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# ALTERNATIVE INTERSECTION DESIGN STRATEGIES

How Georgia and the U.S. are Changing Outdated  
Transportation Design Techniques

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# ALTERNATIVE INTERSECTION DESIGN STRATEGIES:

How Georgia and the U.S. Are Changing Outdated Transportation Design Techniques

by

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# ABSTRACT

## ALTERNATIVE INTERSECTION DESIGN STRATEGIES:

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The most deadly locations on our roads are the intersections. A 2008 study found that stop-controlled intersections were responsible for 70% of the deaths on United States roadways that year. The alarming significance of one particular aspect of the transportation system having such a negative effect on human safety year after year has propelled reconsideration into the design strategies of our roadway intersections and have fueled the need for options in design as opposed to one scripted method. Local and national examples of alternative design strategies are occurring at a faster rate, further demonstrating that the strengths and weaknesses associated with each strategy are largely dependent on site-specific circumstances. This paper presents a myriad of case studies that outline the successful implementation of alternative design strategies in addition to the local circumstances that made them successful. It is the purpose of this study to demonstrate the new standard of alternative design considerations along with developed examples of those still less-common intersection types. These deliberations are conducted in an effort to combat investment fears and promote a more successful and appropriate design of our transportation system.

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# 1 INTRODUCTION

We have probably all had the experience where we are in our car, stopped at a red light, watching the next signal one block away hold a green light with no one going through the intersection, only for the signal to turn red as soon as you reach it. Likewise it has probably been a past driving decision to circumnavigate a particular intersection or interchange because of frequent congestion at the location. Although design cannot solve all problems we face on the road, it has been proven, as will be presented with many cases in this paper, that the configuration of a roadway or intersection can have a significant impact on driver decision-making as well as overall ability to meet the objectives that were hopefully envisioned when the site was developed.

This paper is primarily a case study analysis of the methods leading the way in impacting the weaknesses in the conventional four-way stop signalized intersection. Some methods are as old or older in concept than the four-way stop but have just begun to gain traction in the past decade or two as the research and experience in the strengths and opportunities of some of these alternative methods continues to grow. Although local examples here in Georgia are the primary focus of this paper, some national examples of alternative intersection design are included with additional strategies those efforts bring to the subject.

## 1.1 Problem Statement

According to the National Highway Traffic Safety Administration, 70% of all fatal car crashes that occurred in the United States in 2008 occurred at a stop-controlled intersection (NHTSA 2008); furthermore, it has been found that 35% of all vehicle collisions occur at a roadway intersection (Green and Agent 2003). Intersections provide for the success of our roadway network as they enhance access and facilitate a higher level of efficiency in travel with more connections to alternative network links. It is therefore ironic that a key and necessary feature of a comprehensive transportation network is also the most deadly aspect of that system.

There are 32 vehicle to vehicle conflict points and 16 vehicle-to-pedestrian points (4 at each approach from right turn and through movements going each direction) in the conventional 4-way intersection. The reason why there is more than one vehicle-to-pedestrian conflict point for each approach and exit is because the design of the intersection lends for the right-turn movement to present a point of conflict that is slightly different than the through and left-turn movements, which merge onto the same vehicle path before reaching the pedestrian crosswalk. Additionally, given that conventional 4-way intersections generally permit a right turn on a red light, the conflict point is presented continuously and not with certain phases of a cycle.

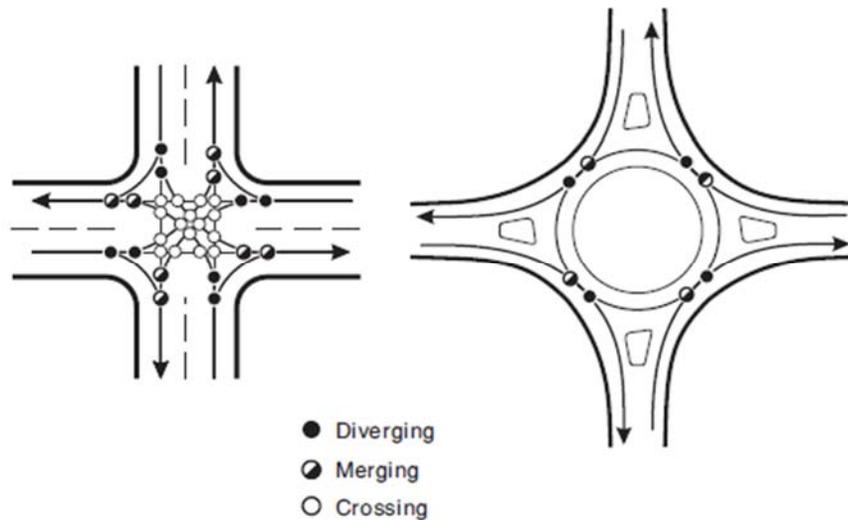


Figure 1. Vehicle -to-Vehicle Conflict Point Locations at 4-Way and Circle Intersections. *Source: Monroe, 2001*

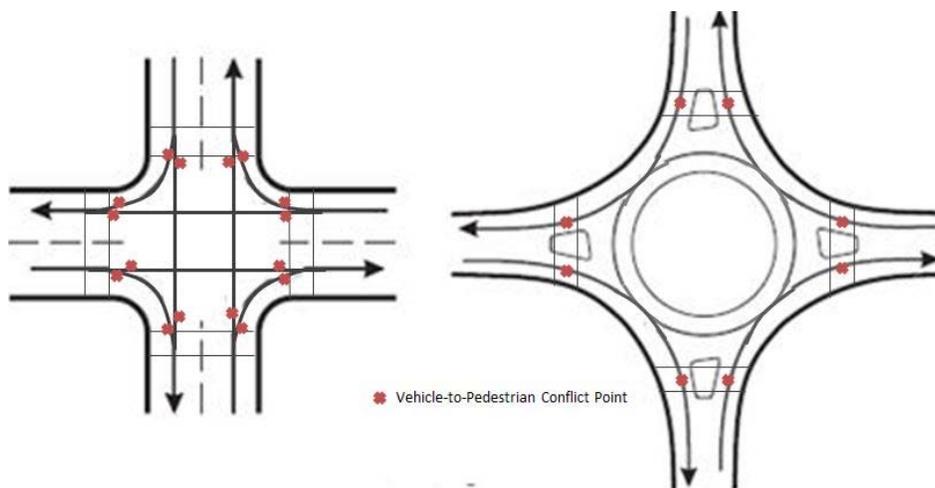


Figure 2. Vehicle-to-Pedestrian Conflict Point Locations at 4-way and Circle Intersections.

The previous figure shows the stark reduction of conflict points between a conventional 4-way intersection and a traffic circle. In total, there are 75% fewer vehicle to vehicle conflict points at a traffic circle and 50% fewer vehicle to pedestrian conflict points. The number of conflict points in a three-way or “T” intersection are also significantly lower than a four-way intersection with 9 vehicle-to-vehicle points, 70% fewer than 4-way, and 10 vehicle-to-pedestrian points, 40% fewer. Likewise, as depicted below, a three way traffic circle has fewer conflict points than a three-way, stop-controlled intersection.

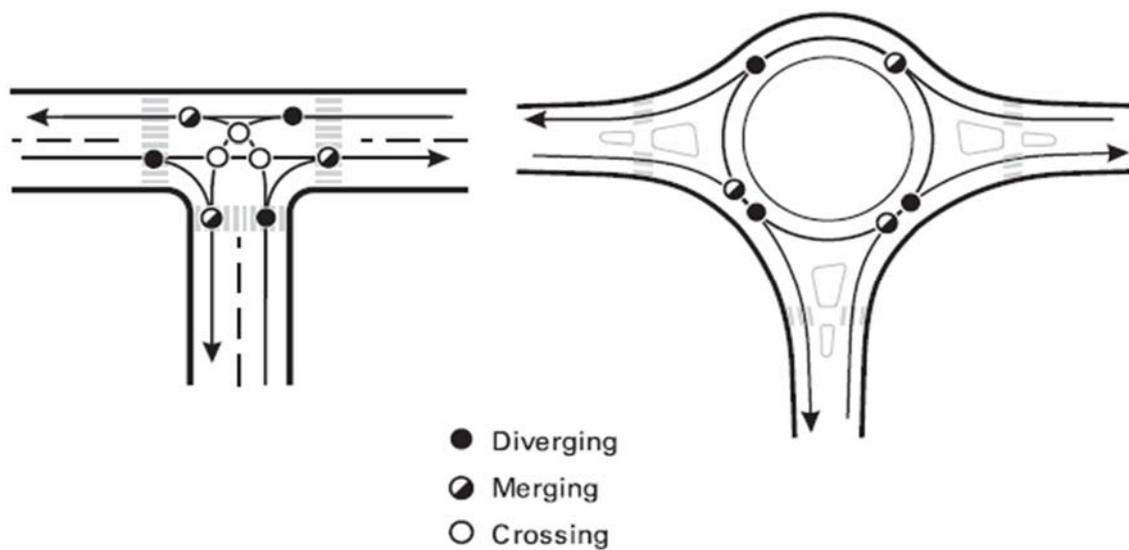


Figure 3. Vehicle-to-Vehicle Conflict Point Locations at T and Circle Intersections. *Source: Monroe, 2001*

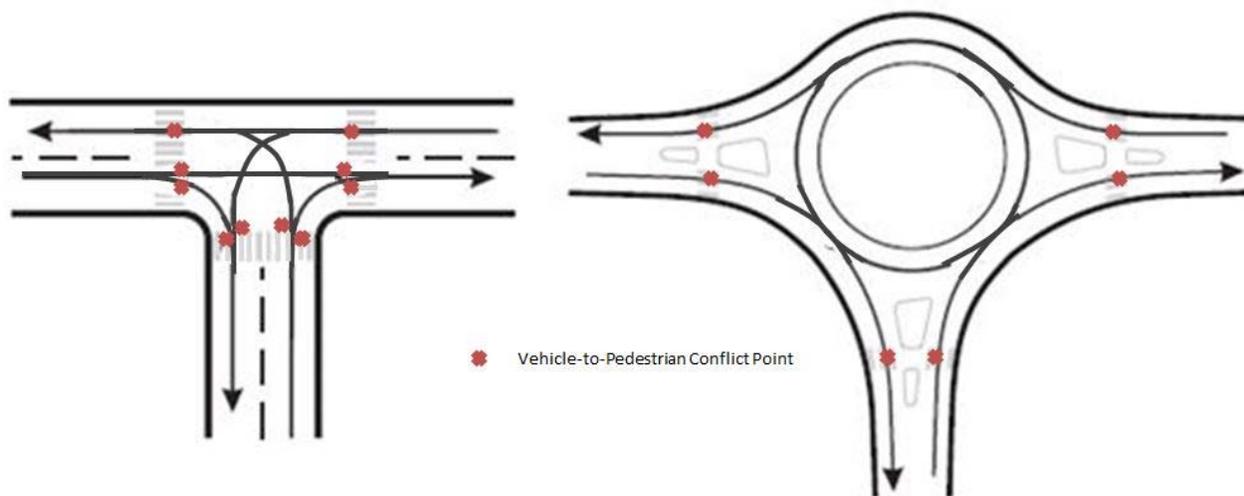


Figure 4. Vehicle-to-Pedestrian Conflict Point Locations

The number of conflict points at an intersection has a measurable impact on the number of collisions that can be expected to occur at an intersection. The following crash rates are determined by the number of collisions per million vehicles entering the intersection and were calculated by CalTrans and MNDOT. The results demonstrate the relationship between the number of conflict points present at an intersection and the amount of “realized risk” (crashes) that occur at that intersection (Monroe, 2001).

Table 1. Conflict Point and Crash Rate Relationship (per million vehicles entering intersection)

	4-Way Stop- controlled	3-Way Stop- controlled	4-way Traffic Circle
Number of Conflict Points	32 vehicle 16 ped	9 vehicle 10 ped	8 vehicle 8 ped
Crash Rate	0.77	0.47	.25

*Source: Monroe, 2001*

As the performance of any intersection or roadway segment is judged by its local use and how well it serves the communities that it ties together, the priorities and objectives of intersection design will differ from location to location. This is the first reason why the one-size-fits-all approach with the 4-way stop that has been used for the greater part of the last century is not appropriate at every location and can result in a low performance for any travel experience.

## 1.2 Objective

Because transportation projects commonly have not only a high price tag but induce social and further development implications for years and even decades, there is a common fear of investment into creative solutions to everyday problems. Although this fear is understandable, it is increasingly unfounded as municipalities, communities, planning boards, private investors and more continually break the mold on how we impact the usability of our transportation network in more ways than just vehicle operations. The overarching objective of this paper is to measure developed “alternative” strategies in their

abilities to meet local demand and solve mobility concerns. The amount of observed and tested examples included in this argument demonstrate that these “creative solutions” are not only being increasingly implemented and studied in locations across the country but becoming the new standard in some locations, given qualifying feasibility for the particular strategy. No more are the days where a fear of the unknown dictated the dismissal of a non-standard solution at the replacement of a 4-way stop-controlled intersection that fits poorly and creates additional inefficiencies and hazards on our roadways.

There are four general measures to the function of an intersection that can either be a priority strength or supporting factor to the performance of an intersection. As the different design strategies are presented in this analysis, these measures will be used to weigh the differing methods employed to engage with local needs and future demand. It is the objective that all strategies, including the conventional 4-way stop, will be shown to have a criterion of strengths and weaknesses that must be considered upon implementation. The four judgment criteria are:

- Safety
- Efficiency
- Sense of Place
- Accessibility

Safety is a primary concern given the sheer amount of risks, damage, injuries and deaths that occur along our roadways, especially at roadway intersections. The consideration of safety is not a strategy *per se* but of course must be a consideration in any development. The reason why this factor is included in this analysis is because differing designs can offer slight modifications on exactly how a user is safe by altering the locations of potential risk. Therefore the strategy in safety is not whether to include it or not but how to implement it in a way that addresses local needs and prevailing circumstances.

