DCMI (Double Crossover Merging Interchange) Design, Operations, and Application

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ABSTRACT

As traffic demands continue to rise, the need for innovative traffic control devices continues to grow as well. One method of addressing this need has been the use of less conventional intersection types. Many of these less conventional intersection types have been implemented successfully for many years in various geographic locations throughout the United States and abroad. These less used intersection types are commonly referred to as “Alternative Intersection Control”.

In other instances, new and unique intersection control types are invented to address the growing needs of increased traffic and the resulting congestion. In this instance, the author presents a new and unique interchange configuration, here after referred to as the DCMI (Double Crossover Merging Interchange). The DCMI’s lane configuration and design provides a method of constructing a high capacity interchange with free-flow operations in a relatively small area, as opposed to the area needs of a full clover leaf interchange, or an interchange with flyovers. The DCMI uses a unique configuration of a main bridge with two minor side-bridges on either side of it. This allows traffic to crossover the opposing/conflicting traffic streams while eliminating weaving sections and resulting in a lane configuration with primarily merging sections. This paper outlines the key components of the DCMI operations, design, and application, including Lane Configuration, Operational Analysis, Grade and Profile Considerations, Design Speed and Curvature of Roadway, Pedestrian and Bicyclist, Right-of-way Requirements, Integrating Local Access System, Wayfinding System, and Cost Versus Benefit and Application Assessment.

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1.0 INTRODUCTION

As traffic demands continue to rise, the need for innovative traffic control devices continues to grow as well. Often, the type of intersection control is an essential key component of a safe and efficient traffic control system/network. One method of addressing this need has been the use of less conventional intersection types. Many of these less conventional intersection types have been implemented successfully for many years in various geographic locations throughout the United States and abroad. These less used intersection types are commonly referred to as "Alternative Intersection Control".

In other instances, new and unique intersection control types are invented to address the growing needs of increased traffic and the resulting congestion. In this instance, the author presents a new and unique interchange configuration, here after referred to as the DCMI (Double Crossover Merging Interchange). The DCMI's lane configuration and design provides a method of constructing a high capacity interchange with free-flow operations in a relatively small area, as opposed to the area needs of a full clover leaf interchange, or an interchange with flyovers. The DCMI uses a unique configuration of a main bridge with two minor side-bridges on either side of it. This allows traffic to crossover the opposing/conflicting traffic streams while eliminating weaving sections and resulting in a lane configuration with primarily merging sections.

The DCMI has some of the characteristics of a relatively newer alternative intersection control called a DCD (Double Crossover Diamond), also referred to as a Diverging Diamond Interchange (DDI). As illustrated in Figure 1 and Figure 2, the DCD features a reversal of the directional traffic movement on the crossing arterial roadway through the interchange area. At a conventional diamond interchange, left turns are executed across the path of opposing traffic. By flipping the traffic streams within the interchange area, the conflict between the left turn and the major road can be removed. Left turning traffic from the minor road onto an on-ramp to the freeway (major) can be made without conflict from the opposing traffic[1]. Although it is less common in the United States, the DCD has been effectively used for many decades in France, first being constructed during the 1970s[2]. The DCD uses at-grade traffic signals to crossover traffic streams.

Figure 1: Double Crossover Diamond (DCD)[3]

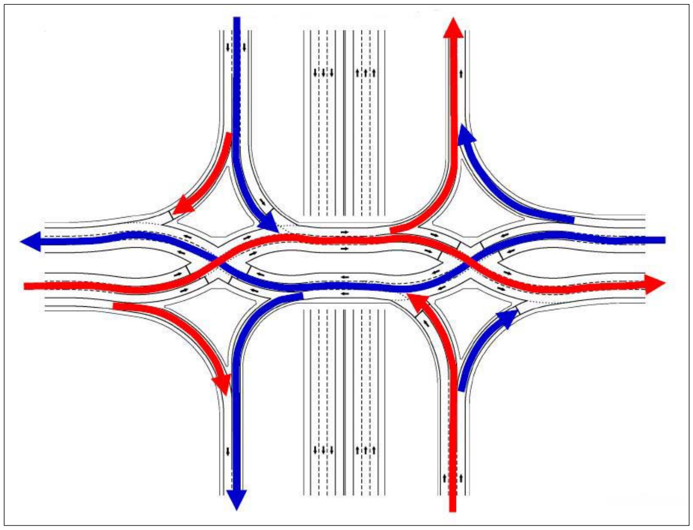
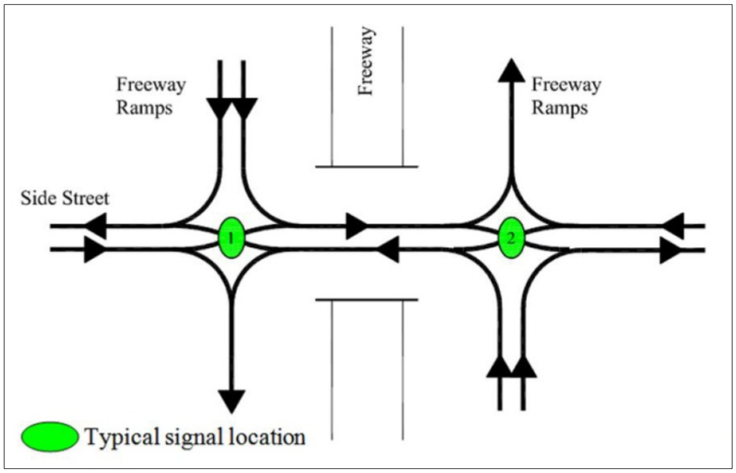


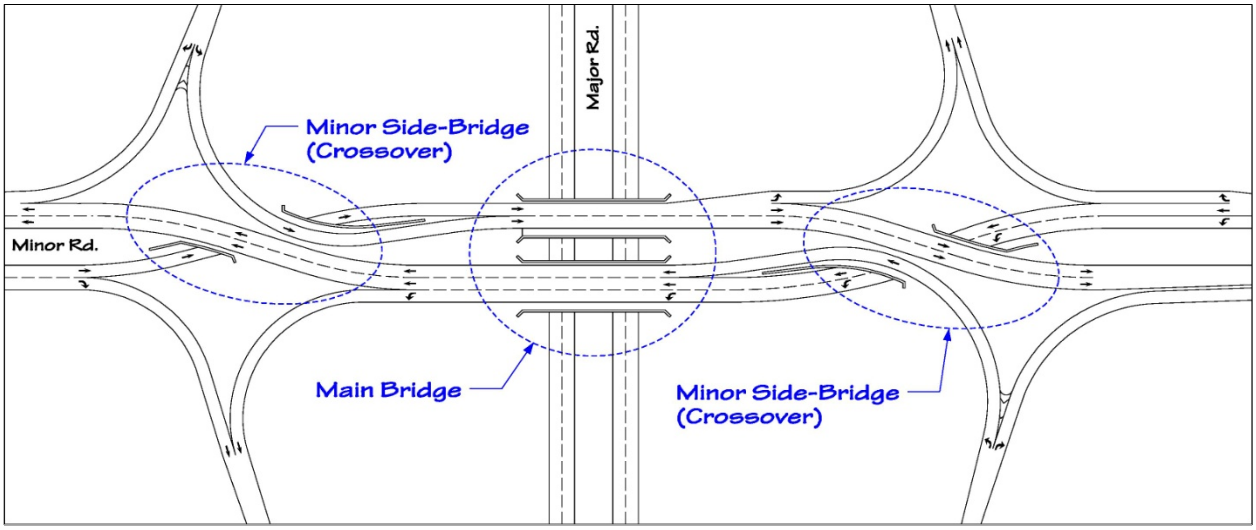
Figure 2: Typical 2-Phase Traffic Signal Locations (DCD)[3]



2.0 THE DOUBLE CROSSOVER "MERGING INTERCHANGE" (DCMI)

Although the DCMI incorporates some of the benefits of the DCD, it has several new and novel components and resulting benefits not rendered by the DCD. The DCMI is able to provide free-flow operations while eliminating the need for traffic signals and/or weaving sections within the influence of the interchange. By employing two minor-bridges (grade separation) on either side of the main bridge the traffic signals can be removed. Moreover, the off-ramp traffic can be crossed over on the same minor bridges as the through and left turn traffic streams of the minor road. In turn, this would eliminate conflicts that would occur with the at-grade traffic signal. Figure 3 illustrates this configuration. This unique configuration not only allows the elimination of the conflicts that occur at-grade, but also it allows the off-ramp traffic to cross over without the need for lane changes or weaving within the interchange.

Figure 3: Minor Side-Bridges on Either Side of Main Bridge (DCMI)



While the typical DCMI configuration is usually at the intersection point where a major road (highway, freeway) and minor road (arterial, collector) meet, the DCMI can also be used in numerous situations where various ranges of traffic meets/crosses. One of the primary benefits of the DCMI is to provide continuous traffic flow (free-flow operations), without the need to stop or yield.

The DCMI has an unusual combination of characteristics from both a standard intersection and a freeway interchange. A full standard freeway interchange with free-flow operations typically has a higher design speed and provides route continuity with other traffic operations designed to occur to the right[4]. With a DCMI however, certain movements will occur on the left. In addition, due to the two minor side-bridges and the roadway horizontal and vertical curvature needed to accommodate them, the DCMI usually has low speeds on the minor road for traffic passing through the minor side-bridges.

2.1 LANE CONFIGURATION

Given the unique characteristics of the DCMI, developing the optimal lane configuration can be challenging. Since both the crossroads have free-flow traffic operations, the ability to provide standard route continuity seems logical. However, by its nature, the DCMI requires some of the traffic operations to occur on the left, as opposed to the right side of a highway[4]. This results in the need to consider two primary methods to achieve an optimal lane configuration for any given location.

1. Lane Continuity
2. Turning Movement & Distribution

Lane Continuity

The AASHTO (American Association of State Highway & Transportation Officials) Green Book defines this concept as providing a route or lane continuity in which changing lanes is not necessary to continue on the through route. Guidance for route continuity in typical interchanges is well documented in the AASHTO Green Book. However, strategies for providing appropriate route continuity are less defined for complex interchanges[5]. This is also the case with unique or alternative interchange configurations. Exhibit 1 illustrates a DCMI that provides lane continuity for the through movement on the minor road. Please note this type of lane configuration provides lane continuity, but adversely it produces merging and diverging sections on/near the main bridge in-between the minor side-bridges, resulting in more turbulence between traffic streams. The merging section can be moved further away from the bridge, or the traffic can be carried on a full-lane until it is outside the direct influence of the interchange. Although moving merging sections further away from the interchange, or carrying full lanes past the interchange may improve operations, it can result in an increase of required right-away and/or lanes as well, leading to increased construction costs. The benefits of providing lane continuity versus additional construction cost needs to be evaluated to determine if the benefits overtime will outweigh the initial construction costs.

