transportation improvements in Genesee County are planned, designed and constructed to encourage walking, bicycling, and transit use while promoting safety for all users" (GCMPC undated). Another example includes the "pedscape plan" adopted in Charlotte, North Carolina (Sak 2007). These techniques provide an accepting atmosphere because residents are more receptive to change and look forward to "reinventing" their community with a broader scope. Additionally, this couples the road diet with other actions which may, for example, have as a goal restoring an out-dated downtown setting. The intent of public meetings during this phase should be to:

- gain an understanding of the needs of a community by generating a list of transportation, economic, and safety objectives;
- develop a broad plan (e.g., a master plan, complete streets program) which considers community objectives and provides a list of projects which fulfill these objectives and provides a context for the road diet;
- provide several alternatives to road diets and explain how different alternatives succeed or fail to meet the goals of corridor and the community;
- demonstrate how a road diet will affect all modes of transportation by providing equal access to motorists, cyclists, and walkers while maintaining safety; and
- perhaps most importantly, provide an unbiased assessment of both the advantages and disadvantages of road diets—overstating the benefits of a road diet sets the project up for failure in the public eye.

With reference to the last point, the operational and safety effects of road diets in Michigan presented earlier in this report provide realistic and relevant information that can be used in “phase I” activities. It is important to not oversell the effects of road diets and to point out the high degree of variance in the safety outcomes that are associated with them.

To maintain community involvement from beginning to end, many engineers/planners involved with road diet projects have utilized public forums such as blogs or social networking sites (e.g., Kazis 2011). This sort of public forum allows citizens to voice concerns, opinions, or support concerning the process of the design and implementation. In turn, this gives the agency an opportunity to answer questions which generally alleviate concerns voiced by community members. Such sites can also provide a central hub for pertinent information regarding street closures, detours, and project progress. Use of the electronic media is much better than relying solely on just one or two “standard” public hearings or meetings in that the new media allow for a dynamic process.

During **phase II, implementation/construction**, public concern, which can arise during the planning phase, can be heightened when construction begins. The degree of discontent will largely be based on the extent of the project. If a road diet is implemented simply by pavement marking re-striping, negative response will be minimal. If the project requires reconstruction, causing travel/commuting to become difficult, additional measures will be necessary to alleviate any concerns. Regardless of the size of the project, any precautions that will lessen the stress associated with the road diet should be taken. Based on past experiences, the following techniques have been used to maintain a positive attitude throughout the community during the construction phase:

- reduce the impact of constructing the road diet on the community by shortening the construction timeline as possible (Sak 2007);
- provide proper detours to maintain access and mobility through the area;
- if logical/possible, consider public transportation options through the corridor;
- select a design which uses the existing curb line;
- change traffic signal timing before construction to allow motorists to become acquainted with the new cycle lengths (Sak 2007);
- implement the road diet in concert with other projects (e.g., installing new utilities); and
- again, use a blog or website to keep users up-to-date on the progress of the project while relaying important detour and closure information.

An often overlooked part of a road diet project is **phase III, project follow-up** to analyze, for example, the post-implementation operational characteristics to understand if the project was successful. This assessment will be important to members of the community who will want to understand if the project met the intended objectives. Similarly, other agencies will be interested if this type of roadway conversion could be successful in their own communities. Success of a road diet should be based on the totality of the project and not just, for example, on motorist delay.

A follow-up evaluation of a road diet plays an important role in the success of the project. By assessing the characteristics of the updated roadway and presenting findings to community members, a sense of satisfaction and accomplishment can be instilled in the community. Finally, information collected from a converted site can be of use to other agencies considering a similar roadway conversion.

TYPICAL QUESTIONS AND INFORMATION NEEDS REGARDING ROAD DIETS

It is instructive to present a list of typical questions that have come up (Sak 2007) or issues that have been identified (City of Orlando 2002) in various venues regarding road diets. Thinking about these questions/topics in the context of a specific proposal may help frame the content for future presentations.

Some questions (Sak 2007):

- Where does the additional traffic go when the capacity is reduced by half?
- When some communities are widening roadways, why are we narrowing ours?
- How will bus stops be accommodated with a road diet?
- How will emergency response units be affected?
- What if it doesn't work?

Some typical measures of effectiveness (MOEs) that might be developed for a project (City of Orlando 2002):

- increased traffic on neighboring streets
- speeding
- pedestrian and bicyclist volumes
- vehicle (and/or pedestrian/vehicle) crashes
- on-street parking use rates
- resident and merchant pedestrian satisfaction
- parking satisfaction

Actions to address overarching concerns:

- Conduct a thorough analysis of the corridor and make certain a road diet is suitable alternative for the roadway.