The efficiency of an intersection is judged by its ability to handle the needs that it is being designed for. It is important to note that throughput (automobile level of service) and efficiency are not synonymous as throughput is only one piece of what makes an

intersection efficient or not. For example, an efficient intersection may constrict throughput if the design is planned to do this.

Intersections having a sense of “place” sounds fluffy but is the primary reason “places” have been developed throughout recorded human history. Intersections of rivers, land and sea, trade routes (including modern highways), and national borders define the location of almost every major and most minor human establishments around the world. Even this place, Atlanta, was the result of intersecting railroads and sub-continental divides. Intersections provide a vital opportunity not only for the success of the transportation network but for the land uses surrounding it, given the advanced accessibility. Too often however intersections are developed as a conventional expanse of pavement with traffic signals overhead and painted crosswalks on each side (maybe), leaving no individual impact on the user whether in a car or on their bike or feet. Given the level of impact these locations can have on the surrounding area, the conventional system leaves a lot of opportunity untapped. More recently however, an increasing number of strategies to support intersection functions in addition to distinguishing the location as a memorable place have been implemented along with the pavement and crosswalks.

Finally accessibility, a strategy that can be as efficient when it is promoted as it can be when it is restricted. As will be further demonstrated later, although a certain amount of accessibility is required to make the transportation network work, too many access points in a certain area, how many depending on what the area is, can actually detract from efficiency and create safety risks.

### 1.3 Background

The 21st century has benefited civilized society with a myriad of technological advances that both advance how we interact with society and the environment around us as well as our ability to react with informed reason to the challenges that growth and social progress develop. With the advent of the affordable personal automobile and the economic boom of the post-World War II condition of the United States, the American population began an unprecedented relocation movement farther and farther from traditional urban cores.

The roadway network exploded in size and capacity over the second half of the 20th century along with the addition of the world's most comprehensive highway system in human history. With the sprawling effect this movement had on American cities, vehicle access became the primary consideration over much of the country and the number of roadway intersections multiplied with the continuing development of the modern American city. For all of this growth a need was developed whereby the increasingly dominant transportation mode of the automobile could efficiently access all functions of the urban setting with the highest amount of convenience or Level of Service (LOS) possible. Throughput was the resulting goal of roadway design in the 20th century.

Although efficiency, place and accessibility are vital measures of the success in a roadway, the primary concern of any roadway design strategy must be safety. This is the case not only because it should always be the design of any development to improve the human condition and not kill it, but also because of the fact that our roadways claim so many lives each year already. As stated previously, the National Highway Traffic Safety Administration reported that 70% of all fatal car crashes that occurred in the United States in 2008 took place at a stop-controlled intersection (NHTSA 2008), meaning that over 26,000 people were killed that year at intersections that were designed to enhance human life. Bear in mind that not all of these deaths occurred inside of an automobile, that year 5,320 of the 37,423 deaths on American roads, or over 14%, were deaths of non-motorist such as pedestrians and cyclist (FARS 2015).

## **2. LITERATURE REVIEW**

Due to the high level of risk that has been present on our roads for decades, a significant amount of data has been collected and analyzed on roadway functions. A review has been performed on analyses done in consideration of alternative intersection design and is presented generally hereafter. Although a complete report on all studies into the subject would be impractical to the purposes of this paper, a comprehensive overview on the types and depth of those studies is included.

## 2.1 Intersection Safety Implementation Planning

Created as a resource for each States' Strategic Highway Safety Plan (SHSP), the "Intersection Safety Implementation Plan Process" is a Federal Highway Administration (FHWA) report that outlines the steps for creating a comprehensive process on designing a modern intersection. Detailed in the title of the plan, this process includes the usage of historical lessons in unjustifiable safety risks (Bryer 2009). This process is initiated by the setting of a "Crash Reduction Goal", whereby the planning, analysis, development and implementation of the plan as a whole revolves around the benchmark goal of enhanced safety.

FHWA's process of developing an intersection or roadway, presented in Figure 5, ensures that there is more depth and consideration in the design process that revolves around a predetermined, measurable "crash reduction goal". Furthermore, the inclusion of identifying countermeasures in the third step of the process promotes the use of alternative strategies detailed further on and implores the project stakeholders to stray from conventional design in order to capitalize on the newest design strategies that impact travel function in different ways.

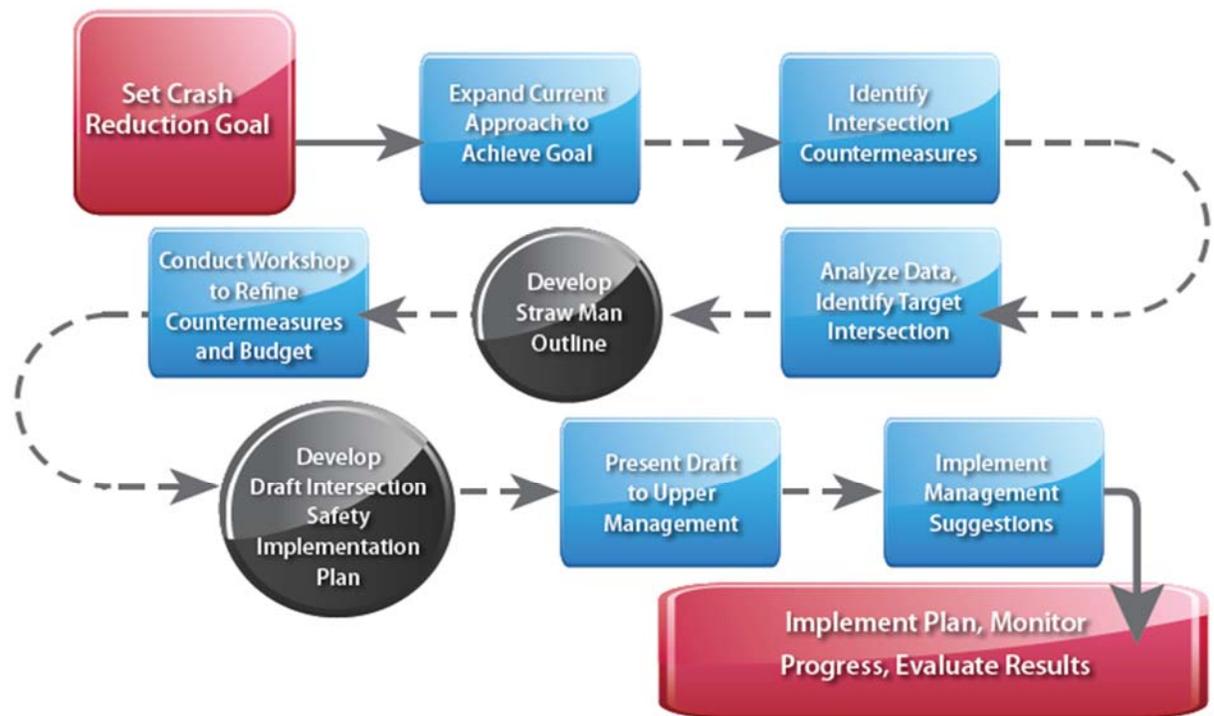


Figure 5. Intersection Safety Implementation Plan Process. *Source: Bryer 2009*

This step-by-step process would be appropriate as a focus on the aspect of vehicle operations as part of a much larger process that includes the other essential elements of a successful intersection. The Federal Highway Administration’s (FHWA) process is limited to consideration of safety implementation in regards to vehicle travel with no consideration to pedestrian, bicycle or transit modes. Although it can be assumed that a strategy successfully implemented in order to reduce vehicle crashes would have a positive impact on reducing pedestrian and transit collisions as well, the lack of inclusive consideration may fail to optimize the overall safety of the location or design. Having a narrowed focus on enhancing only vehicular operations could implicate hazards for other modes at the expense of a more thorough consideration of automobile traffic.

A secondary concern with this process is that its linear nature could have restrictive effects on the creation process and therefore limit the range of solutions that could be employed to respond to site-specific intersection needs.

## 2.2 Intersection Design Guidelines

The Institute of Transportation Engineers is a professional group made up of much of the personnel primarily responsible for how and what gets developed in the world of transportation across the country. In tandem with other transportation professional groups and agencies such as the Transportation Research Board (TRB), Federal Highway Administration (FHWA), National Association of City Transportation Officials (NACTO), and Texas Transportation Institute (TTI), all of which will be well-represented in this paper, these organizations are part of the leading effort to impact our transportation strategies by means of analysis, design standards and policy recommendations.

Design manuals are an aspect of the history of transportation that did almost as much hurt as they did good to the public realm. With the dynamic nature of these public spaces, setting fixed design guidelines generally restricts a local official's ability to respond to site-specific transportation needs.

Although the ITE publishes Intersection Design Guidelines, they are researched and proven recommendations as opposed to standard methods and predetermined form. In addition to the dynamic nature of this particular manual, the recommendations are updated frequently as further developments in research by ITE or other agencies advance the field of possibilities. This publication as well as several similar works published by the other mentioned agencies and more will be heavily relied upon to establish the argument of this paper.

## 2.3 Proven Safety Countermeasures and Safety Strategies

Although safety countermeasures can vary greatly depending on local issues or site-specific intersection considerations there are a set of "Proven Safety Countermeasures" put forth by the FHWA Office of Safety (FHWA 2012). These are nine tactics that at a national level can be appropriate for any intersection conflict reduction strategy in the United States (and globally). The "proven countermeasures" for national consideration, many of which are included in this paper later, are:

- Roundabouts
- Corridor Access Management
- Backplates on Traffic Signals with Retroreflective Borders
- Longitudinal Rumble Strips
- Enhanced Delineation and Friction for Horizontal Curves
- Safety Edge
- Medians and Pedestrian Crossing Islands in Urban and Suburban Areas
- Pedestrian Hybrid Beacon
- Road Diet

Meanwhile, the National Highway Cooperative Research Program (NCHRP), a research program administered by the TRB, published their own set of “safety strategies” that include physical elements such as the ones found in FHWA’s list but also incorporate tactical elements of intersection design. Surveying planning agencies and public works offices around the country, this list represents a collection of the most sought after changes in intersection design with the perspective of utilizing developing tactics of making signalized intersections safer. The shortened list, in no order of priority and without consideration for pedestrian or bicycle safety, included the following strategies (Srinivasan et al, 2011):

- Split phasing
- Adding protected left-turn phasing
- Modifying the change interval
- Restricting or eliminating turns at the intersection
- Remove unwarranted signals
- Adding left-turn lanes
- Lengthening left-turn lanes
- Improving right-turn channelization
- Modify intersection skew
- Improve sight distance

- Advance Warning Signs for Red Signal
- Improvements in signal visibility and conspicuity

## 2.4 Accuracy vs. Precision

The final insert into this literature review pertains to the nature in which the analysis of the varying strategies presented in this paper as well as in other like sources on the subject is conducted and perceived. In his comparison of utilizing either accuracy or precision in measuring transportation efficiency measures, Todd Litman of the Victoria Transport Policy Institute says that “... vehicle traffic volumes and speeds are relatively easy to measure and so are often used to evaluate transport system quality. But other more difficult factors may be equally important, such as walking conditions, the distribution of common destinations, and the ease with which non-drivers can perform activities such as commuting and shopping. An accurate assessment of transport system quality requires that these factors be considered even if their measurement is less precise than those measuring traffic.” (Litman 2003)

Furthermore, in consideration of the strategies included hereafter, results of safety, efficiency and accessibility measures will be presented within the frame of being an accurate representation of the design’s ability to impact transportation functions rather than simply a very precise measurement of a certain traffic phenomenon.

## **3. NON- MOTORIST CONSIDERATION**

In the common transportation dialogue, pedestrian consideration is specialized depending on the issue at hand at the time; these topics could be “pedestrian safety” or “pedestrian accessibility”, or others along that line. Pedestrian consideration however should be matched at every step of a design process with that of the vehicle consideration. Because of land development patterns over the past century nationwide, the road network is almost always the only means of traveling from any point to another with a certain level

of efficiency. By that reason, traveling persons outside of a vehicle have the same necessity of a roadway intersection as those who are inside a vehicle.

Consider for example, the safety countermeasures and strategies published by the FHWA and NCHRP in the previous chapter of this paper. Although the FHWA includes some consideration to pedestrian involvement at roadway intersections in their “proven countermeasures” such as pedestrian hybrid beacons and crosswalks, no such consideration is given in the NCHRP safety strategies. Although some of the measures could have a positive impact on non-motorist safety at intersections, such as improving sight distance, it is clear that the creators of this list were only directly considering vehicle safety on the roads. This is a common mistake that could give unbalanced attention to one type of users of the road, even though they are the primary users in most cases, at the possible expense of the minority modes that use the same facilities.

### **3.1 Site-Specific Consideration**

There is an understandable exception with rural intersections that may see a pedestrian once every other year; urban and suburban intersections however, even if not popular to pedestrian traffic, must have equivalent attention to pedestrian safety, efficiency, sense of place and accessibility with that of the car. Although the surrounding land use patterns will largely determine the overall demand of pedestrian travel and whether a sense of place can be achievable, a built intersection should retain an effective standard of these qualities regardless, much like the treatment of a vehicle at a rural intersection would allow for safe and efficient travel regardless of any immediate development at that location.

Generic guidelines for design may be a risk to site-specific consideration but certain considerations are basic enough that holding them as a minimum standard should not impose on either creative abilities or local functions. Infrastructure for alternative modes that should be held standard at any location include sidewalks, working detection and marked vehicle stop locations for stop-controlled intersections. Furthermore, enhanced

pedestrian visibility should be a consideration in any design because of the risk not only inherent with vehicle interaction, but also presented with the aforementioned conflict points created at an intersection.

### 3.2 The Complete Streets Movement

Although the movement to develop intersections that more adequately adhere to the needs of multiple transportation modes has been an ongoing battle, the branding of this movement of redevelopment into “complete streets” was initiated by Smart Growth America (SGA) in 2004 as the National Complete Streets Coalition (NCSC) (SGA 2015). Commonly tied with another redevelopment strategy of road dieting that will be expounded on later, the complete streets movement is not a singular list of strategies but a comprehensive process of turning an automobile-oriented design that is unfriendly and dangerous to all other modes, in addition to automobiles themselves, into a place that interacts with and accommodates multiple modes and necessities of the individual location.

