PAPER NO. IRC3-0060

RETROFITTING CLOSELY SPACED INTERSECTIONS USING THE PEANUT-TURBO ROUNDABOUT CONCEPT

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Paper prepared for Consideration for Transportation Research Board International Roundabout Conference
Carmel, Indiana
May 2011

Revised paper submitted May 31, 2011 for publication in the Conference Proceedings

Word Count (6554): Abstract (243) + Text (2811) + Tables (1) + Figures (13)

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Michael Trueblood

ABSTRACT

St. Charles County, Missouri is located approximately 30 miles from the City of St. Louis and boasts a population of just over 350,000. Interstate 70 traverses the County and provides key access to the region. The County Highway Department desired to improve access to I-70 by extending Deer Creek Drive from Highway P to the I-70/Bryan Road Interchange. Currently, Bryan Road is a key arterial south of I-70 but terminates at the north outer road (typically referred to as West Terra Lane). West Terra Lane is located approximately 375 feet from the Westbound I-70 On/Off Ramp at Bryan Road. Due to the close proximity of West Terra Lane to the interchange ramps, several traditional intersection designs were reviewed to determine if acceptable traffic operations could be achieved. Most of the design concepts, however, required extensive right-of-way beyond what the County desired. Several roundabout concepts were then reviewed, but were unable to provide acceptable traffic operations. Non-standard roundabout alternatives were then analyzed to determine if acceptable traffic operations could be achieved, while at the same time minimizing both right-of-way and access-related issues. After review of several concepts, the Peanut-Turbo Roundabout concept was found to meet all three of the County's goals. The focus of this presentation/paper will be to highlight the roundabout options that were considered and the process used (including analysis with the software packages Synchro, SIDRA INTERSECTION, and VISSIM) to assist the design team in determining the appropriateness of the various alternatives.

PROJECT OVERIVEW

St. Charles County's Highway Department's desire to plan and design a two-mile extension of Bryan Road from just north of I-70 to Highway P would significantly improve access to I-70. The new roadway, named Deer Creek Drive, would begin as the north approach of the Bryan Road/West Terra Road intersection and would extend in a northeasterly direction to Highway P. The proposed roadway would become an important north-south roadway corridor, providing St. Charles County residents with an alternative north-south route to/from I-70.

Several tasks were completed during the initial planning stages of the project, including data collection, development of Year 2030 traffic forecasts, and the development of several alternatives at the West Terra Lane/Bryan Road/Deer Creek Drive intersection. The focus of the initial planning stage was on accommodating the forecasted traffic volumes. Right-of-way issues, construction costs, and property access issues were considered only secondarily.

During the preliminary design phase of the project, however, the focus switched to a more balanced approach that placed more emphasis on right-of-way issues, property access, and construction costs. This change resulted in the development of additional roundabout alternatives.

EXISTING CONDITIONS OVERVIEW

Understanding existing traffic flow patterns was key to understanding the implications of future access changes within the project area. West Terra Lane currently serves as a key roadway connection to several north-south roadways such as Genteman Road and Elaine Drive (See Figure 1). These north-south roadways provide access to a variety of land uses, including an industrial park, several commercial businesses, car dealerships, subdivisions, retirement homes, and a private high school. Other observations include:

FIGURE 1 – Location Map

- Traffic flow is relatively heavy to/from the I-70 ramps.
- Bryan Road provides access to one of the largest employers, Mastercard, within St. Charles County. The Mastercard complex is located approximately 4.25 miles south of the I-70/Bryan Road interchange.
- Two large industrial business parks are located north of I-70, one west of Bryan Road at Hoff Road, and the other east of Bryan Road along Elaine Drive.
- St. Dominic's Catholic High School (750 students) is located northeast of the Bryan Road/I-70 interchange. With no bussing, all students either drive or are driven to the school, thus creating surges of traffic prior to and immediately after school.
- Genteman Road, located just east of Bryan Road, provides access to a retirement home as well as a subdivision including homes with parcels greater than three to four acres.