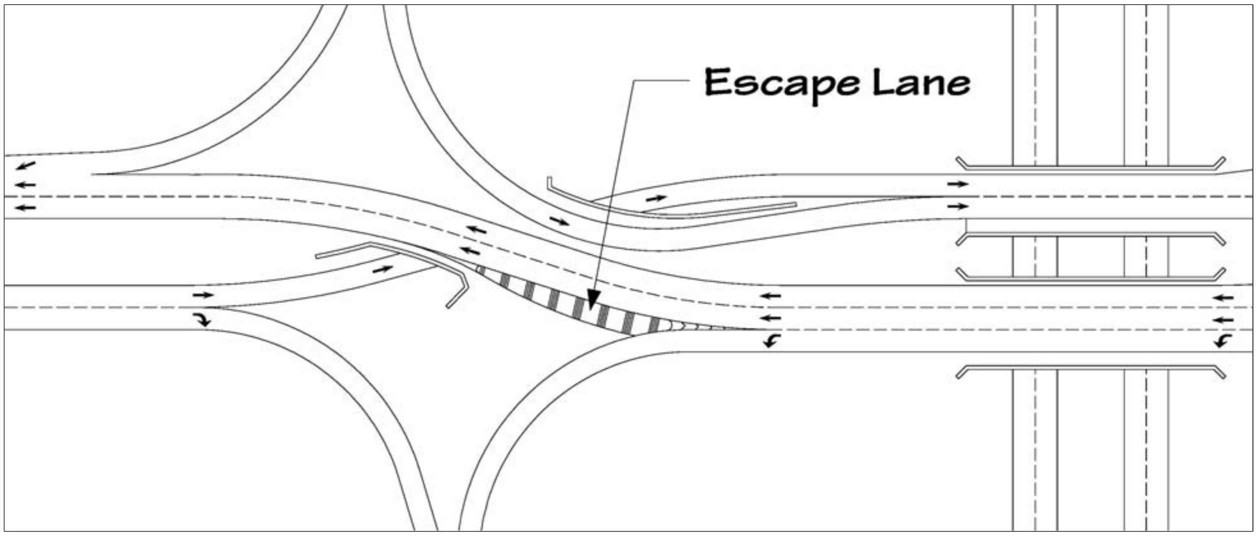
Turning Movement & Distribution

Developing the lane configuration based on the turning movements and traffic volumes distribution usually produces a configuration with a smaller cross-section. This allows for reduced costs, especially in the area of bridge construction. This type of analysis approach also places focus on balancing traffic volumes in each lane within adjacent lanes as they move through the interchange. Balancing traffic volumes in adjacent lanes should not be confused with the standard term “Lane Balance”. The term “Lane Balance” refers to the number of approach lanes on a highway in relation to the number of lanes beyond a highway exit. In contrast, balancing traffic volumes in adjacent lanes aims to distribute the number of vehicles in a manner that maximizes the utilization of a lanes capacity, while minimizing the number and length of required lanes. The traffic volumes in each lane are also a consideration when using the lane continuity method. However in that procedure, the lane continuity is the primary objective, and capacity needs are addressed by adding additional auxiliary lanes.

Although this method can produce an efficient lane configuration, often with a smaller foot print and elimination for additional auxiliary lanes, due to the required crossovers and merging sections of the DCMI, it may not provide the ability for the through movement without requiring some of the vehicles to change lanes prior to entering the interchange. Moving the vehicles into the proper lane prior to entering the influence of the interchange is vital to achieve efficient operations. This can be accomplished through effective signing, preferably overhead.

Exhibit 2 illustrates a DCMI lane configuration based on turning movement and traffic distribution. Please note if this type of lane configuration is employed, escape lanes can be used to provide an emergency refuge for drivers that may be in the wrong lane. The escape lane can be paint markings, although mountable rumble medians have more visible lane guidance as well as the ability to deter non-essential use of the escape lane. Figure 4 illustrates how an escape lane can be incorporated in a lane configuration that does not explicitly provide lane continuity.

Figure 4: Escape Lane



The benefits received from providing “lane continuity” needs to be compared to the increased cost typically associated with providing the additional lanes and bridge structure required. In some instances were a Turning Movement & Distribution method is applied and lane continuity is not, a directed lane change may be needed. There are several common situations where directed lane changes are implemented routinely. To better understand how a driver may interpret a directed lane change at a DCMI, we can reference the following commonly used configurations. Often, a 4-lane cross-section will change to a 2-lane cross-section, this transition usually occurs at an intersection. When this occurs, the driver will need to change lanes to execute a through movement, as lane continuity is not provided. Figure 5 illustrates the right-lane of a 2-lane approach becoming an exclusive right-turn lane, as such; the driver needs to change into the left lane to perform a through movement. Figure 6 illustrates the left-lane of a 2-lane approach becoming an exclusive left-turn lane, in this case; the driver needs to change into the right lane to perform a through movement. 4-lane cross-sections that transition to a 2-lane cross-section at an intersection are usually constructed with the intention of continued expansion of the 2-lane cross-section to a 4-lane cross-section in the future; however, the 2-lane cross-sections often stay in place for years, decades, or never change to a 4-lane cross-section.

Other directed lane change configurations or lane change behaviors that are similar can be observed in Figure 7 and Figure 8. Figure 7 Illustrates a rural auxiliary / passing-lane geometric configuration. In this case, a 1-lane approach is flared to 2-lanes to allow vehicles to pass slower moving vehicles. This often occurs at a location with a T-crossroad, and allows the inside lane to serve as a left turn lane as well as an auxiliary lane. Although a vehicle can stay in the inside lane to perform a through movement, the pavement marking typical "directs" the vehicles to the outside lane. Figure 8 illustrates a configuration that elicits similar behavior to directed lane changes, although it is not explicitly marked. Common urban intersection may not have a left turn lane; consequently, the inner lane serves as a through/left lane. This may queue traffic in the inner lane, forcing drivers to change into the outer lane to perform a through movement. This results in a consistent driver behavior similar to that of a directed lane change. As seen in Figure 5 through Figure 8, there are many situations that do not provide lane continuity and operate satisfactory, and although lane continuity is heavily promoted in the industry as the ideal, the decision to provide lane continuity at a DCMI should be carefully evaluated.

Figure 5: Directed Lane Change - Left

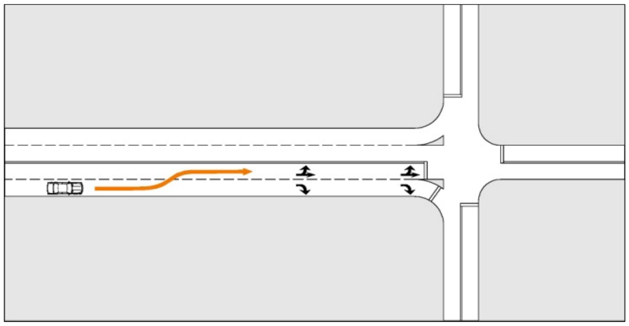


Figure 6: Directed Lane Change - Right

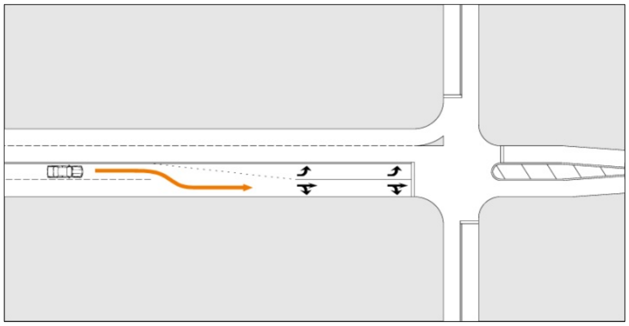


Figure 7: Directed Lane Change - Right - Rural

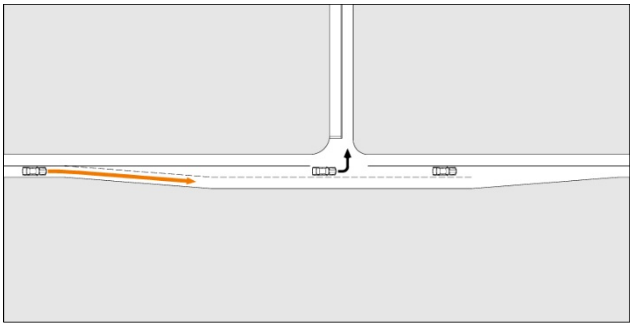
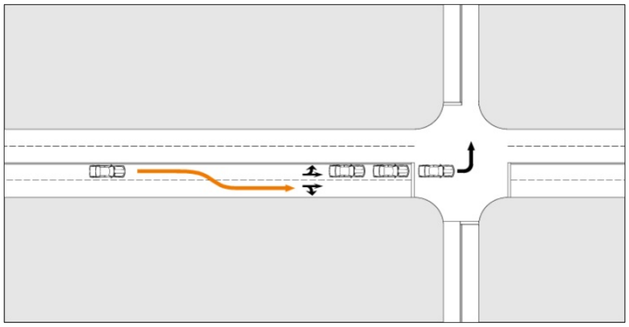
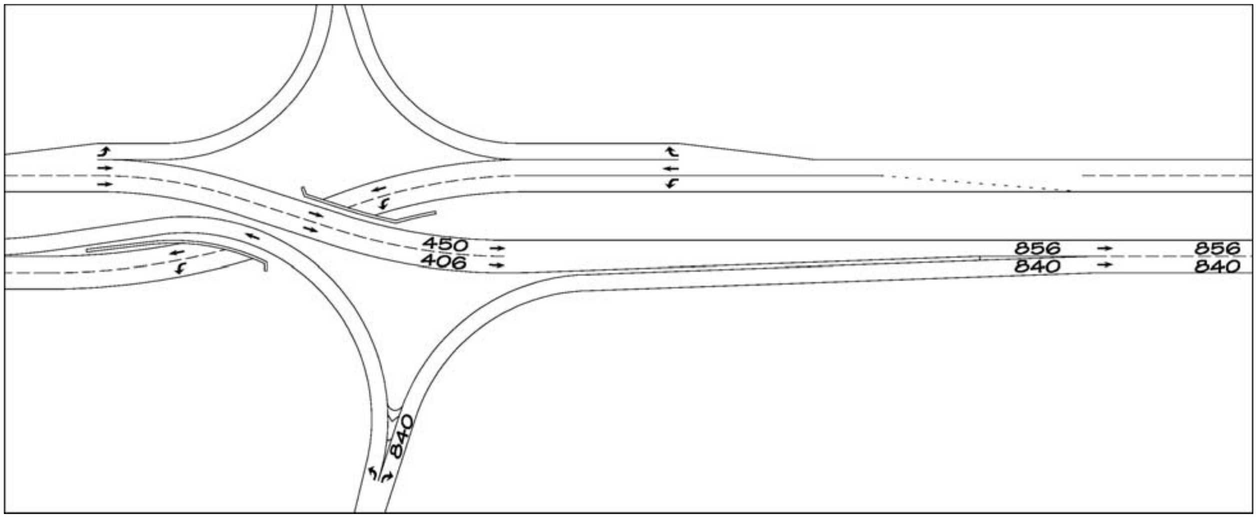