Individual consideration is an essential approach to the complete streets coalition. The goal of the complete streets movement is not simply to make pedestrian operations dominant at the expense of automobile operations, as some would argue it can only do, but to engage in an exhaustive process of optimizing roadway efficiency, as deemed appropriate by surrounding land uses and considering *all* transportation modes that require the facility. Cited from the NCSC’s fundamental objectives: “A “complete” street in a rural area will look quite different from a “complete” street in a highly urban area, but both are designed to balance safety and convenience for everyone using the road” (SGA 2015)

In its decade-long existence, Complete Street policy recommendations, design guidelines, and education efforts in professional and community forums have resulted in over 700 “agencies at the local, regional, and state levels” adopting Complete Street policies (SGA 2015)



Figure 6. Example of Complete Street project. *Source: Best Complete Streets Policies of 2014*

### 3.3 Pedestrian Signals

Mentioned as one of the nine proven safety countermeasures by the FHWA, pedestrian signals have a significant impact on pedestrian safety on the roadway. Typically located between and at vehicle intersections, several different styles of pedestrian signals have been evaluated and found that “motorist yielding to pedestrians increased from 31 to 93 percent.” (Fitzpatrick et al. 2005)

The implementation of a pedestrian signal produces an opportunity signal that in most systems is activity-activated, where vehicle traffic operates normally unless a sensor is triggered by a pedestrian and warning lights begin to flash. Although this method is optimal according to NACTO, other methods could require virtually no maintenance and therefore may more easily be implemented in more locations (NACTO 2015). These methods could be as simple as a painted crosswalk and warning signs alerting vehicles to the possible occurrence of pedestrian traffic. Figure 7 includes a pedestrian signal opportunity intersection located in Midtown, Atlanta.



Figure 7. Crossing with Pedestrian Beacon in Midtown, Atlanta. Source: NACTO Urban Street Design Guide

## 4. TRAFFIC CALMING STRATEGIES

In an effort to impact high-speed traffic flow as an alternative to a policy-led speed limit change, certain design tactics can be implemented that enhance driver perception. The view of the driver, especially one travelling faster than the design speed of the road, is critical to safety along the roadway and even more so when approaching an intersection as vehicles and pedestrians cross the direct path of the vehicle.

These strategies are not solely engineered to make every street a residential-style road with cars slowed down to a crawl, although they could definitely be used to achieve that result, but these strategies are effective in making the speed of vehicles appropriate to the activities to which the road gives access.

### 4.1 Curb Extensions

Traffic calming strategies can work to not only slow the speed of passing vehicles but force drivers to pay more attention to their surroundings than the historical straight-shot, linear vehicle path with minimal impediments does. Curb extensions are one way to narrow the roadway at a specific location, which effectively brings approaching vehicle

speeds down and driver's attention up as well as shortening the distance that a pedestrian must walk to cross over each approach (Figure 8).

Promoted in Texas Transportation Institute's "Urban Intersection Design Guide", curb extensions also "Improve the visibility of pedestrians by placing them where drivers can see them and where parked vehicles do not obscure their presence" (Fitzpatrick et al., 2005). Some disadvantages of this option are related to maintenance issues whereby it creates difficulties for sweepers and snowplows to adequately remove trash and debris from the roadway. Storm water drainage was an issue in the past but has been observed to be remedied by making the curb extension an island with a small canal in between the



extension and the curb as opposed to one solid piece. This small canal allows storm water to drain past the extension and not create an unsafe build-up at the intersection.

Figure 8. Example of Channelized Curb Extension for Pedestrian Safety mitigated for Storm water Flow.  
*Source: NACTO*

## 4.2 Woonerf Design

In some locations where high-speed vehicles diminish or even eliminate the sense of place and community from an area craving for a community space, the woonerf concept has been able to create a place from the roadway by reducing vehicular speed and designing for a place of community interaction, not just car travel. This concept deals more with roadway between intersections but has an impact on intersection design in that one of the primary principles of the woonerf concept is a distinct entrance into the shared space. The guidelines of a woonerf are outlined in "The Woonerf Concept" (Collarte 2012).

- Have a clear and distinct entrance.
- Eliminate the continuous curb- Pedestrian and automobile on same level.
- Implementation of traffic calming measures- slow speeds needed for shared space
- On street parking- A measure of traffic calming as well as safety
- Incorporate outdoor furnishings and landscape- turning the roadway into a place.

Collarte includes an example of Appleton Street in Boston, a one-way street that was previously used as a shortcut by drivers wishing to get to an adjacent arterial quicker. The resulting woonerf design is depicted below:



Figure 9. Western exit of Appleton St Woonerf, Boston. *Source: Google*

The western exit of the block. The Appleton St woonerf can be seen on the right. The pavement changes from asphalt to brick, the street level is raised so there is a decline to exit the woonerf (incline to enter on the other side of the block).



Figure 10. Eastern Entrance of Appleton St Woonerf, Boston. *Source: Google*

A look down the Appleton St. woonerf demonstrates on-street parking, bollards, distinct pavement, landscaping, lighting, and chicanes working to produce an environment where cars are compelled to share the space with neighbors.

The woonerf concept is one that emphasizes safety, place and is efficient in calming traffic speeds in comparison to other non-woonerf segments of the same street, all at the expense of a certain level of mobility. Choosing to make the road an unattractive alternative to the collector road that it runs parallel with, the raised entrance, chicanes (shown in Figure 10 and expounded upon in next section), on street parking and different paving effectively work to restrict mid-to-high levels of mobility and therefore promote only residential use of vehicles and a measurably safer environment for other modes.

### 4.3 Road “Wiggle” or Chicanes

Chicanes are physical impediments that intrude into the straight path of the roadway and force vehicles to perform an s-curve type movement that can only be safely conducted at lowered speeds. Studied as a standard traffic calming measure, the City of Seattle has observed chicane implementation to reduce car speeds from 18 to 35% (Burlington 2007).

Similarly, “wiggling” the road removes the straight-line function of common streets and replaces it with a serpentine curvature that is uncomfortable to drivers at high speeds. Proposed for specific segments of Memorial Dr. in Atlanta, introducing horizontal curvature into the roadway has been observed to be an effective tool in impacting vehicular speeds with roadway design. The degree of how vehicle speeds are impacted depends on the degree of horizontal curvature that is implemented. As an example, this concept of “wiggling” the road as depicted in Figure 11, can be accomplished on developed streetscapes by removing one lane from the existing roadway and therefore gaining 10-12’ of road width in order to restripe the road to include the curvature depicted in the model below. The model also depicts the developed opportunity for on-street parking and widened sidewalks, but bike paths, landscaping and other uses could be helpful additions to the roadway.



Figure 11. Road Wiggle with Chicane on Memorial Dr. Source: Marcus Ashdown and Charles Jiang

#### 4.4 Intersection Retrofit/ Road Diet

Communities change over time and often intersections are designed while the land uses around it are still underdeveloped. Featured in the figure below, the intersection of Memorial Dr, Cottage Grove and 4th St was one that incorporated a T-intersection that is unceremoniously joined by Cottage Grove at an angle, resulting in an intersection with blind corners, irregular phasing, on-street parking (within the area of the intersection as vehicles are parked in front of the stop bar in Figure 12) and access points coming from every direction. Clearly this presents an unsafe situation for any user no matter the mode. This safety hazard was observed while on location when a motorcyclist entered the road from the car dealership (white-roofed building on left side of image) and was instantly hit in the side by a car which had just turned onto the road from 4th St, which is the road that is straight up and down in the figure. Because of the blind spot created by the dealership, the car had already gained too much speed by the time the motorcycle was in view.

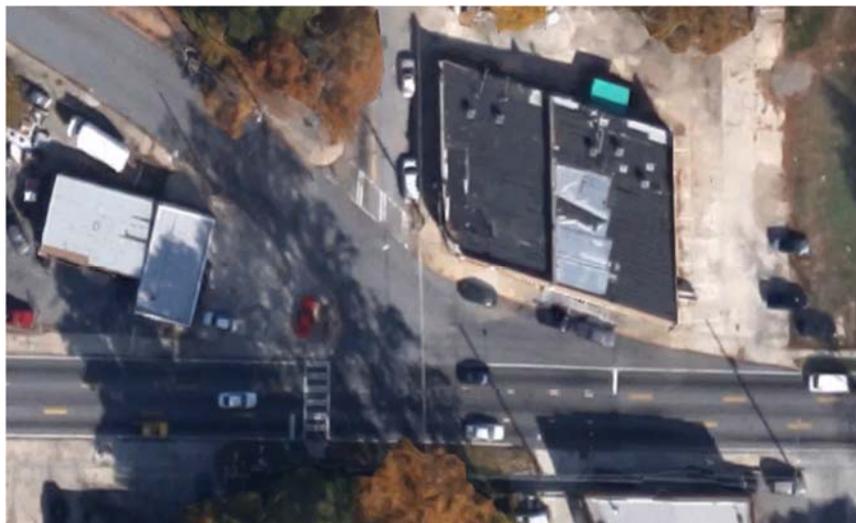


Figure 12. At Memorial Dr, Cottage Grove and 4th St.  
*Source: Google*

After an analysis of traffic demand, it was found that the amount of vehicles traveling on Cottage Grove, the slanted road, was very light even at peak periods. Furthermore, just to the left of the intersection, 3rd St travels straight south from Cottage Grove to link with Memorial Dr., less than 150 meters from this intersection. Since the only access point to Cottage Grove between 3rd St and this intersection was a school driveway, it was proposed that Cottage Grove be closed after 3rd St and the driveway redirected to enter straight onto 4th St as opposed to at the intersection as Cottage Grove presently does.



Figure 13. Overview of area around Memorial Dr. and Cottage Grove intersection. Source: Google

Closing Cottage Grove at 3<sup>rd</sup> St allowed for the retrofitting of this intersection into a smaller, more conventional T-intersection and also resulted in an expanse of land that could be repurposed. After modeling several alternative uses for the acquired land, public opinion expressed preference for a bus pull-out and plaza to be located at the site. The bus pull out would replace a current bus stop 50 feet away and provide space for the bus to stop without holding traffic during the time of day where there is only one westbound travel lane.

The plaza was a positive addition to the surrounding communities that has no such amenities in the immediate area. The location of the coffee shop in this building could encourage outdoor seating, small park functions and most of all, a dash of public space in an area that is in need of such places. Therefore, this concept not only solves the issues and hazards of a roadway intersection but does so in a way that is congruent to the surrounding land uses.



Figure 14. Cottage Grove Retrofit Proposal on Memorial Dr. Source: Marcus Ashdown and Charles Jiang

This retrofit proposal was aimed at taking an existing intersection which failed at adequately providing an efficient level of use to surrounding communities and not only relieving the location of the risks that had been developed there but providing a public place where an elementary school, coffee shop, salon and bus stop could be not only accessed but enjoyed safely. The efficiency of the intersection considering all modes is greater given driver comprehension and pedestrian crossing widths and visibility.

As another example, less than a mile down the road on Memorial Dr. is the intersection of East Lake Blvd where surrounding land uses include residential housing, a YMCA center and a charter school. A young girl was hit while crossing this intersection less than six months prior to this proposal and resulted in some redevelopment including more time given to the crosswalk and lighting upgrades however no changes in the design of the intersection were implemented.

The figure below depicts the street view of the path that pedestrians coming from the Kirkwood neighborhood (to the right) use, which is a dirt path that turns to concrete on Memorial Dr. but is elevated not more than three inches. In addition to this practically at-grade sidewalk, there is a wall that increases with height that restricts the sidewalk to be less than the needed width to be adequate for two people walking side by side, for example a mother and child walking to the YMCA or elementary school located on the other side of Memorial Dr. With vehicles traveling above 40 mph on average, the risk for injury or death is significant.



Figure 15. East Lake Blvd and Memorial Dr. *Source: Google*



Figure 16. East Lake Blvd Retrofit Proposal on Memorial Dr. Source: Marcus Ashdown and Charles Jiang

Therefore it was proposed that a lane be taken (Memorial Dr is three lane reversible at both ends of the segment this intersection is located in) in order to not only reduce vehicle speeds closer to the posted 35 mph limit, but gain opportunities, for wider sidewalks with fencing and landscaping and midblock crosswalks in order for pedestrians to access the elementary school better.

This segment of the arterial highway may have been developed when the surrounding land was either undeveloped or underdeveloped but is now almost completely built out with single-family housing, a charter school and a YMCA facility. This new use structure that involves not only arterial vehicles but community members accessing the intersection to go to school or play requires a reconsideration on the design of that intersection and worthy retrofitting to be implemented. Speaking of roadway intersections that are designed without complete consideration to surrounding land uses, James Kunstler contended in his book *The Geography of Nowhere* that:

“Anybody knows that a child of eight walking home from school at three o’clock in the afternoon uses a street differently than a forty-six-year-old carpet cleaner in a panel truck”(Kunstler 1994)

Besides a reduced vehicle speed, which was planned already and technically required by law, no accessibility was taken or delay added to vehicles on the arterial road, which was operating well within capacity at four lanes. Instead, further development in the safety, accessibility and place and therefore overall efficiency was modeled for all users of the intersection.

## 5 ALTERNATIVE DESIGN STRATEGIES

The strength of the classic four-way stop is its almost universal compatibility. Developed during a time when assembly lines and interchangeable parts were revolutionizing the world over, the four-way approach with timed signals was a standard concept that was functional in almost any intersection scenario. The disadvantages of this style however include the driver's obedience to signaling, attentiveness to signage, and knowledge of right-of-way. These concepts have been found to cause more deaths at intersections than in any other location on American roads (NHTSA, 2008).

Additional disadvantages include breaking up the natural flow of traffic in an attempt to gather and control usage of the intersection. The fallacy in this goal are the many access points in between signalized intersections that work against the "platooning" of vehicle traffic by introducing merging vehicles randomly, as well as creating numerous conflict points that heighten safety risks. For example, between East Lake Dr. and Candler Rd, two signalized intersections along SR-154/ Memorial Dr. about a half mile apart from each other, there are more than 70 access and potential conflict points onto SR-154.