The current location of the West Terra Lane intersection is approximately 400 feet north of the I-70 WB On/Off Ramps intersection. Currently, the intersection of Bryan Road with West Terra Lane is signalized, with vertical curbs and drainage systems in place within the vicinity of the intersection. The northbound approach has a dedicated right-turn lane (yield-controlled), to serve the high number of vehicles traveling east along West Terra Lane, and a shared through/left-turn lane. Sidewalks exist along both sides of Bryan Road between West Terra Lane and the I-70 Westbound On/Off Ramps. The eastbound approach has a dedicated right-turn lane for vehicles accessing Bryan Road, and a shared through/left-turn lane. The westbound approach has a dedicated left-turn lane and a shared through/right-turn lane.

A key element in the existing operational assessment was the close spacing of the I-70/Bryan Road interchange ramps to West Terra Lane. Traffic operations at the existing I-70 Westbound On/Off Ramp intersection fail due to the high peak-hour turning-movement volumes. The congestion created at this ramp causes significant queuing at both ramp terminals as well as at the West Terra Lane intersection. The close intersection spacing was a key challenge during the development of feasible alternatives.

TRAFFIC ANALYSIS TOOLS

The original study used three popular software packages to analyze traffic operations along Deer Creek Drive. As discussed in FHWA's *Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer* (1), selection of the appropriate analysis tool is critical in analyzing the feasibility of various intersection configurations. Due to the site constraints of the study intersections, the study team elected to use a combination of both macro and micro software packages to analyze the alternatives. A brief discussion of each software package is included below:

Synchro (Version 7.0) was used in the development of intersection geometrics, and to develop appropriate signal phasing/timing parameters for the alternatives that included signals. Synchro (Version 7) incorporates methodologies of the *Highway Capacity Manual (Transportation Research Board, 2000)* (2). Figure 2 depicts a screen capture of the Synchro model developed at the key study intersections.

Note: The latest version of Synchro (Version 8.0) incorporates the methodologies of the HCM 2010 for signalized intersections and roundabouts (3).

FIGURE 2 – Synchro Screen Capture

SIDRA INTERSECTION (Version 4.0) (4) was used to analyze roundabout alternatives using Australian-based capacity models. SIDRA's roundabout delay model is based on gap acceptance, as well as various geometric attributes. Version 4 of SIDRA does incorporate some of the methodologies highlighted within NCHRP 572 (5) for roundabouts within the U.S. Some of the gap values were, however, lower than those included within the HCM 2010 (6). Version 5.1 of SIDRA does incorporate the various roundabout methodologies of the HCM 2010.

Due to the close spacing of the study intersections, VISSIM (Version 3.4) was also used. VISSIM is a microscopic, behavior-based multi-purpose traffic simulation program used to assess traffic flow along arterial and/or freeway corridors. One of the benefits of traffic simulation is the ability to analyze an entire corridor and evaluate the overall delay experienced by drivers. Another benefit is the ability to model closely spaced intersections to evaluate interaction effects. Figure 3 depicts a screen capture of the VISSIM model developed at the key study intersections.

FIGURE 3 – VISSIM Screen Capture

One of the underlying purposes for writing this paper was to compare the roundabout delay values generated from the initial study with those of the newly released HCM 2010. The roundabout methodology within the HCM 2010 was developed using research conducted through the NCHRP 3-65 Project. NCHRP Report 572 provided a detailed summary of the research conducted on single- and multi-lane roundabouts within the U.S. One of the key findings of the research concluded that capacities of U.S. roundabouts are generally lower than other countries.

INITIAL ALTERNATIVES

The construction of Deer Creek Drive would reduce traffic along parallel routes and would provide a direct link for residents to access I-70 and the retail areas south of I-70. Four initial alternatives were developed and analyzed for the southern terminus of the proposed Deer Creek Drive extension. The West Terra Lane intersection is approximately 400 feet north of the I-70 WB Ramps intersection. While this spacing falls below current Missouri standards, the first two alternatives examined potential cost-saving configurations that would modify the intersection in its current location as the connection point for the Deer Creek Drive Extension.

Alternative One

Alternative One (See Figure 4) would toe the Deer Creek Drive Extension with Bryan Road at the existing West Terra Lane intersection. The modified intersection would remain signalized with the north leg realigned to tie in with the Deer Creek Drive Extension. Genteman Road would terminate at Deer Creek Drive approximately 600 feet northeast of the Bryan Road/West Terra Lane intersection. Additional geometric improvements would be necessary to accommodate future growth potential within the immediate area.