- Avoid implementing a road diet without community involvement.
- Develop a plan that not only encompasses the road diet project but the community as a whole such as complete streets or a new bicycle/pedestrian initiative.
- Avoid overstating the benefits of a road diet
- Publish road diet success stories in local newspapers or blogs.
- Use blogs or social networking sites to provide as much information as possible to community members while providing a forum to express any concerns.
- Provide opportunity for additional beautification elements such as stamped concrete, brick accents, planter boxes, curb out-crops, and added landscaping.

SUMMARY AND DISCUSSION

A three-phase process associated with planning, constructing/implementing, and follow-up on road diet projects was presented. The major points to be emphasized during execution of that process are:

- Road diets should not be "oversold" with respect to expected benefits, especially safety benefits. The estimated CMF (last section) is relatively modest and is an average of many sites—this suggests that "guaranteeing" crash savings of a certain magnitude would misrepresent what will be experienced in any specific situation. Actual benefits could be significantly higher or lower.
- Both the pros and cons associated with road diets need to be presented and thoughtfully discussed with the community.
- Use of social media to discuss (and resolve) road diet proposals can be successful as an adjunct to traditional public hearings and other traditional community-involvement techniques.

SUMMARY AND CONCLUSIONS

The summary and conclusions from this study of selected road diet conversions in Michigan include the following points.

From the literature and state of practice reviews—

- As a general statement, crash reductions are experienced with most installations and are most typically reported as percentage changes (CMFs would be < 1.0). There is, however, significant variation in the magnitude of the reduction.
- While there appears to be significant "natural variation" in crash reduction percentage (and CMFs), variation is also introduced because of the variance in the before/after geometry and operating conditions at road diet sites.
- Most studies did not result in the estimate of CMFs per se. The most reliable estimates of CMFs are generally thought to be found on the FHWA-funded website "crash modification factors clearinghouse" maintained by the University of North Carolina Highway Safety Research Center [http://www.cmfclearinghouse.org/]. From that source, road diets are estimated to result in the following CMFs for unspecified roadway types in urban areas: all crash types/all severity levels = 0.63; all crash types/all injury crashes = 1.0; all crash types/PDOs-only = 0.54; angle crashes/all severity levels = 0.63-0.76; and rear-end crashes/all severity levels = 0.59.
- Many, if not most, studies did not control for background variation in crash trends. In virtually all areas, the general decrease in crashes at road diet locations must be adjusted for overall changes in crashes in the surrounding areas during the study period. Otherwise, too much of the reduction in crashes may be attributed to the road diet.

From the on-site assessment of pedestrian and bicyclist use of road diets—

- Provisions for pedestrian and bicyclist are most important when there are existing pedestrian/bicyclist generators on the site and/or when the road diet is part of a larger plan for an area.

- If pedestrian/bicyclist provisions are included in the road diet area, they need to be clearly and consistently (i.e., always) marked.
- While there appears to be a need for additional information/education regarding appropriate use of the road and pedestrian/bicyclist facilities at road diet sites, supplemental signs indicating crosswalks and bike lanes should be considered for routine inclusion at road diet sites.

From the operational analysis of several Michigan road diet sites—

- The operational analysis of the several sites provide reasonably consistent results and support a guideline that suggests that 4-to3-lane road diet conversions result in significant increases in delay for **ADTs over 10,000**.
- More importantly, 4-to-3-lane road diet conversions increase delay when **peak hour volumes of exceed 1,000**.
- However, it is clear that "local" conditions (e.g., varying geometry, significant variation in turning movements, and variations in cross-street traffic) can have a significant impact on the viability of any proposed road diet. Thus, while an initial culling of potential road diet sites can be accomplished using the general guidelines above, in all instances a detailed operational analysis of the corridor (including operations at each intersection) for both 4- and 3-lane sections should be undertaken before the road diet conversion is implemented.

From the safety analysis of selected 4-to-3 lane road diets in Michigan—

- There is considerable site-to-site variation in the crash-related results although in almost all instances, there was a reduction in the number of crashes.
- Examination of the background (e.g., citywide, countywide) trends showed that in all cases there was a trend toward lower crash frequencies over time.
- The most appropriate methods for controlling for background trends were a simple control for citywide trends and the consideration of comparison sites.