Figure 8: Lane Change – Right - Urban



Lane volume balance is not only a consideration on the approach to the interchange, but also should be a consideration as vehicles exit the interchange. Figure 9 provides an example of balanced traffic volumes as traffic exiting the DCMI is merged from 2-lanes down to 1-lane, and the heavy northbound right turn from the off-ramp becomes an exclusive second lane. As can be seen in the figure, this creates a relatively equal number of vehicles in each lane as traffic proceeds away from the interchange.

Figure 9: Lane volume balance on exit of interchange



Ultimately, the optimal DCMI lane configuration may be a combination of the lane continuity and turning movements, as well as the traffic volume distribution methods. The preferred lane configuration is usually based on the need to achieve balance among competing objects such as safety, capacity, available right-of-way, local access needs, and construction cost.

Traffic volumes in each lane are also a consideration when using the lane continuity method, but in that procedure, the lane continuity is the primary objective, and capacity needs are addressed by adding additional auxiliary lanes.

2.2 OPERATIONAL ANALYSIS

The Capacity analysis for the DCMI should consider several determining factors:

1. Lane Capacity - Based on the capacity of a single lane, as determined be local saturation limits.
2. Merging sections - Consideration of maximum merging capacity operations.
3. Affect of Pedestrians and Bicyclist on operations.

The capacity of an individual lane can vary depending on geographic location. Lane capacity should be based on observed local saturation limits. This maximum lane capacity will serve as the basis for the capacity analysis. Additionally, the merging operations may have a secondary effect on capacity and operations. The lower of the two limits should be used to determine the capacity of each part of the interchange. To determine the predicted operations of the merging sections, two methods can be applied. The Highway Capacity Manual prescribes formulas for calculating capacity at merging sections; however, these are typical for higher speed merges on freeways. The HCM formulas can be applied, but may produce a more conservative estimation, therefore underestimating optimal maximum capacity of the merging sections. Depending on the design methods applied, the speeds may be substantially lower than on a typical freeway section. Another method includes the use of a micro-simulation model to assess the capacity of the merging sections. This method is typically more time consuming, but may more accurately reflect a merging section with lower speeds then that of a freeway section with higher speeds.

Based on traffic turning movements and volumes (typically a projected design year) and the local lane saturation volumes, a lane configuration can be developed. The preferred lane configuration will allow vehicles to travel through the interchange without having to change lanes once on the interchange. Minimizing the number of merging sections can also enhance operations. Exhibit 3 and Exhibit 4 show the distribution of predicted traffic volumes in each lane as the vehicles pass through the DCMI interchange.

Below are some of the resulting characteristics of a lane configuration based on turning movements and distribution (Exhibit 2):

1. The north section of the main bridge only required 2-lanes, while the south section of the main bridge requires 3-lanes to accommodate the example projected design year volumes.
2. There are no weaving or merging sections within the interchange itself. Any vehicles needing to change lanes are guided to do so prior to entering the interchange. All merging sections occur as vehicles *leave* the interchange, not while they are still in it.
3. Due to the higher right turn volumes on the eastbound approach to the interchange, only 1-lane is used under the minor-bridge on the Westside, while 2-lanes are used on the minor-bridge on the Eastside.
4. The northbound off-ramp has a large number of vehicles turning right. By merging the eastbound minor road traffic down to one lane as it exits the DCMI, a relatively even distribution of traffic can be achieved (Figure 9).

As can be seen in Exhibit 2, this lane configuration allows vehicles to travel though the DCMI without having to change lanes in the interchange, and only requires merging as the vehicles leave the interchange.

2.3 GRADE AND PROFILE CONSIDERATIONS

To implement the minor-bridges on either side of the major bridge, several grade changes are required to the roadway profile. This can have a determining effect on both the distance needed from the main bridge to each of the minor side-bridges as well as the resulting percentage grade change. Acceptable grade change ranges vary depending on geographic location and jurisdictional requirements. Typical grade change ranges for this type of an application are between 4% and 6%. The preferred configuration will provide a natural gravity drainage system for the low points of the minor-bridges. Utilizing this type of gravity drainage systems eliminates the need for pumps at the low points under the minor side-bridges.

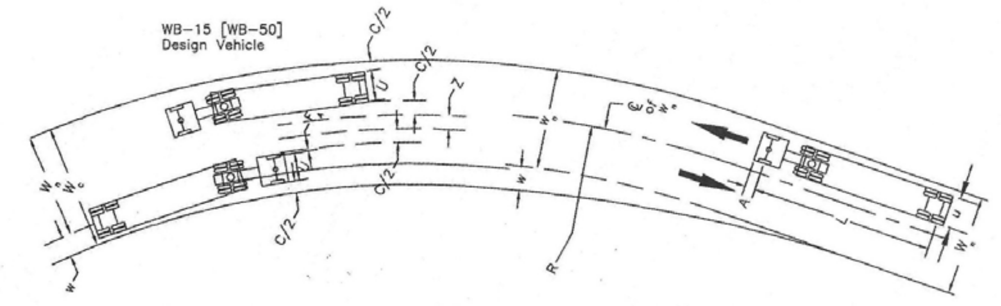
To minimize the space requirements for a DCMI, the minor side-bridges need to be located as close to the main bridges as functionally possible, yet the minor side-bridges need to have adequate distance from the main bridge to allow the required grade changes to accommodate semi-trucks under the minor side-bridges. The preferred method distributes the required grade change evenly between the bi-directional traffic of the minor road, with half the required grade change applied to the roadway going over the side-bridge, and the other half of the required grade change applied to the roadway going under the side-bridge. This allows each direction to experience half of the needed grade change, as opposed to the whole grade change in one direction, which would result in twice the distance requirement to allow semi-trucks to pass under the minor side-bridges. To further assist in minimizing the distance between the main bridge and the minor side-bridges, the main bridge decks can be sloped. By using two separate main bridge sections with opposing slopes, part of the required grade change between the main bridge and the minor side-bridges can be achieved. This can provide a substantial amount of the needed grade change prior to vehicles leaving the bridge deck. For example, a 200 foot long bridge deck, with a 3% slope in each direction would provide 6 feet of the needed grade change. Exhibit 5 illustrates how the vertical profile of the sloped main bridge in conjunction with the two minor side-bridges could be developed.

2.4 DESIGN SPEED AND CURVATURE OF ROADWAY

To allow the minor roadway's bi-directional traffic to crossover each other via the two minor side-bridges, the roadway requires a certain amount of horizontal curvature. Given that one of the primary benefits of the DCMI is the capability of providing free-flow operations within a relatively small footprint, as with the vertical curvature, it is conducive to locate the minor side-bridges in close proximity to the main bridge. However, the closer the minor side-bridges are to the main bridge, the smaller the crossover radii becomes, which can result in remarkably slower speeds as compared to the approach speeds to the interchange. The slower speeds are beneficial for safety and operations of the DCMI, but it needs to be balanced by using appropriate radii size, as too small of a radii can hinder safety and operations. The smaller the crossover radii becomes, the wider the roadway width needs to be for accommodating longer design vehicles such as WB-65 trucks. This competing objective also needs to be considered and fit with the vertical curvature and super-elevation of the crossover radii.

The roadway curvature can be designed to control and reduce speeds through the minor roadway of the interchange to enhance operations and safety. This offers more time for drivers to identify, interpret, and navigate, as well as increasing capacity and safety of merging sections. The design speed of the crossover radii should result in a reasonable reduction of speed from the posted upstream approach speed, while realizing accord with vertical and horizontal design parameters. Providing independent main bridges for each direction of traffic flow also allows design flexibility for the horizontal crossover curves of the minor side-bridges. The ASSHTO Green Book provides discussion and direction on widening for curved roadways[6]. The roadway widening techniques outlined in the Green Book are similar to the widening that should be applied to a DCMI interchange. Figure 10 is an excerpt from the AASHTO Green Book and illustrates how the roadway widening may appear at the minor side-bridges of a DCMI.

Figure 10: Widening On Roadway Curves[6]



Widening Components on Open Highway Curves (Two-Lane Highways, One-Way or Two-Way)

2.5 PEDESTRIAN AND BICYCLIST

There are two primary configurations to accommodate pedestrians and bicyclist at a DCMI. The first uses the two minor side-bridges and crosses the walkways/paths over each other in a similar manner as the roadways. The second provides walkways parallel to the minor roadways in a contiguous manner.

1. Cross-Over Pedestrian and Bicyclist Accommodations :
   The "Cross-over" configuration accommodates pedestrians and bicyclists via the minor side-bridges and central area of the main bridge. As illustrated in Figure 11 and Exhibit 6 (Extended View), the pedestrian and bicycle sidewalk/multi-use paths cross at the right-turn lanes of the on-ramps and off-ramps, proceed over or under the minor side-bridge, and then go over the main bridge section. Once over the main bridge, the same crossing pattern is repeated on the opposite side of the main bridge. The only interaction of pedestrians and cyclists with vehicular traffic in this arrangement occurs only on the at-grade pedestrian and bicyclist crossings where the path crosses with the right-turn on/off-ramps. The crossing can either be signalized or un-signalized, and can be designed to only activate when there is a demand. Speed control and visibility between the pedestrians and bicyclists should be assessed during the design's development. The radius of the right-turn lane can be reduced to physically constrain vehicle speeds to a desired range, while placing the pedestrian crossing in a location that allows the driver and pedestrian to have clear sight lines and high visibility between each other. As the path for the non-motorized users crosses near the main bridge, the users have the choice to change sides of the minor roadway if they desire. This provides full access for pedestrians and bicyclist to /from all four quadrants of the interchange, and does so without conflicting with any of the minor roadways vehicular through movements.