FIGURE 4 – Alternative One

FIGURE 5 – Alternative Two

Alternative Two

Like Alternative One, Alternative Two (See Figure 5) would use the existing West Terra Lane intersection as the tie-in for the Deer Creek Drive extension. The alternative would replace the existing signal control with a two-lane roundabout configuration including right-turn bypass lanes on the northbound and eastbound approaches. As with Alternative One, Genteman Road would terminate at the Deer Creek Road extension.

Alternative Three

Alternative Three (See Figure 6) was developed to improve operations of the overall corridor by increasing the spacing between the existing intersections. West Terra Lane would be realigned further north to provide approximately 700 feet between Bryan Road/West Terra Lane/Deer Creek Drive and the I-70 WB Ramps/Bryan Road intersection. The realigned intersection would be signalized with turn lanes. Genteman Road would connect to Deer Creek Drive approximately 200 feet northeast of the realigned Bryan Road/West Terra Lane intersection.

FIGURE 6 – Alternative Three

Alternative Four

Like Alterative Three, Alternative Four (See Figure 7) would increase the spacing between the existing intersections, but with a two-lane roundabout configuration for the realigned intersection (including northbound and eastbound right-turn bypass lanes). Access to Genteman Road would be similar to that of Alternative Three.

Although not germane to this paper, it should be noted that the Bryan Road/I-70 interchange itself was also analyzed with two alternative configurations: a single-point urban interchange (SPUI) and diverging diamond interchange (DDI). Based on the simulation analysis, both interchange options would provide acceptable traffic operations beyond the Year 2030. The DDI option was computed to be the least expensive option.

FIGURE 7 – Alternative Four

ADDITIONAL ALTERNATIVES

During the development of preliminary plans, the County noted that anticipated right-of-way impacts of the initial alternatives were undesirably high. Therefore, the project team, along with County staff, developed several additional roundabout concepts aimed at reducing right-of-way and access-related impacts. A brief discussion of the additional roundabout alternatives follows.

Revised Four-Leg Roundabout

This option (See Figure 8) consisted of a relocated version of the previously described Alternative Two. The location of the roundabout would allow full access to each of the adjacent commercial parcels, but would continue to impact the residents of the small subdivision located north of the roundabout. The inscribed circle diameter of this roundabout was limited to 150 feet in order to maximize the distance between the roundabout and the Bryan Road/I-70 On/Off Ramp, and to minimize reconstruction of West Terra Lane east of Bryan Road.

FIGURE 8 – Revised Four-Leg Roundabout

Five-Leg Roundabout

The focus of this alternative (See Figure 9) was to further minimize the reconstruction of West Terra Lane west of Bryan Road, while minimizing additional impacts to commercial parcels. The inscribed diameter was increased to 200 feet to accommodate the additional approach leg. Unlike the revised four-leg roundabout alternative, entry/exit path overlap issues along the western and southwestern legs would create design issues/challenges.

The additional approach leg would separate traffic destined for West Terra Lane (west of Bryan Road) and traffic to/from the small subdivision to the north. This alternative would further reduce reconstruction of West Terra Lane (compared to the revised four-leg roundabout).

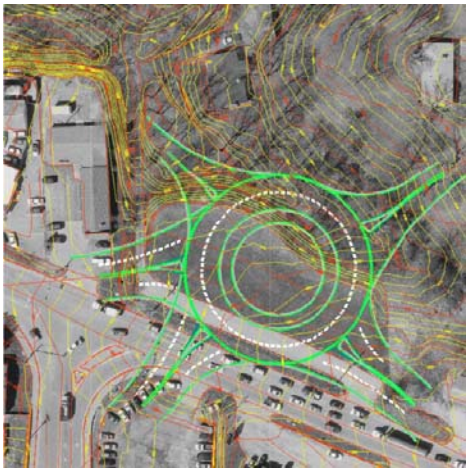

FIGURE 9 – Five-Leg Roundabout

A shortcoming of this alternative, however, is the lack of available queue storage between the roundabout and the WB I-70 On/Off Ramp intersection. The available queue storage would actually be 50 feet less than the current separation, which could create significant congestion issues at the ramp locations.