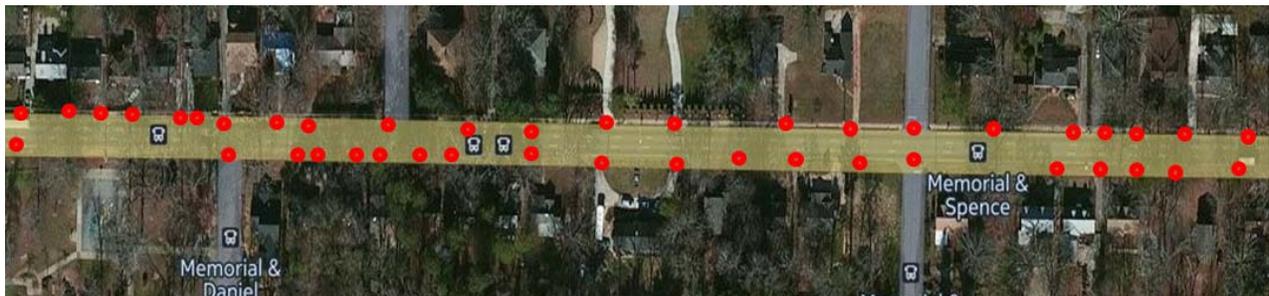


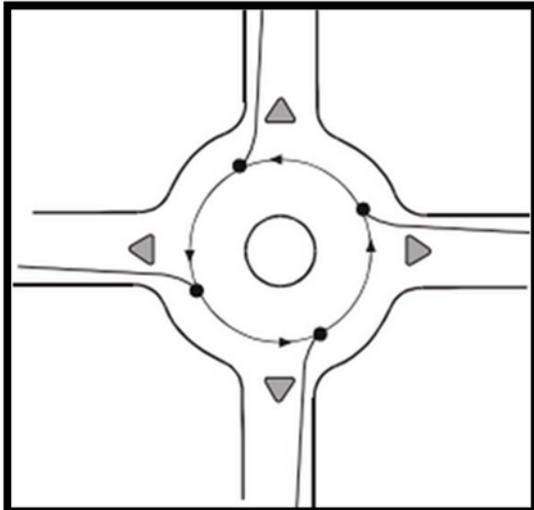
Figure 17. Memorial Dr between Green and Oakridge Ave with access points marked.

There have always been alternative intersection design strategies to that of the four-way stop. Some have been more popular outside of the United States while others are only appropriate in specific circumstances and therefore remain uncommon, either way these options join emerging ideas that have been developed to combat the risks and failures in the classical model.

## 5.1 Traffic Circles

For urban arterial streets, roundabouts may be an effective alternative design to signalized intersections under certain circumstances as they promote continuous flow as opposed to segmented phases and cycles. According to a National Cooperative Highway Research Program report, there was a 35% overall decrease in crashes and 81% decrease in fatal crashes at 55 intersections nationwide after roundabouts were implemented (FHWA 2006).

The advantages to the roundabout have been proven to be very successful in many locations around the country and have even been set as one of FHWA's proven safety countermeasures as indicated before. With the continuous flow nature of the roundabout, lost time waiting for access to the intersection is kept at a minimum where only heavy



traffic flow becomes an impediment (an issue with any intersection). Additionally the roundabout is designed with a consolidated vehicle path so the number of conflict points is significantly reduced to only 4 vehicle to vehicle conflict points and 8 vehicle to pedestrian points.

Figure 18. Roundabout Conflict Point Locations.  
Source: *ITE Intersection Design Standards, Ch. 10*

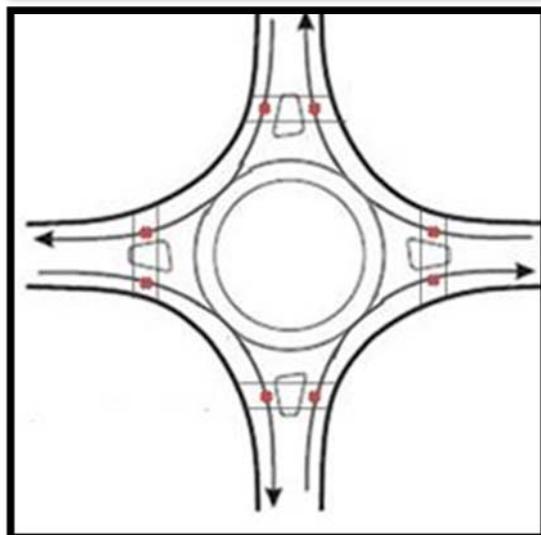


Figure 19. Roundabout Vehicle-to-Pedestrian Conflict Point Locations.

The perceived disadvantage of a roundabout intersection is that it is driver-controlled, a characteristic that American highway engineers in the past have avoided. It is also maintained by American traffic studies that only certain traffic demand patterns would be appropriate for roundabout implementation, one

guideline being that the major road of the intersection should not hold more than 80% of the traffic that enters that intersection (Raff, 2014).

## 5.2 Ovalabout

Another concept developed in the Imagine Memorial Dr. proposal process was that of the "ovalabout", which builds on the continuous efficiency of the roundabout with a focus on mitigating dangerous offset signalized intersections such as Memorial Dr. and Whitefoord. The design feature of an ovalabout is that of an ellipse-shaped median located at the center of the offset. The conceptual illustration of an ovalabout included demonstrates the design's minimal need for additional right of way beyond that of a standard intersection.

This design was appropriate for the location because it is located at a mostly residential portion of Memorial Dr. and therefore rarely requires large trucks to turn onto the side streets. However, the sidewalks and elongated median are designed with gradient curbing that can be easily rolled-over given the infrequent circumstance where a large truck would need to access the neighborhood roads at either end of the offset intersection.



Figure 20. Ovalabout Concept Design at Memorial Dr. and Whitefoord.  
*Source: Marcus Ashdown and Charles Jiang*

Pros of the Ovalabout design:

- Continuous flow design
- Zero head-to-head collision points
- Enhanced pedestrian safety
- Traffic calming results

Cons of the Ovalabout design

- Elongated left turn movement off of primary route
- Difficult turning radius for large trucks (without utilizing the rollover curb)

### 5.3 Access Management Techniques

Although accessibility has been referenced up to this point as an aspect of intersection design that should be further developed, there is a point in which there could be too much access to the transportation network at the expense of other needs. This oversupply of access is most commonly found to be an issue with automobiles and a too-frequent occurrence of curb cuts or access points to the road. Although too few access points diminish the effectiveness of a service road, too many may also have a negative effect on the roads capacity and even safety.

Imagine you were on an urban interstate highway that had consistent back-to-back on and off ramps, not only would the highway lack any priority and would have drivers using the highway for short-distance routes manageable on surface streets, but the amount of lane weaving and entries and exits would result in a congested and unsafe driving experience. Likewise, arterial and collector functioning roads can reach a point where access opportunities are in overabundance and detract from the function of all modes.

When access is not properly managed it can fall to either side of being too limited or too abundant and although it is more often underdeveloped, there are situations where access reaches an ineffective and unsafe point and must be mitigated. The techniques to reign in access are plentiful and almost always greatly disliked by adjacent property

owners, especially those owning businesses, as they have been accustomed to having individual access to their individual parcel.

As converging paths and resulting conflict points are what make intersections a risk to those interacting with it, so do subsequent conflict points around or after the intersection. The previous example of the motorcyclist being hit by a turning vehicle occurred due to the biker accessing the arterial too proximate to the intersection that a safe sight-distance was unattainable for the vehicle driver. It is not unusual to find corner-lot properties with driveways less than 100 feet from an intersection.

Intersections are designed with specific measurements that take into account the stopping sight distance for a vehicle to adequately react to the functions of an intersection within a manageable distance. Furthermore, pedestrian crossings are normally not protected only but share time with the left turn movement in a permissive left phasing sequence and if vehicles are accessing the road far within that sight distance and accelerating quickly in order to make the light, from a design perspective, the driver will not have adequate time or space to avoid a collision with the pedestrian.

Although minimum distance requirements around an intersection should be commonplace, a quantitative measure on when the number of access points within a section of roadway become “too many” is difficult to set as a general rule. Unfortunately, with safety it is often concerns, and regrettable experiences, with safety that reveal an excessive amount of access points. How they are dealt with can range from consolidating curb cuts to installing a raised median.

Installing a raised median is one tactic of access management that has been observed to succeed in addressing safety concerns in particular. The two-way left turn lane, or “suicide lane” as it is often referred to as, has been used as a means to allow vehicles making a left turn to exit the general traffic flow and wait for a gap in the opposing traffic to make their turn. The concerns with this design is that not only is the lane two-way and therefore raises right-of-way battles, but it introduces all of the 32 vehicle to vehicle conflict points found in a standard intersection however with no presence of a traffic light regulating the different movements. It can be assumed that this scenario obviously provides for an unsafe traveling scenario where an accident is waiting to happen.

A study was presented in the Third Annual Access Management Conference held in 1998 on Memorial Drive, where these exact concerns were had and resulted in the Two Way Left Turn Lane (TWLTL) being replaced by a raised median 4.34 miles long, with breaks only at signalized intersections. In a before and after comparison conducted by a Georgia Tech professor and two GDOT officials, it was found that there was a 37% decrease in the collision rate (per million VMT) and a 48% drop in the injury rate along that particular stretch of Memorial Dr. Additionally, “whereas in the 11.6 years preceding the project there was 15 fatalities, including six pedestrian deaths” there was no fatalities of any kind post-construction up to the last point it was measured and reported, 8 years after the median had been implemented (Parsonson et al. 1998).

Meanwhile, a study into crash rates as affected by roadway type was conducted using Utah Department of Transportation data to assess the impact on pedestrian safety that differing access management techniques can produce. For further observation, the crash rates were divided by mid-block collisions and intersection collisions with pedestrians in order to compare the impact these techniques have in both locations. It is significant to note that in all types, pedestrian crash rates at intersections were better than mid-block crash rates, furthering the argument for adequate pedestrian consideration at vehicle intersections in addition to mid-block consideration.

Table 2. Mid-block and Intersection Crash Rates by Median Type. (Lewis 2006)

Roadway Type	Median	Mid-block Pedestrian Crash Rate <sup>1</sup>	Intersection Pedestrian Crash Rate <sup>2</sup>
Undivided 4 lane	None	6.69	2.32
5 lane (TWLTL)	Painted	6.66	2.49
Divided 4 lane	Raised	3.86	0.97

<sup>1</sup> per million VMT,

<sup>2</sup> per million entering vehicles

Access management control strategies such as a raised median are necessary in some areas because of the developed disconnect between land use regulation and transportation infrastructure. “Curb-cutting” on an arterial street in order to create an

access point to a privately-owned local business creates conflict points on a road with typically high levels of activity. Compounding this issue with successive independent curb-cuts up and down the street create a dangerous scenario for pedestrians, cyclist, and vehicle passengers using the public space. Communication between regulation departments such as transportation, public works, community development or planning, and various governing councils is essential to mitigating the creation of this hazardous, yet common, scenario.

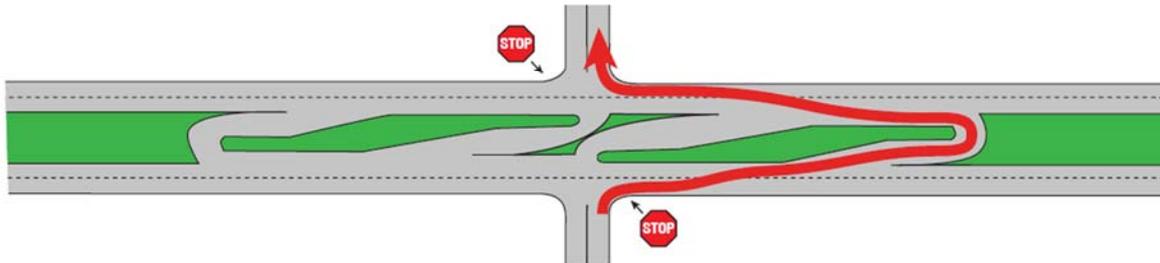
Breaking the compartmentalizing of development plans and strategies could have many more benefits than just optimizing transportation. For example, land use zoning regulations that coordinate more effectively with the transportation network can enhance more walkable development opportunities given that private and priority business access can be on a more versatile local road neighbored by other commercial, office, and residential uses. That scenario contrasts greatly to the private driveway on an arterial highway scenario in the case of Memorial Drive in Atlanta and countless other such-cases.

#### **5.4 Reduced Conflict Intersections**

Currently the State of Minnesota has eight Reduced Conflict Intersections in place with five more planned in the near future (MNDOT 2015). These intersections are designed to be continuous in nature and are most effective at intersections of a rural road with a divided highway. As through traffic is not allowed for the rural road, no signalization is required and the flow of the highway can remain constant. Drivers on the rural road wishing to either make a left turn movement or continue through the highway join the established flow of traffic on the highway and then continue to a designed point where a U-turn can be managed and those movements achieved.



### Crossing a rural divided highway using a Reduced Conflict Intersection



### Left hand turn onto a divided highway using a Reduced Conflict Intersection

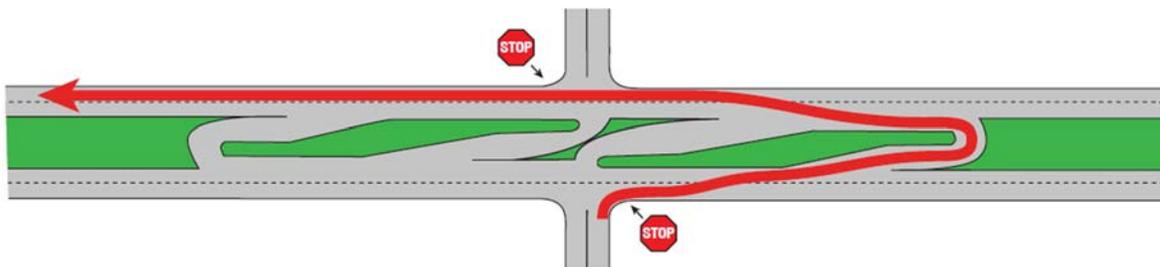


Figure 21. Reduced Conflict Intersection Diagram. *Source: MNDOT*

This type of intersection depends on gaps in the flow of traffic on the highway to be successful and has no pedestrian consideration, both effects of its required rural location.