2. Parallel Pedestrian and Bicyclist Accommodations:
   The "Parallel" configuration accommodates pedestrians and bicyclists via walkways on the outside of the minor roadway. This eliminates the need and expense of the additional structural components needed to cross the pedestrians and bicyclist under at the minor side-bridges, and consequently results in a lower associated cost. Conversely, the parallel configuration introduces an additional conflict area at the on-ramp/off-ramp pedestrian crossing, as both the left-turn and right-turn to the on-ramps/off-ramps are crossed at-grade. Figure 12 and Exhibit 7 (Extended View) illustrate the parallel pedestrian and bicyclist accommodations.

> As with the “Cross-over” configuration, the “Parallel” configuration can either be signalized or un-signalized, and can be designed to only activate when there is a demand. Speed control and visibility should also be addressed in the “Parallel” configuration. In addition to introducing the extra conflict area, the parallel configuration does not provide the ability for user to change sides of the minor roadway.

In many instances the at-grade pedestrian/bicyclist crossing will suffice. If desired, pedestrian crossing bridges or underpasses can be provided at the turns to the on/off-ramps in order to totally eliminate pedestrian-bicyclist interaction with vehicular traffic. However, this would increase the cost. Assessment of pedestrian volumes and needs should be evaluated to determine benefit to cost ratios for pedestrian bridges or underpasses at the turn lanes to the on/off-ramps. If visually impaired pedestrians are identified in the area, they could be accommodated using crossing solutions for channelized turn lanes.[6]

Figure 11: Cross-Over Pedestrian and Bicyclist Accommodations, Non Motorized Users (DCMI)

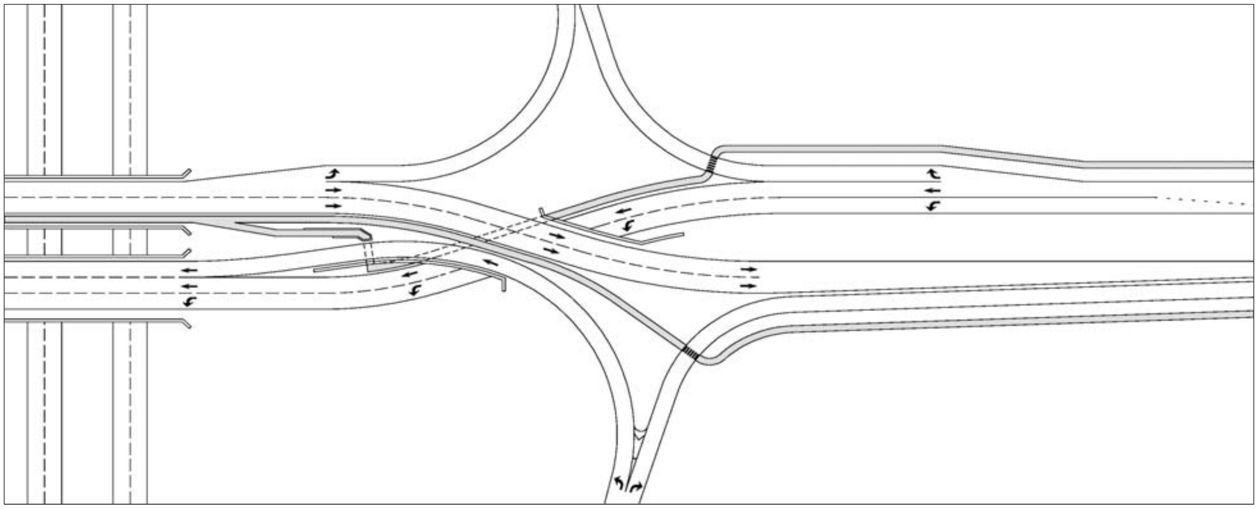
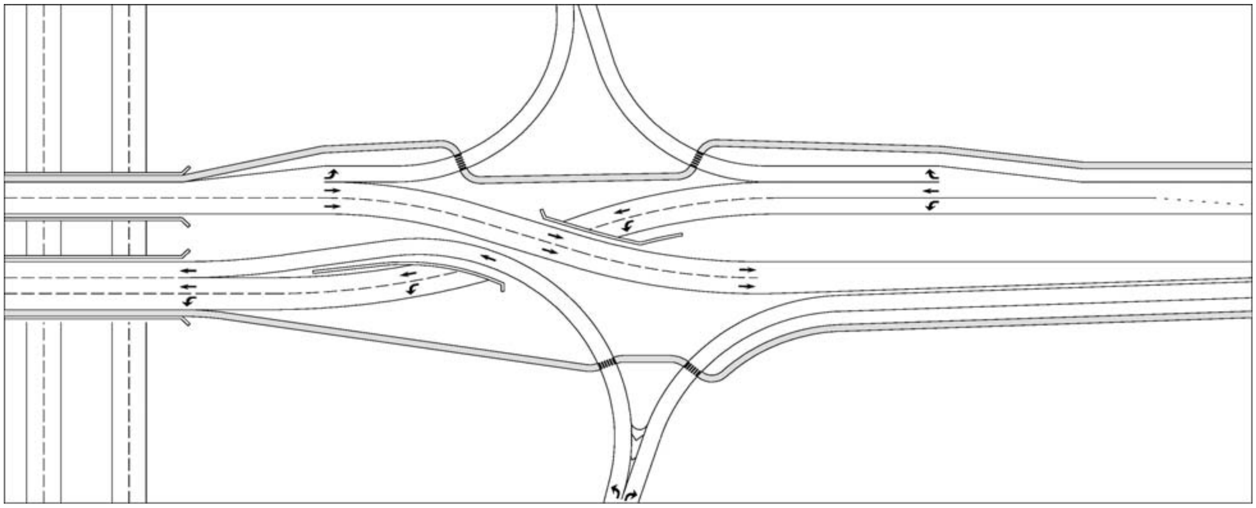


Figure 12: Parallel Pedestrian and Bicyclist Accommodations, Non Motorized Users (DCMI)



2.6 RIGHT-OF-WAY REQUIREMENTS

One of the cardinal advantages of the DCMI is the means to offer a continuously flowing interchange within less right-of-way and subsequent cost then a standard full interchange with the same capabilities. Full Interchanges, such as a cloverleaf usually required larger ramp radii and outer right-turn bypass lanes, which typically results in a large foot print. Other interchange options that are commonly favored over the cloverleaf often utilize flyovers. The flyovers can dramatically increase the cost, and use large radii to accommodate the higher design speed. This also results in a larger foot-print in addition to increase cost. Given the DCMI's similar characteristics as a tight diamond interchange, allowing for ramps to parallel the main highway upon exiting, and allowing for a smaller foot print, the DCMI can provide a unique advantage in terms of space requirements and cost.

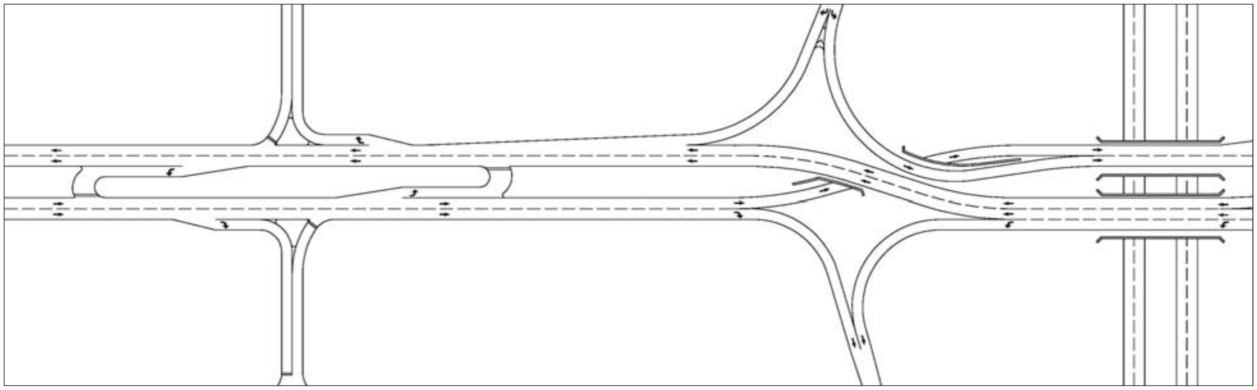
One of the principal factors of the ramp alignments, and consequently the area requirements of the DCMI interchange, is the need to address the grade separation requirements for the minor side-bridges. This results in a slightly larger distance and subsequent alignment for the main bridge. Nonetheless, even with the additional distance of the ramp alignment from the main bridge, the area requirements are still sustainably less than other interchange options that allow free flowing traffic, such as the traditional full cloverleaf or fly-over interchanges.

3.0 INTEGRATING LOCAL ACCESS SYSTEM

Typical, free-flow interchanges do not provide for local access within the vicinity of the interchange. In contrast to this standard, the DCMI can be configured to provide full local access within close proximity of the interchange. This is due in-part to the reduced speed of traffic on the minor roadway. The preferred method of providing local access while maintaining free flowing traffic is the use of median u-turns in conjunction with the DCMI. The use of median u-turns provides enhanced safety for the left turns. It also moves the left turn further away from the interchange while allowing the access drives to be located closer to the interchange.