In addition, the roundabout's location would create topography issues due to existing ground elevation drops 25 feet between the proposed east and west legs of the roundabout. This severe differential would result in difficulties meeting standard grades required for successful roundabout operation. Most likely, MSE walls would be required along the north side to limit impacts to surrounding parcels.

Peanut-Turbo Roundabout

To address the topography issues raised by the five-legged roundabout, and better facilitate access to local businesses, a two-roundabout solution was developed, called the "peanut-turbo" concept:

- "Peanut", because the two roundabouts and the connection between them form something akin to a peanut shape (the term "dumbbell" is also often used to describe this configuration).
- "Turbo", because the roundabouts feature modified non-circular central islands to facilitate the addition of a second circulating lane in roughly one-third of each circulatory roadway, a lane into which vehicles would be guided by spiral striping. This configuration has been dubbed a "turbo" roundabout by its original creators in the Netherlands. The Turbo Roundabout has been defined as providing "a forced spiraling flow of traffic, thus requiring motorists to choose their direction before entering the roundabout. By eliminating many conflicting paths and choices on the roundabout itself, traffic safety is increased, as well as speed, and as a result, capacity. A turbo roundabout does not allow travelling a full circle."[7] A "traditional" turbo design is shown in Figure 10.

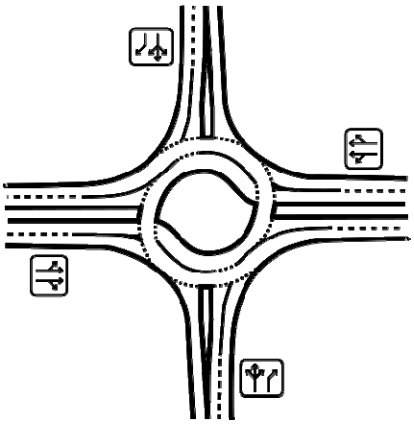

FIGURE 10 – Traditional Turbo Roundabout Design

The design proposed for the Deer Creek project provides a turbo-like design on only one leg of each of the roundabouts, and therefore could be called a "modified turbo". The modified turbo concept would result in a smaller roundabout footprint by reducing the central island size. The peanut concept would allow the creation of two smaller three-legged roundabouts as opposed to a single, larger four- or-five-legged roundabout. Both of these design approaches would contribute toward reducing the right-of-way footprint in the areas where the topography challenges are the greatest. And, as Figure 11 illustrates, service roads could integrate with this concept (much better than any of the other roundabout alternatives) to provide access to the existing businesses on the north and south sides of West Terra Lane.