- Good/acceptable comparison sites could be identified for only a few of the 24 sites and none of the eventual comparisons gave statistically significant results—that is, the calculated CMFs for specific sites were not statistically different from 1.0.
- Average CMFs, adjusted for citywide trends, were calculated across all 24 sites. The result was that the overall naïve (unadjusted) CMF was estimated as 0.63, and **0.91** after adjustment. Considering only those crash types expected to be affected by the road diet (not necessarily only reduced), the CMF was 0.90. And, finally, considering only those crash types expected to be reduced by a road diet, the adjusted CMF was 0.59. Use of the latter is problematic since there are typically offsetting changes in crash type frequencies. Only the CMF for the "correctable" crashes was statistically different from 1.0.
- While **the best estimate of a usable CMF is 0.91**, it should be noted that this is not statistically different from 1.0 and is an average across all sites. Perhaps more importantly, there is a great deal of variation from site to site.
- Considering effects of other variables on the overall CMF, it was seen that there was not much change due to controlling for other variables except for adjacent land use—residential sites tended to have a lower CMF than mixed-use or commercial sites.
- Changes in crash severity due to road diets were examined and the distributional shift over all sites was estimated (and then compared to statewide changes). The finding was that although there was a slightly more substantial shift to less severe crashes for the road diet sites, it did not seem operationally significant. Moreover, the shift could have easily been due to changes in operating speeds or enforcement rather than the road diets themselves.

From the implementation of road diets—

- Road diets should not be "oversold" with respect to expected benefits, especially safety benefits. Actual benefits of a road diet can vary significantly by site.

- Both the pros and cons associated with road diets need to be presented and thoughtfully discussed with the community.
- Use of social media to discuss (and resolve) road diet proposals can be successful as an adjunct to traditional public hearings and other traditional community-involvement techniques.

Road diets are a useful tool in the traffic engineer's arsenal of making streets and roads a more integral part of the community. As a part of broader plans, they open up "traditional" roads to greater use by pedestrians and, especially, bicyclists. In general, safety benefits can be expected but vary greatly from site to site. When corrected for citywide trends, the results here indicate that only a relatively modest CMF (0.91) is appropriate. This indicates that crash/safety benefits are likely to be considerably less than what is suggested by naïve comparison of before and after crash statistics. Similarly, the results reported here also suggest that operational analyses (e.g., using Synchro) should always be performed early on in the consideration of a road diet proposal. Moreover, the commonly-quoted threshold ADT of 20,000 for consideration of a road diet should be lower (10,000) and, more importantly, realistic peak-hour analyses (based on actual counts) are much more useful. For the sites evaluated here, the peak-hour threshold volume is estimated as 1,000 vph although this could vary with varying volumes of cross traffic at intersections.

RECOMMENDATIONS FOR IMPLEMENTATION OF RESEARCH FINDINGS

The recommendations for implementation of the research findings are presented below as "action items" for MDOT and based on the discussion in each section of the report.

- The results of the literature review and the article-by-article review in Appendix A should be made available to MDOT and local-agency engineers and planners who are interested in and/or dealing with road diet projects.
- When pedestrian/bicyclist provisions are included in a road diet, they need to be clearly and consistently (i.e., always) marked.
- MDOT should share the following quantitative, operations-related findings of this research with the FHWA and suggest changes to the appropriate section of the **Michigan Operations Manual** which is addressed to "4-to-3 Lane Conversions."
    - The ADT threshold for considering such road diets should be changed to ≤10,000.
    - More importantly, detailed operational analysis should be done when ADTs are 10,000 or more **OR** when peak hour volumes exceed 1,000.
    - Finally, because of the variation in intersection geometry, turning volumes, and signal timing from site to site, detailed operations analysis **always** be done.
- Results of the safety analysis and development of crash modification factors (CMFs) related to 4-to-3 lane road diets should also be shared with the FHWA (as above).
    - When studies of the effects (or effectiveness) of road diets are done, there must always be control for background trends with citywide trends generally being the most appropriate to consider.
    - The overall naïve (unadjusted) estimated CMF is 0.63 and **0.91** after adjusting for citywide trends. Considering only those crash types expected to be affected by the road diet (not necessarily only reduced), the estimated CMF is 0.90. If only those crash types expected to be reduced by a road diet are considered, the adjusted CMF is 0.59. Use of the latter is problematic since there are typically offsetting changes in crash type frequencies. Only the CMF for the "correctable" crashes was statistically different from 1.0.

- Operations- and safety-related results should be incorporated into any presentation material developed by MDOT and local agencies regarding the planning and implementation of road diets.
- Road diets should not be “oversold” with respect to expected benefits, especially safety benefits. Actual benefits of a road diet can vary significantly by site.
- Both the pros and cons associated with road diets need to be presented and thoughtfully discussed with the community.
- Use of social media to discuss (and resolve) road diet proposals can be successful as an adjunct to traditional public hearings and other traditional community-involvement techniques.

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The references shown below represent a list relevant to the body of the report and the appendices. Because of the nature of the presentation in Appendix A (a source-by-source review), part of the reference list is reproduced there as well.

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