Although the median u-turn requires a larger median to accommodate the u-turn, the DCMI's crossover radii create a wider median on the approach to the interchange anyway. This wider median can be extended to provide for the median u-turn. Standard permissive left turns could be implemented, but they generally have a lower level of safety and require the left turn to occur closer to the interchange and crossover radii. Figure 8 illustrate the use of median u-turns with the DCMI to provide full access while maintaining free-flow traffic operations. In addition to the median u-turns, the use of right-in/right-out access drives along the on-ramps and off-ramps can provide additional flexibility to develop an enriched local access scheme. In certain situations, the use of the right-in/right-out access drive may also be used to reduce required lane changes within the influence of the interchange. Ideally, the median u-turns would be stop controlled; be that as it may, if the left turn volumes are higher, or if there are insufficient gaps available to the left turning vehicles, signalization at the median u-turn may need to be considered. In this situation, a two-phase timing scheme can be applied in lieu of stop control. This provides greater flexibility for the timing scheme development, as each of the median u-turns can run independently of each other, for example, the westbound minor roadway traffic can continue to flow, even when the eastbound minor roadway traffic is stopped (red light) to allow median u-turn vehicles to enter onto the eastbound minor roadway. The 2-phase signal at the DCMI median u-turn is very different than the 2-phase signal of the at-grade signalized DCI (Diverging Diamond), as the through movements on the minor roadway never cross, only the left turns and one direction of traffic conflict at the median u-turn. This can result is substantially less conflict and reduced delay. Any combinations of the median u-turn(s) or right-in/right-out(s) can be utilized to optimize the local access scheme.

Figure 13: Local Access Scheme (Free-flow on Minor Road)



4.0 WAYFINDING SYSTEM

Due to the unique nature of the crossover method used in the DCMI, and the fact that using the crossover scenario is not yet common practice, the wayfinding system is increasingly important to elicit an error free response from drivers. The preferred signing scheme used in-part depends on how the lane configuration was developed, namely, the use of Lane Continuity, or Turning Movements and Traffic Distribution. Overhead signing is preferable or at least partial overhead signing, for the atypical movements, or movements that require some vehicles to change lanes prior to entering the DCMI interchange.

The implementation of local access near the DCMI can also dramatically complicate the wayfinding task and required signing. Although the use of right-in/right-out access drives on the on-ramps/off-ramps can enhance the access scheme, it can also provide two points of access to a destination, which can further complicate the wayfinding, and may encourage lane changes within the interchange if the signing is not clear and concise.

In more complex DCMI configurations, especially where local access is needed, the use of a color coded wayfinding scheme may be beneficial. A color coded wayfinding scheme may be similar to the type of system used in hospital halls for navigating through the building to different destinations. However, in most instances, the use of a color coded system would deviate from common practice, and may require some type of application to deviate from it.

5.0 COST VERSUS BENEFIT AND APPLICATION ASSESSMENT

The DCMI requires the use of two minor side-bridges on either side of the main bridge, which can result in an increased cost of construction. Even so, it may still be less expensive and provide a higher level of benefit than other options that provide free-flow operations. In situations where a free flowing traffic interchange is desirable, the DCMI can provide a less expensive alternative than schemes where fly-overs are required, or situations where extensive land acquisition for full interchange configurations are needed. An additional DCMI operational benefit that should be considered is the possible elimination of short weaving section, such as experienced in a full cloverleaf interchange configuration.

The simplest and most common cost-benefit analysis compares the cost of construction to the anticipated level of service, or more precisely, the anticipated average delay. While this type of analysis provides a fundamental comparison, a more comprehensive cost-benefit analysis may include other pertinent factors.

Components included in a more comprehensive cost-benefit analysis include:

1. Level of Service (Delay)
2. Safety Performance
3. Right-of-way Acquisition
4. Vehicle Emissions
5. Esthetics
6. Noise
7. Fuel Consumption

The Level of Service component typically does not have a direct cost associated with it. Moreover, it usually serves as a benchmark for the anticipated operations. When comparing it with other options, however, a cost can be associated with the additional delay anticipated above and beyond the benchmark delay. This cost is usually computed by seconds of additional delay and is derived from a cost to society. As society continues to place higher emphasis and responsibility for safer and more sustainable roads on engineers; consequently, roadway systems that offer a higher level of safety are increasingly favored.

In general, the DCMI removes the weaving sections from an interchange and results in lower speed merging sections, which typically provides a higher level of safety. Subsequently, the cost to society for collisions may be greatly reduced. As with safety, society has begun to focus on sustainability in transportation systems. Some of the sustainability components that can directly be incorporated into a cost-benefit analysis include vehicle emission reduction and fuel consumption. Intersections/interchanges that provide free flowing traffic can result in reduced vehicle emissions, reduced fuel consumption, and reduced noise pollution, as vehicles do not need to stop, idle, and then start again. Esthetics and noise pollution are usually categorized in a more qualitative fashion, and may be harder to find costing information to directly include in the cost-benefit calculations, but they should still be considered.

Ideally, since movement agencies are created to serve society, the cost to society outside of the initial construction cost should be considered. Unfortunately, government agencies do not typically have unlimited funds to consider and construct the optimal facility that provides for the cost of construction as well as the cost to society. As such, a balance between actual construction cost and cost to society is usually sought after.

6.0 CONCLUSION

By implementing the unique crossover configuration of two minor side-bridges on either side of a main bridge, the DCMI can provide a new type of interchange/intersection, which allows free flow traffic operations with area requirements similar to a diamond interchange configuration. The two minor side-bridges allow the through traffic movements on the minor road to temporally cross over each other. This also allows the left turning traffic from the off-ramps to crossover the minor street traffic and become a merging movement, as opposed to a weaving movement, while providing safer and more efficient traffic operations. The DCMI provides the benefit of free-flow traffic operations and offers a new and unique interchange/intersection configuration that reduces or eliminates the need for traffic to weave. In addition, the DCMI encourages slower, more efficient, and safer merging operations along the minor street, or where traffic would typically need to cross conflicting traffic. In situations where there is a need to provide an interchange/intersection with free flowing traffic characteristics, the DCMI can offer many advantages in lieu of typical full interchange options, or interchanges with fly-over roadways.

The analysis and design of the lane configuration is critical in assuring error free operations. Determining the optimal lane configuration requires careful consideration, including the assessment of lane continuity, turning movements, lane balance and distribution. The optimal lane configuration should be developed based on site-specific characteristics and goals. Ultimately the preferred lane configuration may be a combination of lane continuity, turning movements, lane balance and distribution, and their competing objectives. Even if a DCMI does not provide explicit lane continuity, if there is a sufficient advanced signing system, the DCMI can operate without lane changes, weaving, or merging between the two minor side-bridges; hence, the operations between the two minor side-bridges can be simplified while reducing the number of lanes and bridge construction cost.

Although the DCMI functions like a full interchange, allowing free-flowing traffic, it has characteristics of both an interchange and a standard at-grade signalized intersection. As such, this requires the designer to be critical in considering how the driver may interpret, and subsequently react to the DCMI's lane configuration, geometric body language, and wayfinder system.

The DCMI can be designed and constructed to accommodate all non-motorized users, including pedestrians and bicyclists. If visually impaired pedestrians are identified in the area, they could be accommodated using crossing solutions for channelized turn lanes[7]. Vertical and horizontal grade and profile issues can be addressed and developed to operate within acceptable ranges while still allowing for a smaller diamond type interchange, moreover, without the need for costly fly-over or full size interchange configurations such as a cloverleaf. If required, a local access system can be provided while still maintaining free-flow operations.

The DCMI offers an innovative and efficient alternative to standard interchange design. In certain situations, the DCMI can allow free-flow operations, increase capacity and safety, reduce construction cost, and reduce right-of-way needed (as opposed to other free-flow alternatives). This is increasingly evident if social cost such as vehicle emissions fuel consumption, noise pollution, and safety are considered.

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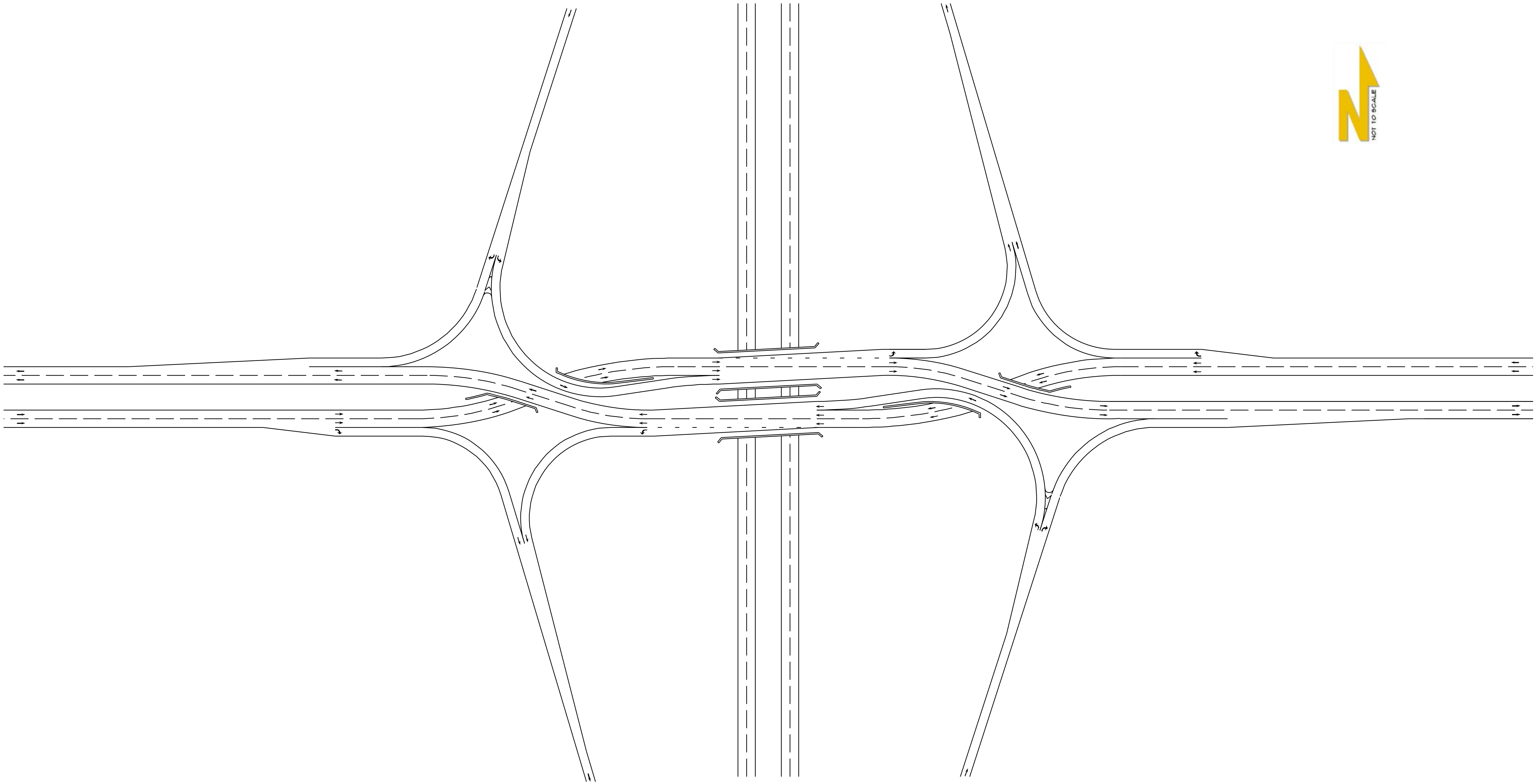
Author Background:

Mr. Gingrich has been providing transportation planning, analysis, and design services for over 15 years. He has managed and designed over 250 traffic signal and intersection geometric design projects. Michael has been a guest speaker at numerous seminars and conferences, including ASCE, ITE and TRB (Transportation Research Board) sponsored events, making several presentations at the 2008 and 2011 TRB National Roundabout Conference. Michael has taught US and Canadian roundabout training courses for Northwestern University and University of Wisconsin in Madison. In addition, he has served on the ITE National Roundabout Task Force. His roundabout related work to date includes approximately ninety roundabout projects. Mr. Gingrich has traveled extensively in England to study roundabout design with international roundabout experts Robert Barry Crown and Clive Sawers, and to consult with Transportation Research Laboratory (TRL) senior staff scientists.