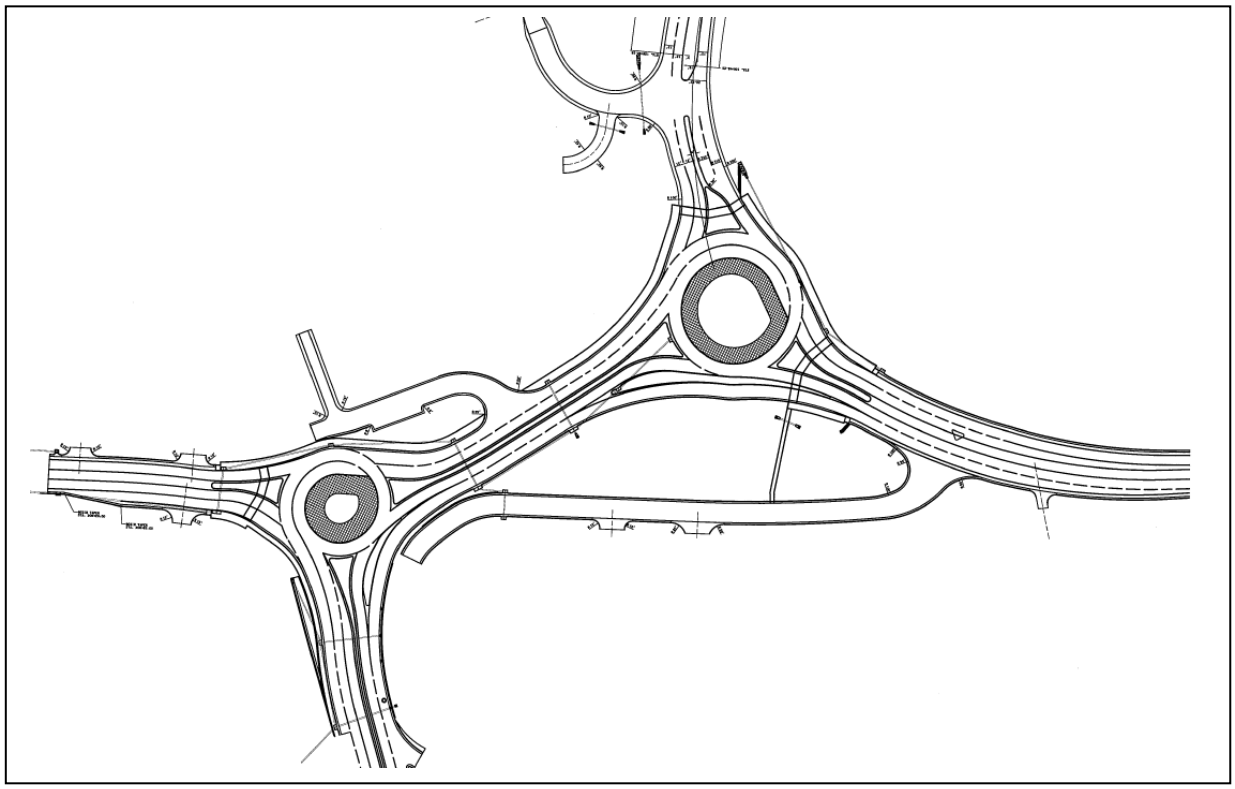

FIGURE 11 – Deer Creek Peanut-Turbo Roundabout Alternative

COMPARISON OF ALTERNATIVE ANALYSES

As noted above, the alternatives analysis was conducted in late 2009 and 2010. Synchro was used to define both the geometric and signal phasing requirements of the signalized alternatives, while SIDRA INTERSECTION was used for defining geometrics of the roundabout alternatives. Some of the capacity-related parameters used in the SIDRA INTERSECTION roundabout methodologies (critical gap, follow-up headway) are based on research conducted on Australian roundabouts. Research conducted for NCHRP 572 indicated that capacity thresholds for U.S. roundabouts are lower than those in Australia. It should be noted that an Environment Factor of 1.2 was used within SIDRA.

Although a number of alternative configurations were analyzed for the study, this paper focuses on the operational results for two of the alternatives: the Alternative Four roundabout (as depicted in Figure 8) and the Peanut-Turbo Alternative.

Two volume scenarios were analyzed for each of the alternatives, corresponding to the two anticipated phases of project development. Phase One (2020 horizon year) would consist of constructing the preferred alternative at West Terra Lane/Deer Creek Drive. The extension of Deer Creek Drive, however, would end just north of Genteman Road in this phase. The northern section of Deer Creek Drive would be extended from Highway P to provide a connection to Elaine Drive. This connection would route traffic from Highway P to Elaine Drive to West Terra Lane. Phase Two (2030 horizon year) would complete the connection of Deer Creek Drive across the railroad tracks to connect to the northern section of Deer Creek Drive. Figure 12 depicts the PM peak-hour volumes developed for both Phases.