Safety is the main objective of an RCI and has been observed to be effective in accomplishing it. MNDOT reports that in a before and after study on the RCIs, there was an observed 49% decrease in the total number of crashes at the locations with a 70% reduction in the number of fatal crashes and 42% less injury crashes.

Because of the lack of a bridge or signal equipment and maintenance, MNDOT has also reported that the cost of an RCI is noticeably lower than a typical intersection would be. Costs are also lower in that constructing a CFI typically takes no more than a year whereas a typical highway interchange would take 3-5 years to construct.

## 5.5 Continuous Flow Intersections

Closely related to the RCI concept is the Continuous Flow Intersection (CFI). CFIs include the similar designs with median access points but employ coordinated traffic signals and all turning movement capabilities, allowing for a more adequate fit into more urban locations. As depicted by Compass, a planning firm out of Idaho, a CFI separates the movements at an intersection spatially and therefore allows for carefully coordinated signal timing to increase the vehicle capacity in each signal phase.



Figure 22. Continuous Flow Intersection Diagram.  
*Source: Compass*

The purpose of a CFI is to separate the multiple functions required at a traditional four-way intersection. If an intersection has an adequate amount of demand for left turn service, protected time is given where only the left run movement is allowed to access the intersection. The drawback to this function is that with each additional phase of an intersection, additional time is required for yellow and all red time between phases. It is also common that despite a significant demand for left turn service, the through movement still carries the majority of the road's activity.

As depicted in this pie chart developed by Compass (Figure 23), only 62% of the overall signal time goes to the through movements when a protected left turn phase is included in the phasing cycle. Since it is common that 75-80% of the vehicles approaching an intersection are not turning but going straight through, there is an imbalance created and driver time and intersection service capacity are lost (Compass).

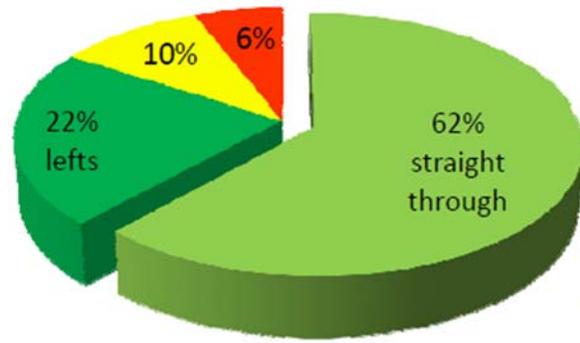


Figure 23. 4-Phase Signal Cycle Times. *Compass*

Although a CFI contains all turning and through movements that are present in a standard interchange, by displacing the left turn movement the number of conflict points is reduced to 28 instead of 32. As has been previously argued, the number of conflict points can be a reliable, although general, measure in predicting the overall safety opportunity of an intersection.

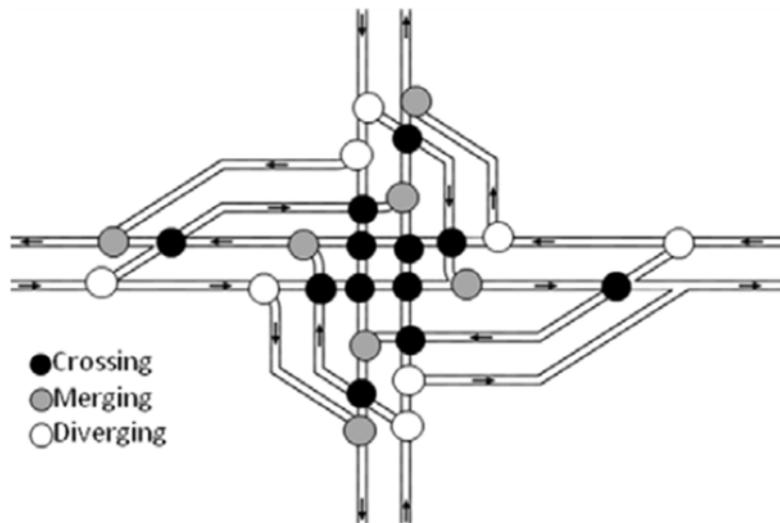


Figure 24. Conflict Point Locations at Common CFI

*Source: Hughes, et al, 2010*

The location of the conflict points however is different than a standard intersection as although there are almost as many conflict points in total, they are dispersed throughout a significantly greater area than a traditional intersection that holds all conflict points together. It can be therefore argued that the number of total conflict points is less significant at a CFI due to the reduced amount of interaction between all the intersecting paths. This can be one reason why it has been observed that converting a traditional interchange into a CFI saw a 24% reduction in the number of crashes, despite only

removing four total conflict points. This point can be seen illustrated below in a side by side comparison.

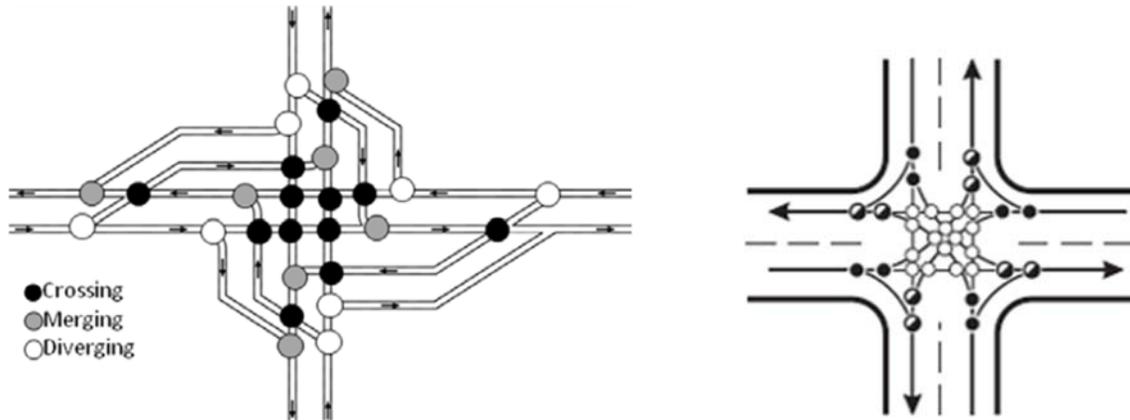


Figure 25. Traditional vs. CFI Conflict Point Locations

There are currently thirty CFIs in different variations across the U.S., Georgia has planned its first CFI in Dawsonville and will be assessed further later on. Depending on specific site characteristics and local traffic, the currently operating CFIs have had an observed impact on vehicle delay decrease within a range of 20-90%. This benefit is in addition to a 15-30% increase in available capacity (CFI 2015).

## 6 TRAFFIC OPERATIONS STRATEGIES

Referenced heavily in the “Safety Strategies” list published by NCHRP, certain techniques in the actual operation of vehicles and pedestrians at an intersection are changing partly in response to efficiency and safety pressures but also largely as a product of the added capabilities with modern traffic control technologies.

### 6.1 Traffic Signal Coordination

The paper was introduced by describing a common scenario when a group of vehicles sitting a red light watch the downstream signal go from green to yellow to red before they even get there, therefore causing the vehicles to stop at successive signals.

According to *Traffic Engineering*, after being released from a traffic signal, vehicles remain in a group for well over 1000 feet. It is common consideration in traffic engineering that signals located within a mile of each other be coordinated (Roess et al. 2004).

Signal coordination is modeled using time space diagrams and utilizes equivalent cycle lengths and vehicle speeds to time downstream lights to turn green as vehicle platoons approach. Successive downstream signals are delayed for the amount of time that it takes a vehicle to reach that intersection after being released from the upstream signal, a measurement of time referred to as an offset. The result is a wave of green lights that progress at the calculated speed of the vehicles, allowing for corridor efficiency in traffic flow (Roess et al. 2004).

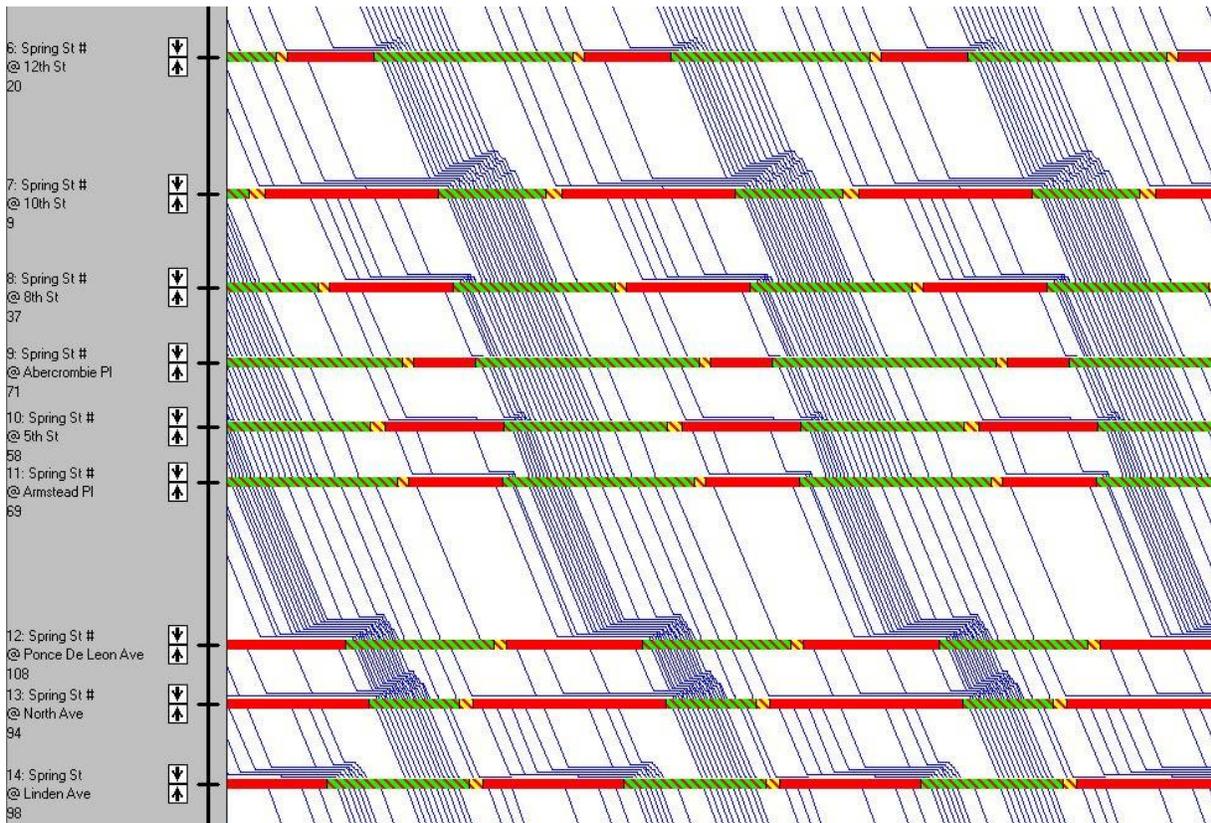


Figure 26. Time-Space Diagram from Traffic Modeling Software. Source: MTOP 2015

By coordinating downstream signals, a speed regulatory effect is also realized as vehicles who accelerate quickly to speeds higher than the corridor design speeds will continue outrunning the green wave and running into each successive red light. The conclusive result is that signal

coordination can platoon vehicle flow and therefore create more crossing opportunities for bikes and pedestrians in addition to punishing speeding vehicles with successive stops as they traverse the corridor.

Locally, the City of Atlanta announces in the first part of 2015 that plans of complete system signal optimization were in progress with budget approval. Although certain segments of roadway have been coordinated and routinely optimized under other traffic operations programs, a system-

wide coordination project has not been under taken in the City of Atlanta for over three decades (Blau 2015).

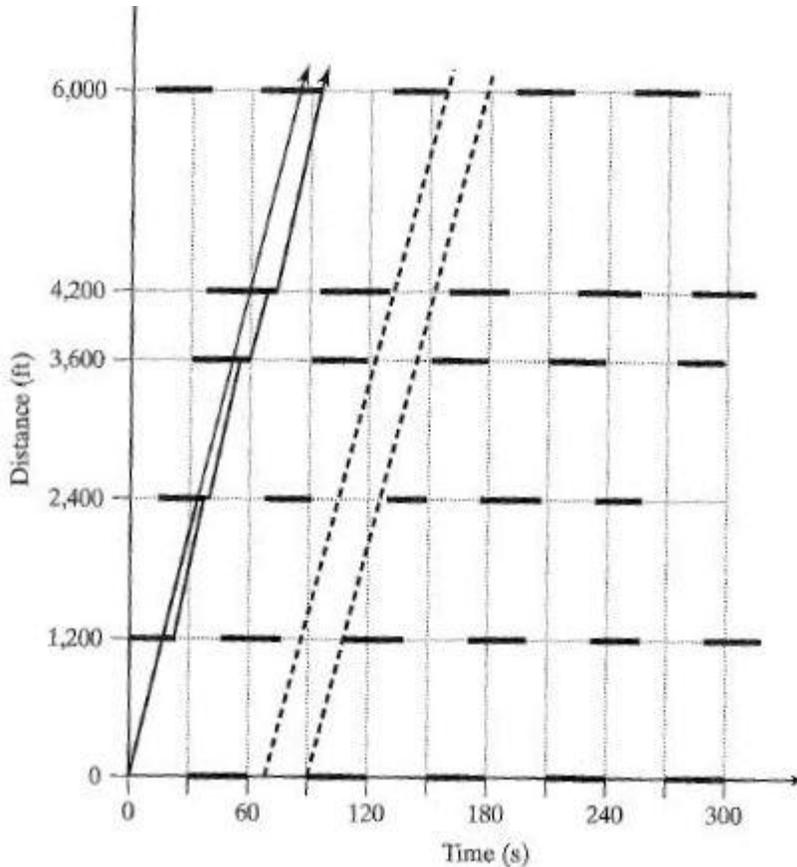


Figure 27. Time Space Diagram of Speeding Vehicle Hitting Successive Lights.  
Source: Roess et al. 2004. Pg 689

## 6.2 The Barnes Dance

Known as the Barnes Dance, named after the Denver Traffic Engineer Henry Barnes who pioneered the concept, diagonal crosswalks at select intersections paired with a pedestrian-only phase reduced pedestrian-vehicle collisions by 40% in Oakland. Conversely intersections saw non-compliance to traffic signals increase by 25% due to longer red lights for vehicles (Reimink 2012).