Over the past decade, Mr. Gingrich has advocated and provided expert instruction on the benefits and application of alternative intersection control. Recognizing that delay along a traffic system usually occurs at the intersections, Mr. Gingrich teaches the importance of meeting the capacity needs of intersections within a roadway network. Mr. Gingrich recognizes that all types of intersection control have advantages and disadvantages, depending on travel patterns, turning movements, cost, and site constraints. He focuses on incorporating the correct combination of alternative attributes to develop a highly efficient roadway system with optimized intersection control.

When working on a project, Mr. Gingrich typically evaluates several intersection control options, including combinations of different control types to determine the optimal intersection for a roadway network. Mr. Gingrich applies a comprehensive methodology and understanding of different intersection control types, offering a balance of safety and capacity while meeting the needs of motorists, pedestrians, bicyclists, transit users, and individuals with disabilities.



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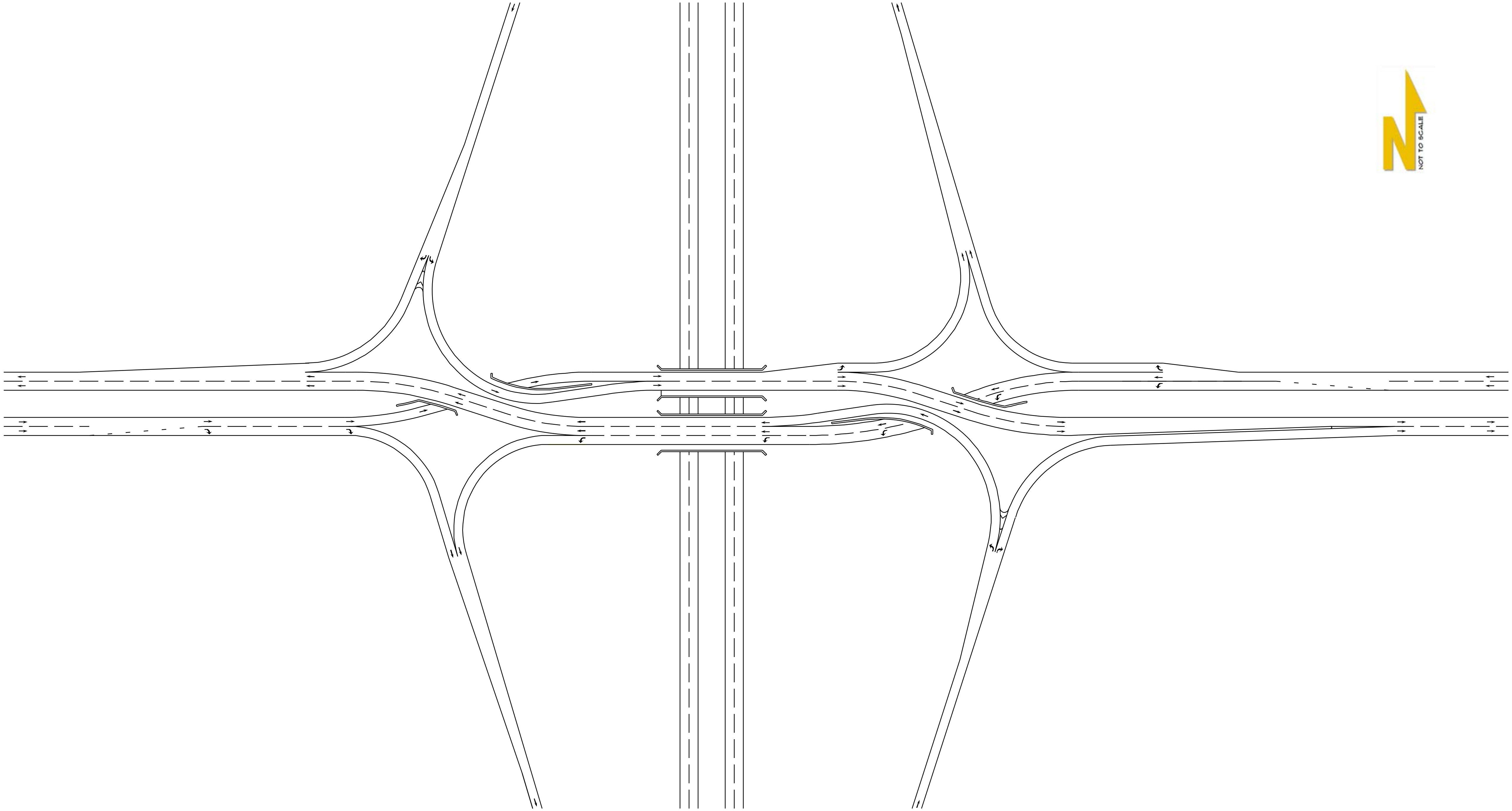
Double Crossover Merging Interchange (DCMI)

Lane Continuity - Interchange Configuration

June - 2011

Exhibit: 1 of 8



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Double Crossover Merging Interchange (DCMI)

Turning Movements & Distribution - Interchange Configuration

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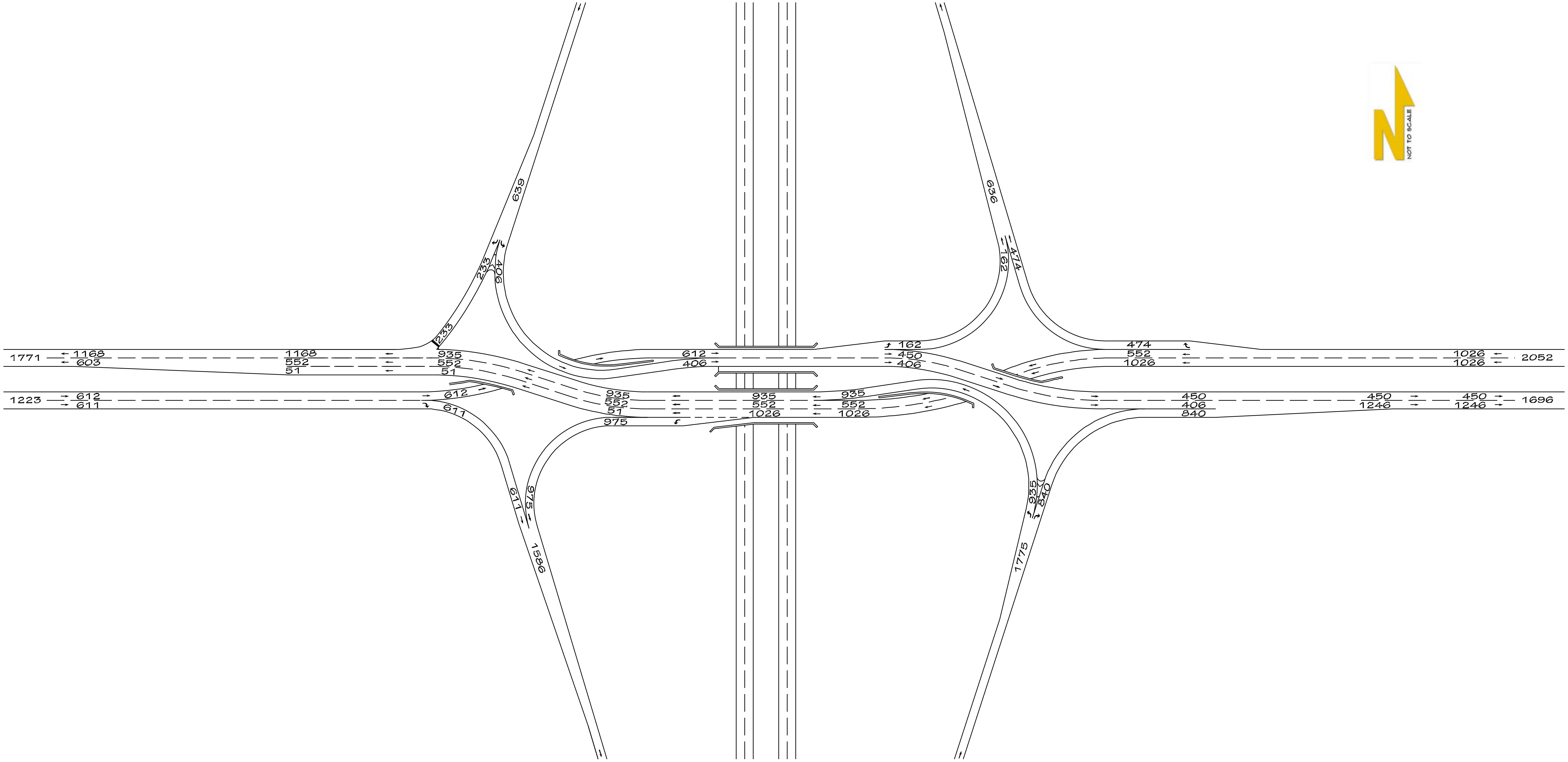
Exhibit: 2 of 8