The effectiveness of this technique more commonly referred to as a “ped scramble” relies on a high demand of pedestrian traffic on multiple sides of an intersection. Because the operation requires a pedestrian-only phase in the signal cycle, all vehicles are restricted from any protected or permissive movements and consequently reduce the risk for vehicle-to-pedestrian collisions. There is only one pedestrian scramble currently implemented in Atlanta, located on the Georgia State University’s urban campus in downtown. There is however consideration into implementing a ped scramble at the intersection of Spring St and 5th St in Midtown on Georgia Tech campus (MTOP 2015).

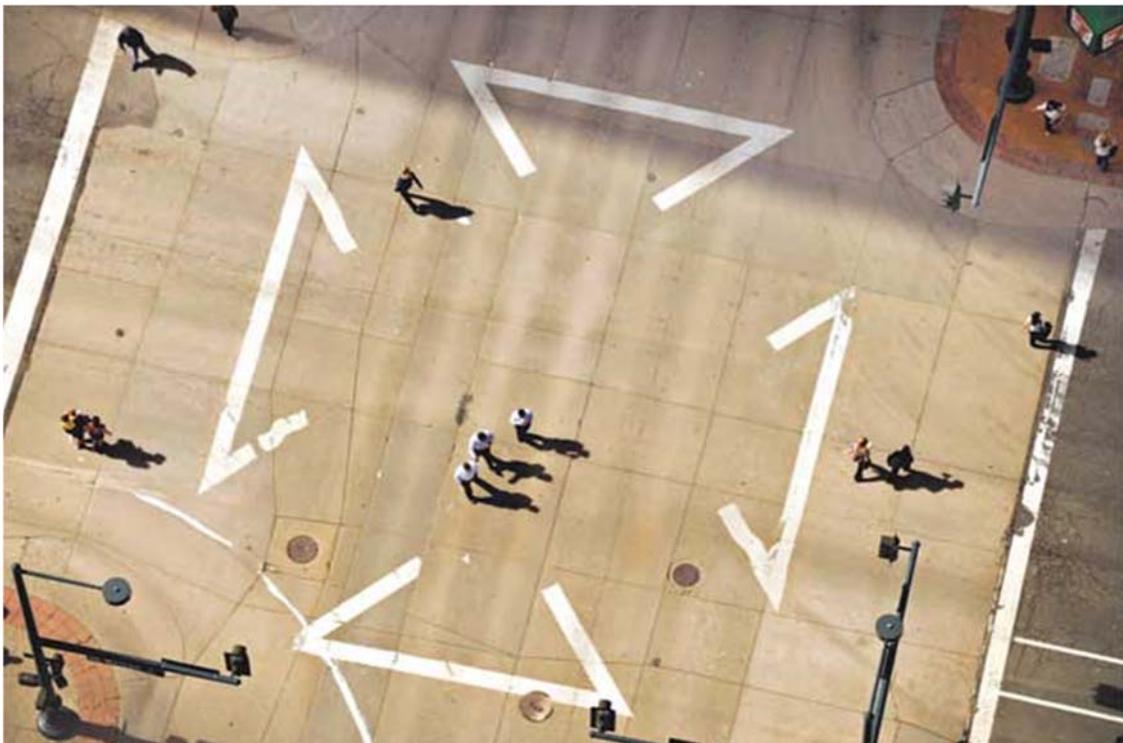


Figure 28. Ped Scramble in Denver. *Source: Denver Post, 2011*

### 6.3 Flashing Yellow Arrow

Flashing yellow arrow (FYA) signaling is the newest front in Protected-Permissive Left Turn (PPLT) phasing where vehicles making a left turn have a protected phase in addition to being permitted to make a left turn between gaps of vehicles in oncoming traffic. PPLT phasing has a 30 to 50% reduction in vehicle delay when compared to

protected-only phasing. PPLT phasing has also been observed to reduce standardly-measured emissions by 12% per day (Brehmer et al. 2003).

According to the NCHRP report on the FYA operation, the benefits of FYA as opposed to the common solid green circle for through traffic are:

- Statistically significant higher driver comprehension
- Operational plus in ability to lead-lag left turns without developing a “yellow trap”
- “Displays with the circular green permissive indication were associated with significantly more fail critical responses than displays with either the flashing yellow arrow or circular green/ flashing yellow arrow permissive indications.” (Brehmer et al. 2003)

Simulation and static tests also revealed that signal comprehension and opposing vehicle movements combined make the turning decision; therefore, having a yellow trap scenario is extremely dangerous and signal comprehension should be maximized.

There are currently 30 locations statewide have already been implemented with FYA statewide with the configuration becoming the new standard for all future PPLT traffic signals (GDOT 2015).

- Reduces left turn crashes by 35% (cited FHWA)
- Operational efficiency with a safe lead-lag phasing sequence possible
- Reduces vehicle idling and air pollution.

## **7 POLICY STRATEGIES**

The use of policy to regulate built form and transportation activities should be a careful consideration as unlike site-specific design, enacted policy tends to cover a collection of locations and situations. Although uniformity created by policy guidelines has benefits in more general comprehension and minimum standards to protect user safety and product quality, it also restricts the amount of specific consideration that is required to

make a location or region, depending on the significance of the project, effective to the uses that it is being designed to accomplish.

An example of this could be many historical engineering guidelines that restricted traffic flow from being left-side-oriented for even a portion of a roadway segment due to the fear of confusion that the driver would not understand the different treatment and injurious collisions would occur. If these guidelines were still prevailing today, alternative intersection forms such as the diverging diamond would be politically impossible rendering the observed benefits of this design, which will be depicted in detail later, unattainable.

Furthermore, highly-generalized minimum parking requirements which were set forth in engineering manuals and followed religiously for decades required, by law, an often oversupply of individual parking treatments for each land use development. The implementation of these parking lots greatly diminished densities needed for connected social activity in addition to creating the argument for the need for increasingly more access points along our roadways. As previously presented, the continuing development of these access points multiplies the existence of conflict points along the roadway and can not only detract from the effectiveness of an intersection but can also present a potentially fatal risk to users of the roadway.

It is for the concerns of design-restriction, over-generalization and the possible production of external risks in safety and transportation efficiency, that caution is added when considering policy implementation as a means of impacting intersection and roadway development. That being said, there are many positive examples of policies and guideline manuals that delineate comprehensive consideration of quality and effectiveness without compromising individualistic design in known significant ways. Such a guideline should allow for the dynamic nature that empowers efficient development.

## 7.1 Speed Limit Reduction

Unlike previous strategies that impact prevailing vehicle speeds by design implements, policy enactments that reduce speed limits require individual willingness to obey and enforcement to encourage obedience. Speed limit alterations, whether up or

down, have been common means to further classify the road type a vehicle is driving on. The recent hiking of Texas highway speeds in certain locations to 85 mph encourages swift travel and does so with the argument of no considerable development of safety risks with the higher speeds.

At intersections however, automobiles are sharing space with pedestrians, cyclist and other automobiles traveling in conflicting directions. Therefore at more urban locations where intersections are more clustered, lower speeds may prove to not only increase traffic efficiency by avoiding congestion, but also save the life of one of the users of the road, no matter their mode of travel.

The main argument behind lowering urban speeds is commonly for the safety of pedestrians, although obviously adding reaction time, stopping distance, and reducing collision force will have a significant impact on vehicle to vehicle collisions as well. The local Atlantian voice for pedestrian safety is most often the Pedestrians Educating Drivers on Safety (PEDS) initiative. Leading programs to educate drivers and pedestrians on current laws about pedestrian interaction on the roadway in addition to promoting and supporting new policies on the subject, PEDS is a consistent force in Atlanta on analyzing pedestrian safety and pushing design to make consideration changes in facilitating non-vehicular modes of travel. Included in this analysis was the chance a vehicle to pedestrian collision would result in a fatality given varying speeds of the automobile.

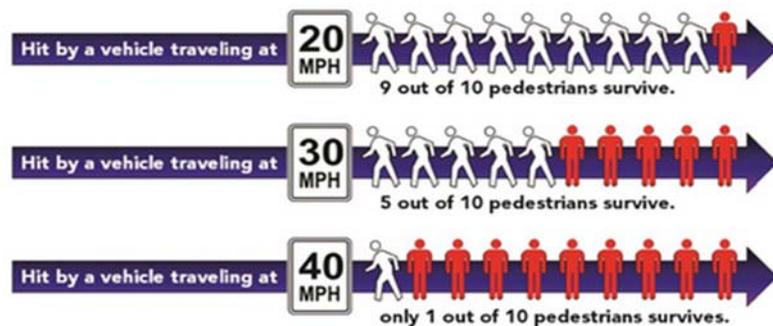


Figure 29. Pedestrian's Chance of Death if Hit by a Motor Vehicle.  
Source: PEDS 2015

Although pedestrian fatalities are almost guaranteed at traveling speeds above 40 mph, these speeds are not commonly found at intersection locations. The two other findings depicted in the figure however illustrate the chance of pedestrian death at 30 and 20 mph at 50% and 10% respectively. Therefore although the speed of the vehicle is only reduced by 10 mph, the chance a

pedestrian survives if struck by a car is almost eliminated. “A little speed is a lot more deadly.” (PEDS 2015)

Although the actual speed of a vehicle is important, the main factor involved in pedestrian safety is not the speed of vehicles directly but the stopping distance, which grows longer with increasing speeds. It has been observed that an average driver, travelling 40 mph, who sees and reacts to a pedestrian in the road 100 feet ahead, will still be traveling 38 mph at the point of impact. Conversely, given the same situation and the vehicle is driving only 25 mph, there is enough distance for the driver to come to a complete stop before the pedestrian is hit (McLean et al. 1997).

A foreign example of these results took place in Zurich when the speed limit was lowered to 31 mph (a 6 mph reduction) for environmental purposes and in result lowered pedestrian collisions by 16% and pedestrian fatalities by 25% (McLean et al. 1994). In areas of pedestrian activity, not just frequent pedestrian activity, lowering legal vehicle speeds to 20-30 mph significantly increases the chance of avoiding pedestrian fatalities more commonly located at urban intersections (ones the can often be avoided).

## 7.2 Design Guideline Implementation

Usually an extension of local land-use zoning codes, design guidelines can be a local asset in ensuring the quality and consideration of how developments are planned and built. Primarily, municipalities will develop a set of design guidelines for a particular district or region within the area that is either planned to hold a higher level of urban quality or is already developed to a standard that is wanted to be upheld, a situation usually involving historical land uses.

Few municipalities create city-wide design regulation. New York City; however, will be detailed further on as an exception and may serve as a model. The amount of conception that needs to be taken under consideration with many different land-use types and specific scenarios can be difficult for local governments.

## **8 LOCAL CASE STUDIES**

There have been local implementation mentions in the strategies detailed above; however a detailed look into local examples of these alternative strategies is included to consider the impacts these techniques can have here in the Atlanta area.

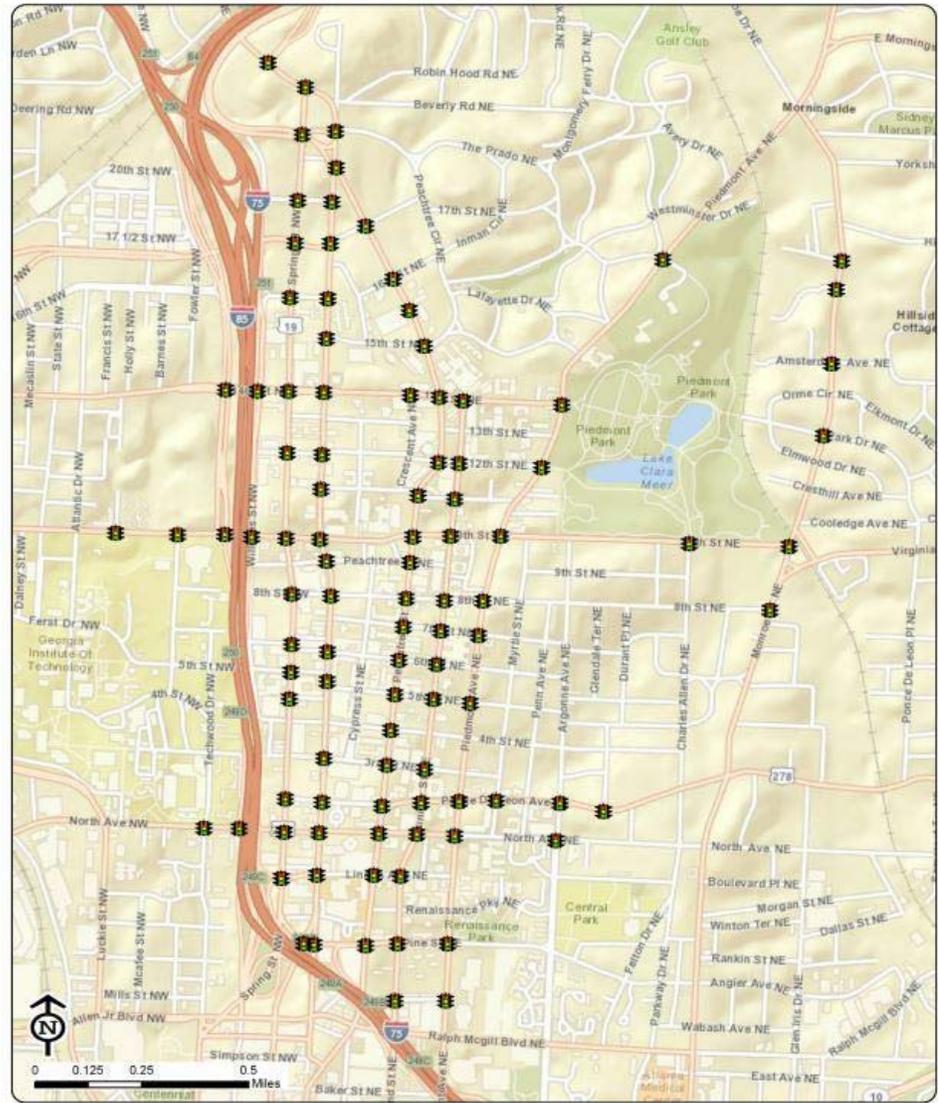
### **8.1 Midtown Traffic Operations Program**

The Midtown Traffic Operations Program (MTOP) is a project that has sought to optimize traffic functions within a certain area, in this case, the Midtown area of the City of Atlanta. The project is funded through GDOT's Regional Traffic Operations Program (RTOP) and is a three-year project with the purpose of enhancing "travel and safety by maximizing the efficiency of all modes of travel (including passenger vehicles, buses, pedestrians and bicycles) through proactively managing traffic signals within the study area." (MTOP 2013)

The MTOP "study area" includes 100 signalized intersections that are each visited at least twice a month to check that signal coordination is precise (to the second), vehicle and pedestrian detection is functioning properly and a general inventory of equipment and overall intersection operations is performed.