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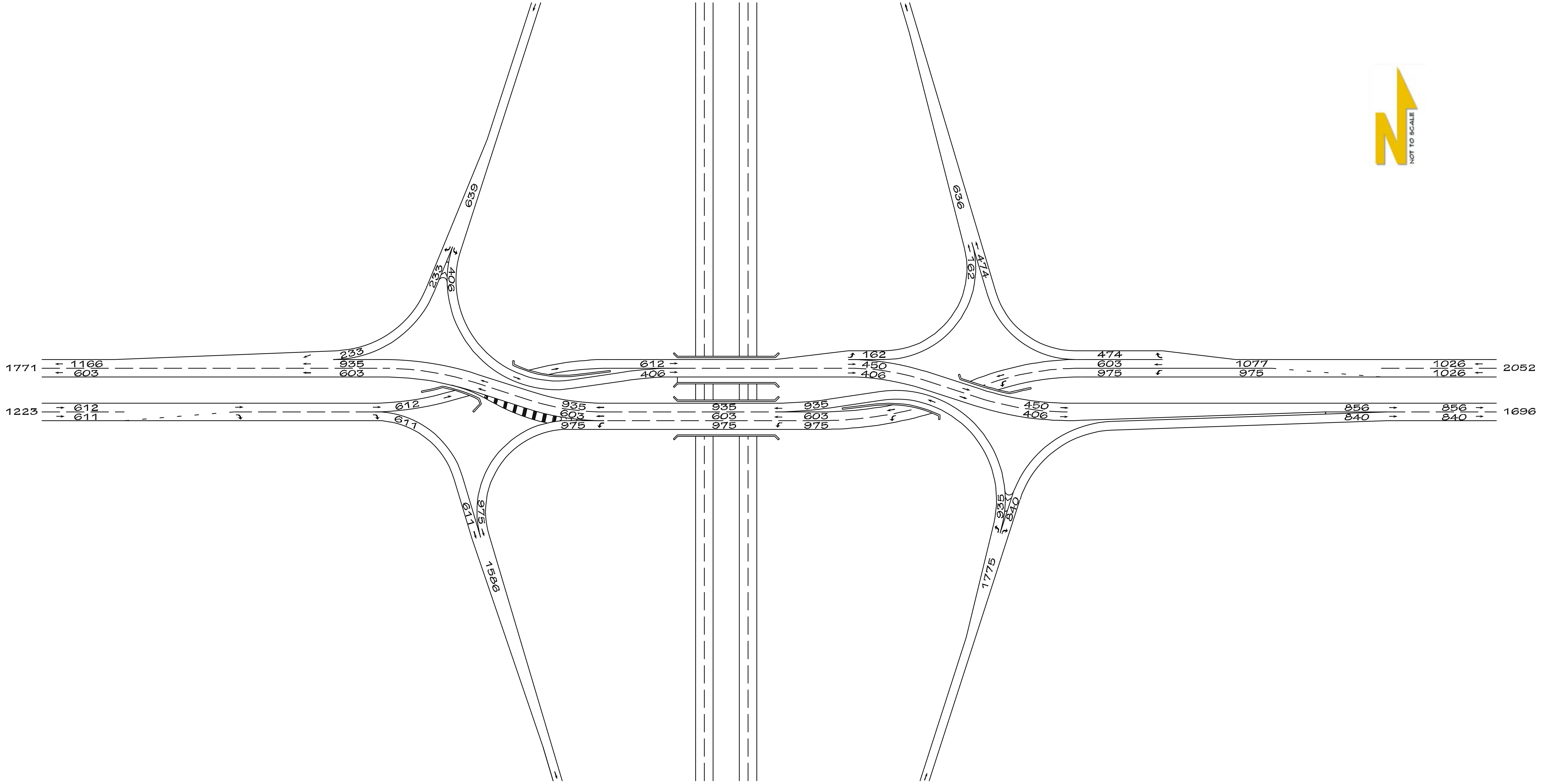
Double Crossover Merging Interchange (DCMI)

Lane Continuity (westbound) - Interchange Configuration with Volumes

June - 2011

Exhibit: 3 of 8



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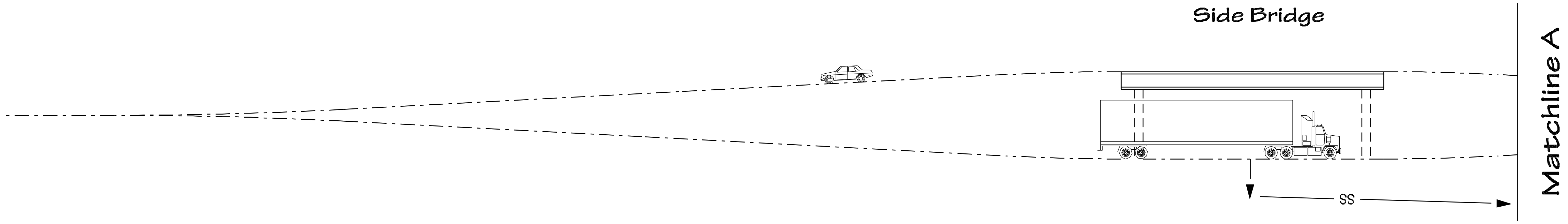
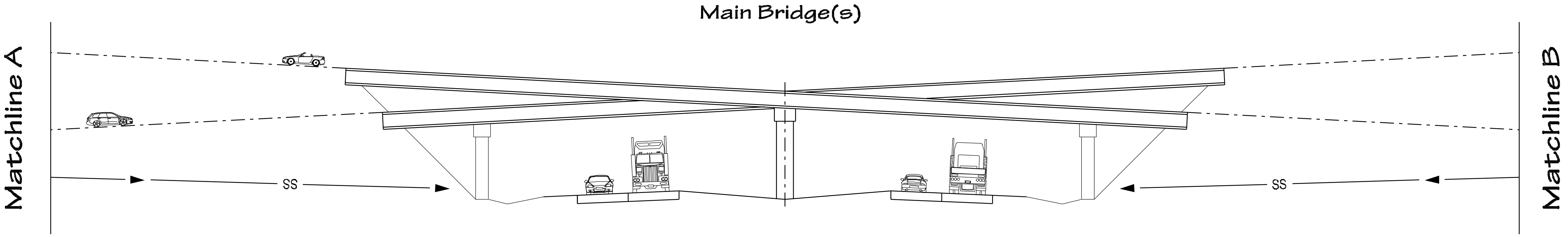
Double Crossover Merging Interchange (DCMI)

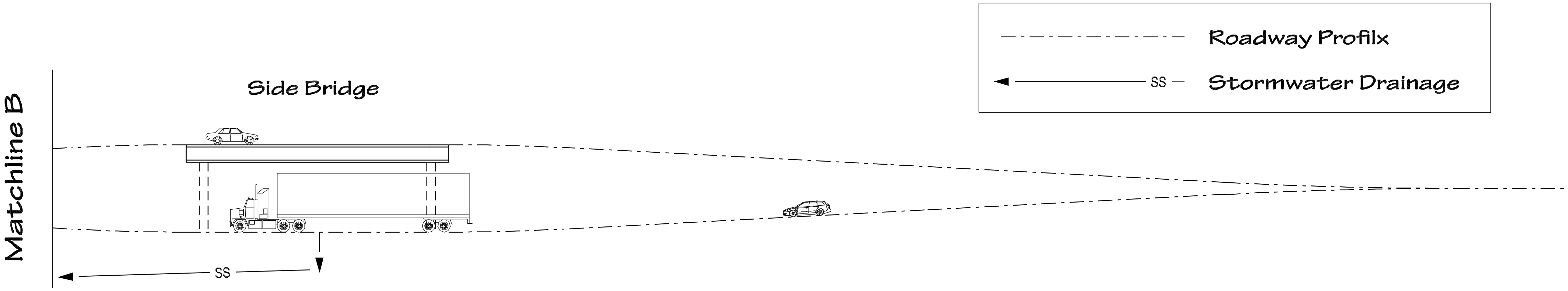
Turning Movements & Distribution - Interchange Configuration with Volumes