Although signal coordination is not a new technique in impacting intersection efficiency, it is an evolving one. With upgrades in more precise communication with the intersection controller through devices such as fiber connections to surrounding intersections and the local traffic control center, GPS clocks for timing precision, Ethernet modems, field switches and a plethora of other techniques that allow near-instantaneous management of any intersection.

Figure 30. MTOP Project Area and Coordinated Signals.  
 Source: MTOP Assessment Report, 2013



After collecting traffic demand data and extensive modeling, new timing plans were downloaded throughout the 100-signal system in late 2014. These new signal times were modeled to enhance travel efficiency through reduction of delay and the number of stops. On average, the east-west corridors (14th Street, 10th Street, Ponce De Leon Avenue, and North Avenue) were improved by the upgraded signal coordination by a 41% reduction in travel times, a 57% reduction in delay, and a 35% reduction in the average number of stops a vehicle needs to make traversing the corridor (MTOP 2014). Below are the observed results along one of the main North-South corridors, Spring St.

Table 3. Travel Time Run Results - Spring St. *Source: MTOP 2015*

		<b>AM Peak</b>	<b>Midday</b>	<b>PM Peak</b>
<b>Travel Time (sec)</b>	Before	592	445	671
	After	348	368	501
	<b>% Improved</b>	<b>41%</b>	<b>17%</b>	<b>25%</b>
<b>Average Speed (mph)</b>	Before	12.3	16.4	10.9
	After	20.7	19.5	13.9
	<b>% Improved</b>	<b>68%</b>	<b>19%</b>	<b>28%</b>
<b>Number of Stops</b>	Before	8.7	7.2	11.4
	After	2.3	4.3	5.6
	<b>% Improved</b>	<b>74%</b>	<b>40%</b>	<b>51%</b>

Through the reduction of travel time inefficiencies, the number and amount of time and one vehicle spends traveling through Midtown is reduced. Furthermore, the reduction in the number of stops and amount of delay per vehicle reduces the number of idling cars in the area, all factors of reducing air pollution in Midtown. The measured effect on air quality can be measured with the travel time run data collected before and after the new signal timing was implemented. Table 3 below presents an example of the impact efficient signal coordination can have on air pollutant production in a region. Volatile Oxygen Compounds, Carbon Monoxide and Nitrogen Oxides are all pollutants that are federally regulated as part of the Clean Air Act by the Environmental Protection Agency.

Table 4. Air Pollutant Impact - Spring St. *Source: MTOP 2015*

		<b>AM Peak</b>	<b>Midday</b>	<b>PM Peak</b>
<b>Volatile Oxygen Compounds (g/veh)</b>	Before	18.869	16.022	19.920
	After	12.623	13.993	15.730
	<b>% Improved</b>	<b>33%</b>	<b>13%</b>	<b>21%</b>
<b>Carbon Monoxide (g/veh)</b>	Before	153.318	129.121	157.603
	After	121.461	124.470	134.595
	<b>% Improved</b>	<b>21%</b>	<b>4%</b>	<b>15%</b>
<b>Oxides of Nitrogen (g/veh)</b>	Before	10.183	9.816	10.061
	After	7.301	8.648	8.213
	<b>% Improved</b>	<b>28%</b>	<b>12%</b>	<b>18%</b>

The MTOP portion of GDOT's RTOP program is significant as although it is financed by the RTOP program, it has an additional stakeholder in Midtown Alliance, the CID for the Midtown area (MTOP 2013). This unique relationship differentiates MTOP from the maintenance-only oriented RTOP program and includes "special studies" along with the maintenance objective. One of these "special studies" has already been mentioned in that MTOP is currently under consideration of implementing a pedestrian scramble at Spring St and 5th, one of the primary intersections used in accessing Georgia Tech campus from Midtown. Other special studies that have been included in the program are:

- Corridor Speed Study where before and after LiDAR observations were taken along major corridors in Midtown. The results concluded that the number of high-speed vehicles, traveling 50 mph and above, was reduced by 55% during the PM peak period after the new signal coordination timings were implemented. (MTOP Speed Study 2015)
- 10th St. I-85 on-ramp was re-designed in order to accommodate higher traffic flow with fewer conflict points.

- South Midtown Pedestrian and Circulation Improvement Project
- Lead Pedestrian Intervals (LPI) implementation on Peachtree St. to better accommodate the higher pedestrian traffic along the segment of the corridor.
- 15th St. extension to Williams St in order to improve connectivity and break up a vertical block that is currently over 1000 feet long.

## **8.2 Ashford Dunwoody Diverging Diamond Interchange**

The diverging diamond interchange (DDI) form is an exciting example of design that makes drivers slightly less secure and effectively results in all users of the facility being safer. Several of these forms have been recently implemented in the Atlanta area and are currently at different stages of development. The Ashford Dunwoody interchange was the State of Georgia's first DDI and was opened to the public in June of 2012 and immediately saw a reduction in the number of crashes by 30% (Fox, 2012).

## **8.3 Pleasant Hill Diverging Diamond Interchange**

The diverging diamond at Pleasant Hill Rd followed the Ashford Dunwoody DDI as the second such interchange in the State of Georgia and was opened to traffic on June 9, 2013. The construction of the DDI at Pleasant Hill was part of a congestion relief initiative conducted by the Gwinnett Place Community Improvement District (GPCID) in Gwinnett County GA. Providing access to I-85, the most congested interstate serving the Atlanta metro, the growth in activity in the region over the past few decades have increasingly clogged the arterials of the area with vehicles pushing to access the interstate in the very highway and interstate-dependent Atlanta-fashion. Because of the high volume of vehicles accessing the interchange in order to utilize the ramps in comparison to driving straight through, a diverging diamond design was appropriate for the location.

## DIVERGING DIAMOND

The new style interchange is designed to allow continuous flow onto the interstate without having to wait for a light.

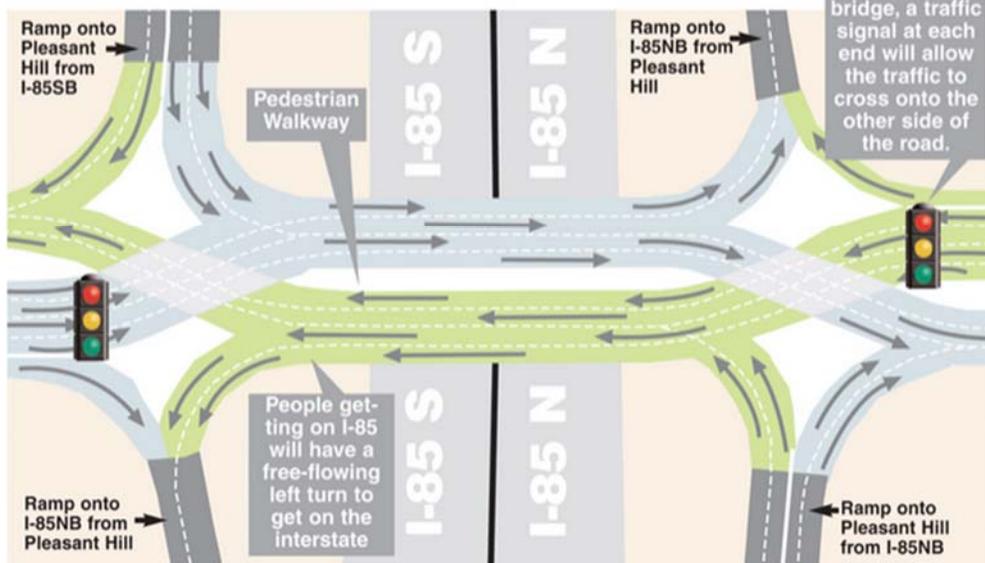


Figure 31. DDI Operations Diagram. DDI graphic courtesy of Nicole Puckett/Gwinnett Daily Post

A modification feasibility study was conducted in order to determine if an alternate interchange form would be more efficient than the tight diamond form that was currently at the bridge. The results of the study determined that a Single Point Urban Interchange (SPUI) would have the greatest operational impact at the location. GDOT however encouraged GPCID to look into the DDI form and upon contracting URS, the engineering firm that eventually designed and constructed the DDI, it was found that the SPUI was projected to have a 35% improvement on operations and the DDI was modeled to have an impact in the range of 30-35% improvement. Given the comparable operationability, the price made this decision as a SPUI was projected to cost \$49 million with bridge widening enhancements whereas the DDI was only projected to cost \$7 million to implement (Fry, 2015).



Figure 32. Example of SPUI form from I-40 in Durham, NC

*Source: Esawey & Sayed 2012*

The goals of this project included keeping all three through lanes going across the bridge, whereas there was a reduction down to two at the bridge before. This loss of a lane in each direction forced more weaving between lanes as vehicles found themselves in the drop lane and caused unnecessary congestion and traffic collisions.

The other goals of the project according to Erick Fry, the contractor's project manager, were based on walkability and place making as GPCID wished to have this improved interchange be a beacon to the hundreds of regional visitors passing beneath the bridge on I-85 every day. The project called for the removal of a common interchange treatment in Georgia where add lanes are included so that vehicles coming off the interstate can "Keep Moving Right" from the exit ramp onto the arterial road. This treatment creates a risk to pedestrians and cyclist as vehicles are less focused on slowing down and looking for non-vehicular traffic.

Pedestrian mobility across the bridge was improved from the tight diamond interchange form that was there before and the aesthetics at the interchange were greatly improved to enhance visual impacts at the very automobile-heavy location.



Figure 33. Overview of completed Pleasant Hill DDI. *Source: GPCID 2015*

Effective implementation of the DDI included precise signal timing of the intersections surrounding the DDI in addition to the traffic signals that operate the different movements of the interchange itself. In a traffic study conducted afterward, and detailed later in this report, traffic flow improvements at the interchange were observed as a 51% decrease in the average number of stops and a 43% decrease in total delay of vehicles traveling along Pleasant Hill Road (GPCID 2015).

A higher level of pedestrian protection was considered as instead of having pedestrian and cyclist take to the outsides of the bridge as is common at standard interchanges, an 8 foot protected walkway was constructed between traffic with barrier walls preventing any conflict points along the route. This treatment also gives pedestrians longer cycle lengths to make their crossing as they share the time of opposing movement that is longer at a highway interchange than at a regular four-way intersection.

To measure the effectiveness of the DDI implementation on Pleasant Hill Rd, a before and after effectiveness study was conducted by the contractor that manages the

traffic signals for Gwinnett Place CID, Wolverton and Associates. The study included analysis at the interchange before and after DDI implementation on typical weekdays during the AM and PM peak periods and a midday period. Among the factors included in the study are federally regulated vehicle emissions, travel times, total delay at the interchange and the average number of stops a vehicle makes during the course of accessing the DDI.

As the implementation of the DDI interchange was primarily focused on relieving the overly-congested interchange at I-85 and Pleasant Hill Rd, the primary determinants of the effectiveness of the DDI implementation are the observed improvements to traffic flow in result of the alternative interchange design. Travel studies measured the average time a vehicle takes to travel through the interchange along with the average number of stops the vehicle makes and the resulting delay that those stops incur. The results of this travel study are included in the figure below.

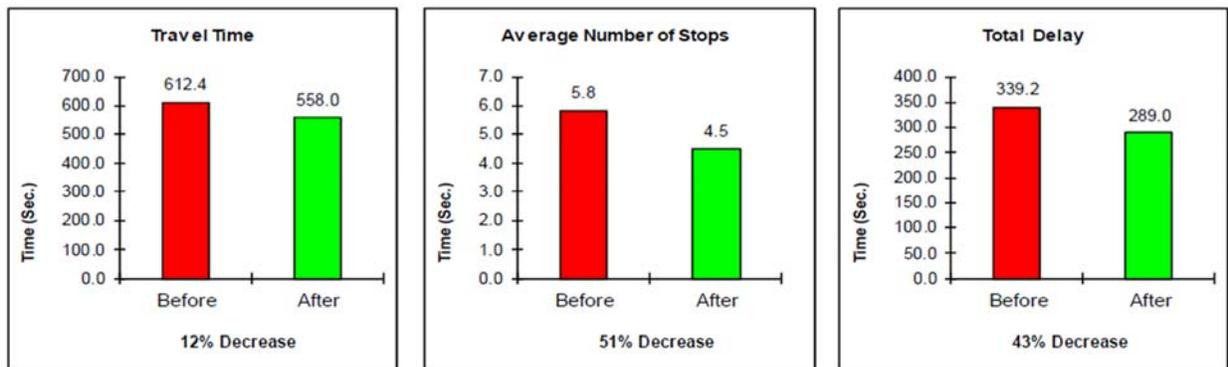


Figure 34. DDI Effectiveness Measurements *Source: Wolverton 2013*

By reducing congestion at an interchange, vehicle-produced emissions are reduced as well. At a congested intersection, vehicles idle more frequently and burn fuel and time while stalled. By improving traffic flow and the level of service an intersection provides, not only will travel times be improved as has been represented already, but the number of stopped and idling vehicles will be reduced and therefore have positive environmental impacts. Three emissions that are federally regulated are carbon monoxide (CO), oxides of nitrogen (NOX) and volatile oxygen (VOC). The results below show the before and after emission reductions at the Pleasant Hill DDI in units of kilograms emitted per hour by the vehicles accessing the interchange (Wolverton 2013).

CO Emissions (kg/hr): 19% reduction  
NOX Emissions (kg/hr): 17% reduction  
VOC Emissions (kg/hr): 26% Reduction

In addition to these traffic improvements, Wolverton and Associates, the contractor conducting the study, included a cost benefit analysis due to the observed improvements to Pleasant Hill Road. The following has been extracted from the Effectiveness Study as the explanation of the cost benefits after the DDI and signal retiming implementation projects:

“Motorists using the signal system during the three (3) peak periods will save 15,600 hours and 9,360 gallons of gasoline each year because of improved traffic flow due to the new timing plans. Conservatively assuming a vehicle occupancy rate of 1.2, \$12.00 per hour for the value of motorist’s time and \$3.50 per gallon for gasoline, annual savings to motorists in the signal system will be \$224,640 in the form of reduced delay and \$32,760 due to reduced fuel consumption, for a total annual savings of \$257,400.”

#### **8.4 Continuous Flow Interchange in Dawsonville**

A Continuous Flow Interchange (CFI) is planned to be implemented in Dawsonville, 45 miles north of the City of Atlanta, at the intersection of SR 400 and SR 53. GDOT has initiated the project in an effort to reduce project cost from a conventional bridge-and-ramp highway interchange. The firm contracted by GDOT for the project, Gresham Smith and Partners, created the model for the planned interchange and reported that similar CFI implementation resulted in 10-20% of the total cost of a grade-separated interchange with the capacity of approximately 75% (Gresham 2011). Therefore, although a grade-separated interchange would provide additional vehicle capacity, GDOT and the municipality are saving 80-90% of what they could be paying with building a bridge.



Figure 35. Dawsonville CFI VISSIM model with turning movements added. *Source: GS&P*

The main difference in a grade-separated conventional bridge interchange and a CFI is not only the operational design but the amount of space a CFI requires. In response to a YouTube video of the CFI model in Dawsonville, local residents expressed concerns on the lack of accessibility mostly by car as this is a more rural area and mostly unwalkable. “If I’m traveling west on 53... how do I get to the gas station.” (Gresham 2011) As mentioned in the overview of the CFI technique these types of intersections rely mostly on the division islands for pedestrian access. Even from a vehicle, if the CFI is implemented in a location that is of average urban development, with developed land on all sides of the interchange, accessibility may take a negative impact due primarily to the sheer amount of land that is required to perform CFI operations. It was reported that 32 parcels of land needed to be purchased by GDOT in order to plan for the interchange, including one commercial relocation (Hester 2014).

Although it is yet to be developed, the Dawsonville CFI will gain a detailed review in driver comprehension, traffic impacts and safety considerations as it will be Georgia’s first CFI type interchange. With similar CFI developments elsewhere in the U.S and modeled traffic volumes, GDOT projects that traffic congestion will be reduced by as much as 85% (Hester 2014)

Table 5. Level of Service Analysis for Dawsonville CFI. Source: GDOT 2011

	Year	AM Peak Hour		PM Peak Hour	
		LOS	Delays (sec)	LOS	Delays (sec)
Existing Condition	2009	D	39.5	D	41.5
No Build Condition	2015	E	55.5	E	66.7
	2035	F	271.8	F	280.6
Build Condition (2-Leg CFI on SR 400)	2015	C	22.6	C	25.3
	2035	C	32.3	D	42.8

<b>Costs</b>	
Total cost	\$ 12,701,950
Annualized cost	\$ 740,693
<b>Auto Delay Costs</b>	
Nobuild	\$ 25,872,825
Build	\$ 3,306,325
Auto delay savings	\$ 22,566,500
<b>Truck Delay Costs</b>	
Nobuild	\$ 18,641,264
Build	\$ 2,382,194
Truck delay savings	\$ 16,259,070
<b>Fuel Costs</b>	
Nobuild	\$ 776,291
Build	\$ 1,064,448
Fuel cost savings	\$ (288,157)
Change in GSP	NA
Auto delay cost adjustment	NA
Truck delay cost adjustment	NA
Fuel cost adjustment	NA
Total benefit adjustment	NA
Benefits in 2035	\$ 38,537,413
Benefit-Cost Ratio	52.03

Figure 36. Benefit Cost Analysis for Dawsonville CFI. Source: GDOT 2011

Detailed in the Cost/Benefit breakdown, the impacts on vehicle traffic congestion will result in a \$38 million savings in reduced delay and time spent accessing the interchange via car from construction to the year 2035. It should be a priority for local officials and transportation administrators to dedicate a significant amount of those monies to mitigating the broken pedestrian connectivity that results from higher vehicle movement through the interchange.

An additional CFI under consideration in Georgia, although not officially planned yet, would be located at the intersection of Jimmy Carter and Buford Highway, a location much more urban than even the Dawsonville interchange consisting of two of metro Atlanta's more formidable arterial highways (GVCID 2014).

## **9 NATIONAL CASE STUDIES**

There are exemplary developments and case studies that have occurred on American roads outside of the Atlanta area that demonstrate not only the opportunity for these alternative strategies but also speak to the general trend of impact that can be expected at similar locations.

### **9.1 Roundabout Implementation in Maryland**

Five intersections were selected to be converted from a signal-controlled configuration to a roundabout. The study was also a before-and-after observation of a minimum of 15 years at each of the five intersections. The intersections were selected from a list of locations that had a history of safety concerns and could therefore possibly benefit greatly from a roundabout. The resulting changes amongst the five roundabout intersections were a 100% reduction in fatal crashes per year, an 88% reduction in injury crashes, and a 69.1% reduction in total crashes per year (FHWA 2010).

A 2007 NCHRP before-and-after study considering 55 American intersections reported that roundabout implementation resulted in the following reductions in safety considerations:

- 35% overall decrease in crashes
- 76% decrease in injury crashes
- 81% decrease in fatal/incapacitating crashes for single lane urban roundabouts
- 71% decrease in fatal/incapacitating crashes for single lane rural roundabouts

*Source: (FHWA 2010)*

## 9.2 New York City

New York City (NYC) is an international standard of modern urbanism and has held a captivating hold on locals and visitors alike for centuries. Unfortunately the “modern” aspect of this great metropolis relies heavily on the heavy use of commercial trucks and personal automobiles, even in the densest places of the city. This high volume of automobile traffic paired with an abnormal, by American standards, volume of pedestrian and cyclist traffic has made for a historically negative relationship.

NYC reports that there are on average 4,000 people seriously injured and 250 killed in NYC as the result of vehicle crashes per year. This means that on average, someone is either seriously injured or killed on NYC streets every two hours. Furthermore, being hit by a vehicle is the leading cause of “injury related death” for children younger than 14 years old and the second highest cause of death for seniors (Vision Zero 2015).

These staggering statistics have supported changes in street design guidelines in the New York City Street Design Manual, “major engineering changes” and a coordinated permanent task force in the Mayor’s Office of Operations on the subject titled Vision Zero. The Vision Zero campaign reported that definitive changes are being observed as traffic fatalities in NYC have fallen “from 701 in 1990, to 381 in 2000, to an all-time low of 249 in 2011” (Vision Zero 2015). The “major engineering changes” that were part of the NYDOT’s commitment to the initiative have been reported at reducing traffic fatalities by 35%, a

value that is twice the rate of improvement than similar locations of the world's most urban cities (Vision Zero 2015).

The initiatives included in Vision Zero include responsibilities for the City Hall, Police Department, Department of Transportation, Taxi & Limousine Commission, Department of Citywide Administrative Services, and Department of Health and Mental Hygiene. Each item on the list for each agency then has an indicator that depicts the level of completeness of each task. The DOT list only has three tasks that are completed in majority with the only item not at least started being "Additional street reconstruction safety project" (Vision Zero 2015). The list of responsibilities for the DOT are:

- Conduct intensive street-level outreach and enforcement on safety problems and traffic laws, focused in areas with known crash histories
- Convene monthly meetings of the DOT Traffic Division and the NYPD Transportation Bureau to review traffic safety performance and set strategy for improvement
- Develop data-driven citywide enforcement strategy
- Develop borough-wide safety plans in close coordination with community boards, community organizations, and the Mayor's Community Affairs Unit
- Conduct targeted outreach in 500 schools each year, educating students about protecting themselves as safe pedestrians and working with their families for safer school zones
- Complete 50 street improvement projects that enhanced safety by reengineering intersections and corridors
- Create 25 new arterial slow zones
- Implement 8 new neighborhood slow zones
- Install speed cameras at 20 new authorized locations
- Install 250 speed bumps, including in neighborhood slow zones
- Enhance street lighting at 1,000 intersections
- Enhance maintenance of street markings
- Install traffic signals where needed
- Additional street reconstruction safety projects
- Survey national and international best practices to expand potential strategies
- Hold workshops for major street design projects
- Undertake a high-quality ad campaign aimed at reducing speeding, failure-to-yield and other forms of reckless driving

- Increase extent of "Choices" anti-DWI campaign
- Double number of programmable speed boards for intensive education/enforcement initiative
- Make effective, age-appropriate safety curriculum available to schools throughout the city
- Partner with senior centers to increase communication and get specific feedback from aging New Yorkers about street safety improvements
- Increase the number and visibility of hands-on safety demonstrations
- Add safety flyers and messaging in DOT mailings such as Alternate Side Parking regulations and construction permits

Supplementary to the Vision Zero task force, New York City's *Street Design Manual* supplements federal engineering and environmental standards while promoting and providing for approved choices of intersection and roadway treatments that take all modes needing access to the facility under consideration. Stated in the manual's "Purpose": "The *Street Design Manual* leaves ample room for choice, and all designs remain subject to case-by-case DOT approval based on established engineering standards and professional judgment, with the safety of all street users being of paramount importance." (NYCDOT 2013)

Consisting of 26.6% of the overall land in NYC, streets make up a significant portion of the overall design of the city. Furthermore, this 26.6% provides an indispensable role in how the local and visiting population of the city access the other 74.4% of NYC made up of housing, parks, cemeteries, employment centers, stores etc. The goals and principles behind the policies in the manual are stated as:

- Design for Safety
- Design to Balance Access and Mobility
- Design for Context
- Design Streets as Public Spaces
- Design for Sustainability
- Design for Cost-Effectiveness

One of the many examples of *The Street Design Manual's* success in impacting road design projects is on West Houston Street. Previously configured much like most urban multiple-lane streets are, with wide thoroughfares complicating pedestrian and vehicular movement, the capital project took the opportunity to enrich travel efficiency for pedestrians and cars in addition to making a better place. The redesign created more usable raised medians that came with landscaping and trees for shading and protection but even had seating available when appropriate as the complete length of the crosswalk was still almost 100 feet in length.

In total there were 74 trees planted in the project area, a new park, extensive implementation of benches and landscaping, enhanced lighting and paving, and roadway improvements. Observations after the project's completion saw that crashes with injuries were reduced by 24% and "motor vehicle travel times in westbound lanes dropped dramatically during weekday afternoon peak" (NYCDOT 2013). This case study is an example of how well-structures policy can impact intersection design choices in a way that benefit the operations and the aesthetics, the mobility and the accessibility, the cars and the people.



Figure 37. Before and after comparison of West Houston Street Source: NYCDOT 2013

## 10 CONCLUSION

This analysis of intersection strategies is in no way exhaustive of the many creative solutions that are impacting modern roadway design and operations efforts. Rather, these case studies and methods represent much larger movement of thinking that not only breaks the conventional mold of one-size-fits-all but also corrects past inadequacies that furthered automobile operability at the expense of pedestrian, cyclist and transit access.

How much time has been lost because of collision-prone 4-way intersections, the form that holds the highest number of conflict points and the greatest level of risk than any other strategy considered in this analysis?. How much money has been lost because of time wasted in congestion? How many communities have been diluted and degraded by separated land uses designed around the automobile because the main goal at roadway intersections for decades was almost exclusively vehicle throughput. How many lives have been lost or injured because an intersection was designed to be legally protected with manuals and agency-backed guidelines, instead of socially protected with considerations of local land uses and travel demands of multiple modes?

The engineering dependency on these manuals must be broken and returned to a place in the process where they are but one resource in designing an intersection and not THE resource or even the primary resource. The amount of information and collected travel data that is available from agencies such as the TTI, FHWA, USDOT, NCHRP, ITE, AASHTO, SGA and NACTO in addition to countless state, local and private sources is not only more than adequate today but continues to grow every year. These sources provide scientifically measured processes for evaluating the feasibility of an alternative intersection design, designing the site-specific facility with a comprehensive review of local needs and goals, and implementing the development in such a way as to optimize the functionality of that place.

Given the amount of data that has been collected and presented in this paper on the fallacies of the “conventional” 4-way intersection, such a form should be considered the alternative design for all future intersection developments. Although the 4-way stop controlled intersection has benefits that are unique just as any other form, its risks have

been observed to be far too great, far too deadly to hold primary consideration for any future intersection design consideration.

Fortunately, there have been pioneers of alternative design strategies both domestic and internationally whom have shown through their examples the significant impact these designs can have on not only the safety and usability of the intersection itself, but its ability to interact with the land uses around it and create a true intersection of places that connect and engage social forces, even if they do it out of their car.

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