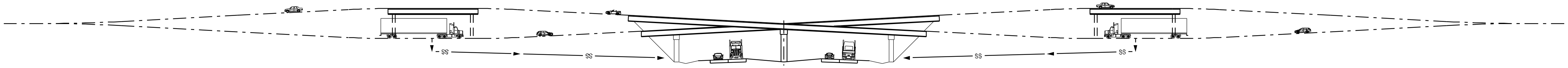
June - 2011

Exhibit: 4 of 8









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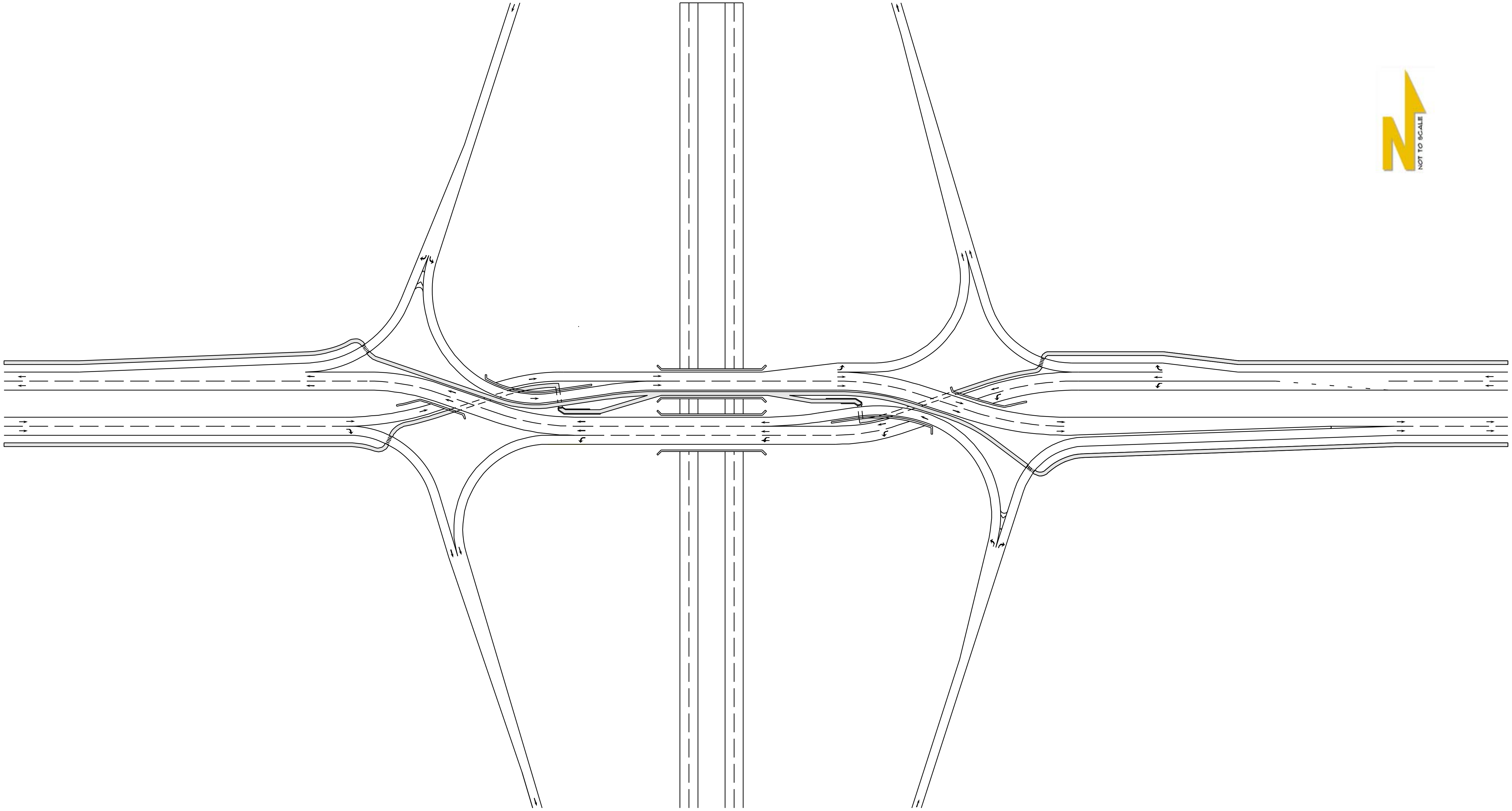
Double Crossover Merging Interchange (DCMI)
Profile & Gravity Drainage System

June - 2011

Exhibit: 5 of 8



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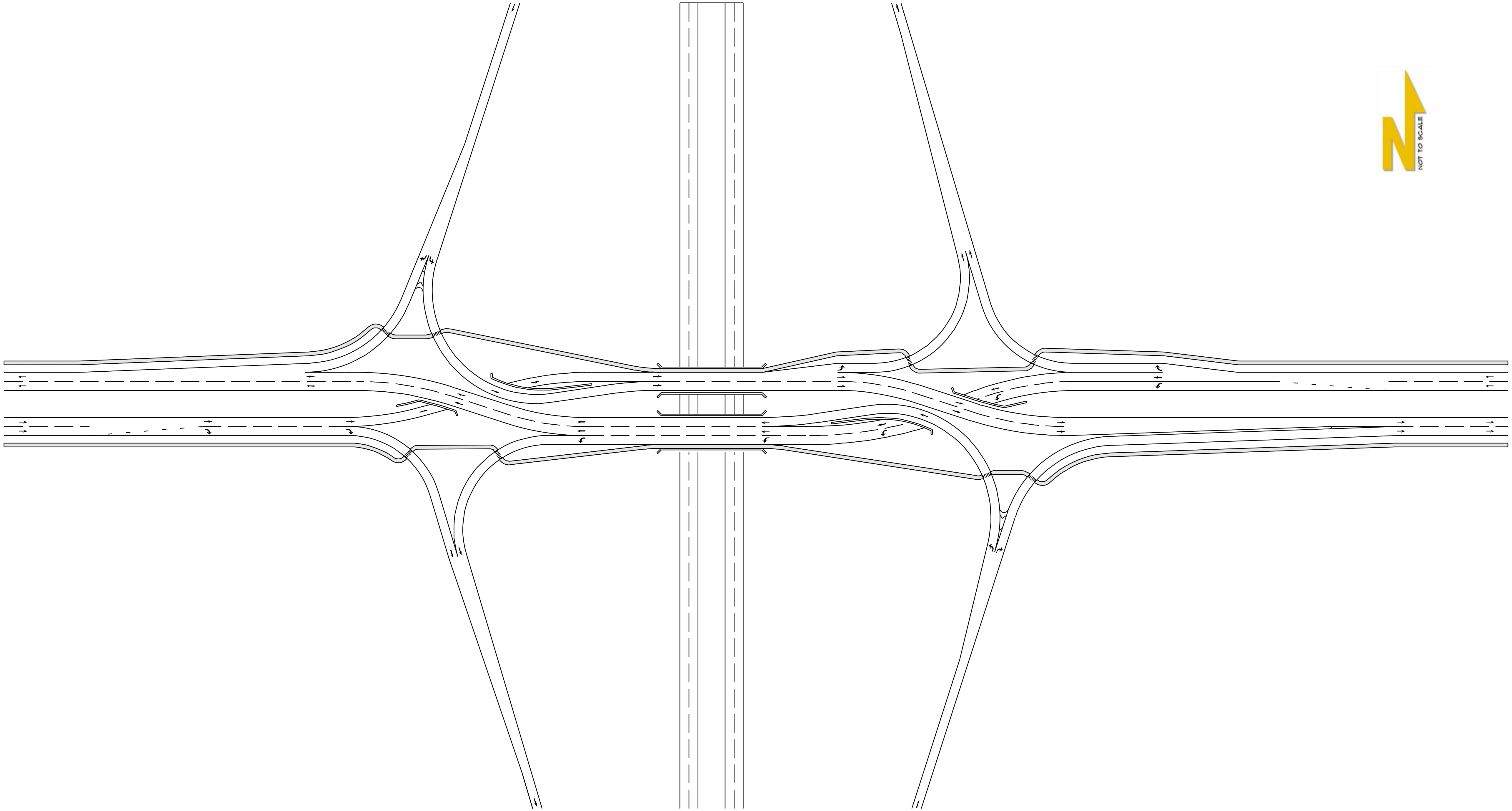
Double Crossover Merging Interchange (DCMI)

Cross-Over Pedestrian and Bicyclist Accommodations, Non Motorized Users (DCMI)

June - 2011

Exhibit: 6 of 8



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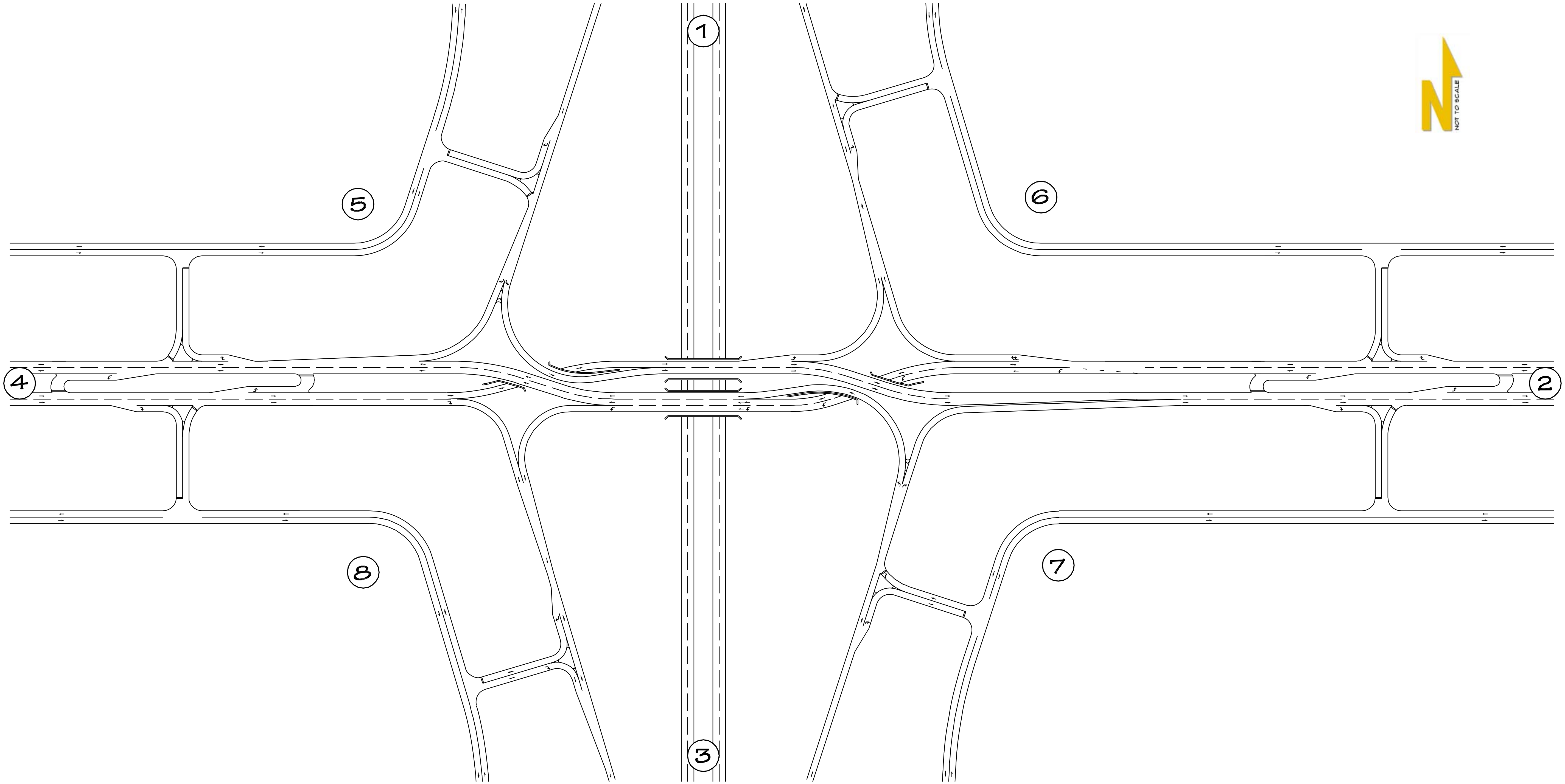
Double Crossover Merging Interchange (DCMI)

Parallel Pedestrian and Bicyclist Accommodations, Non Motorized Users (DCMI)

June - 2011

Exhibit: 7 of 8



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Double Crossover Merging Interchange (DCMI)

Local Access Systems

June - 2011

Exhibit: 8 of 8