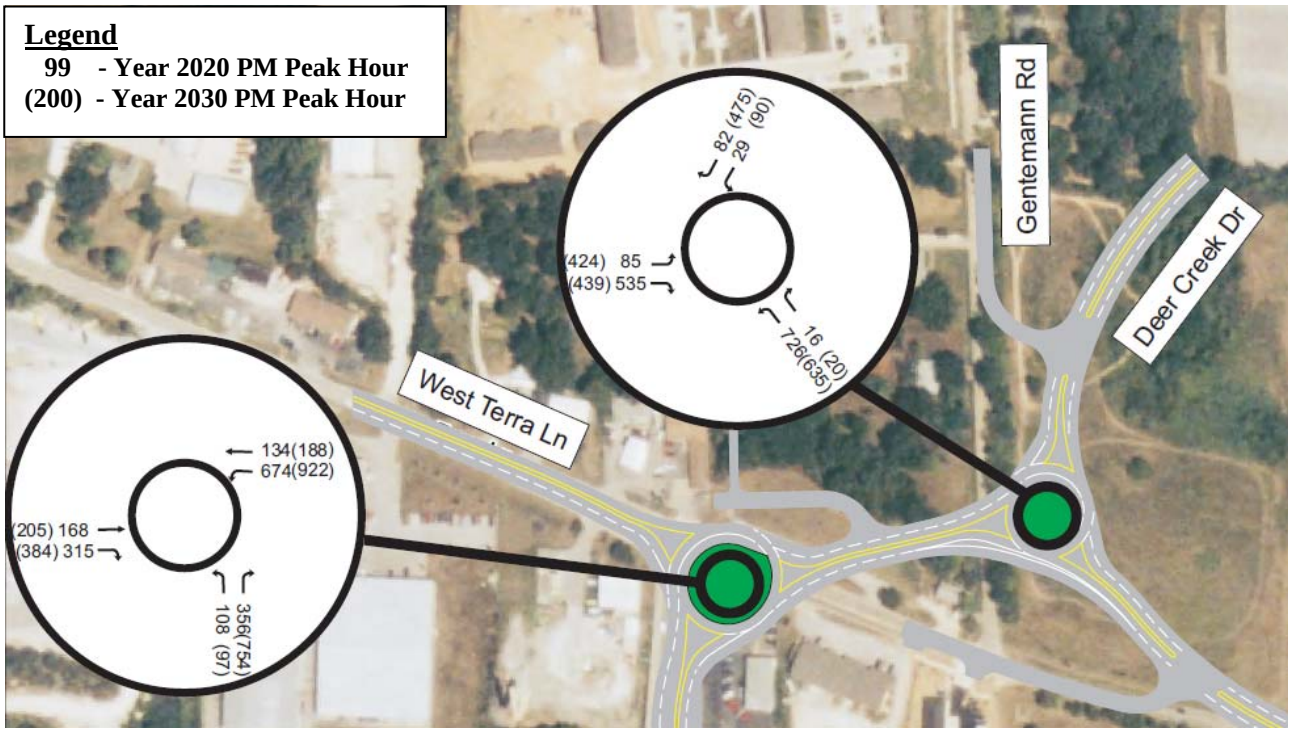

FIGURE 12 – Year 2020 and 2030 PM Peak Hour Volumes

Table 1 depicts the results of both the SIDRA INTERSECTION and Synchro analyses for the two alternatives. SIDRA INTERSECTION's average delay values for the traditional four-legged roundabout alternative were slightly lower than the HCM 2010 methodologies included within Synchro 8.0. This is most likely due to the lower follow-up headway values included within SIDRA.

The operational analysis of the peanut-turbo roundabouts indicated that SIDRA's results were actually higher for the Year 2020 PM Peak Hour. The results of both methods for the Year 2030 PM Peak Hour were closer to each other than the Year 2020 results. The differences could be based on a reduction in the circulating volume, thus reducing the number of conflicting vehicles within the roundabouts.

TABLE 1 - Comparison of Average Delay (seconds per vehicle)

	SIDRA	Synchro (HCM 2010)
Traditional Roundabout (Alternative 4)		
2020	13.2	14.3
2030	14.1	16.5
Peanut-Turbo West Roundabout		
2020	10.2	7.8
2030	10.4	11.0
Peanut-Turbo East Roundabout		
2020	9.9	4.8
2030	12.9	11.8

Notes:
1. SIDRA INTERSECTION results from version 4.0.19.1104
2. SYNCHRO results from version 8.0 (Build 838)

Since the focus of this paper was to compare SIDRA's results with those based on the HCM 2010 methodologies, a detailed discussion related to the VISSIM results was not presented. However, due to the closely spaced interchange ramps, the use of a micro-simulation tool was critical to the operational assessment of the preferred alternative. The use of multiple tools when analyzing complex alternatives is highly recommended, especially when closely spaced intersections are present. For example, the traditional four-legged roundabout alternative (as depicted in Figure 8) average delay within VISSIM for the Year 2030 was 42.6 sec/vehicle. This value is almost three times the results obtained from the macro-level analysis tools. The interaction of nearby intersections must be included to accurately predict future operations of the system as a whole. Macro-level analyses tools can assist in the development of the basic concept, but additional tools should be used to fully understand the future operations of the closely-spaced intersections.

FIGURE 13 – Traffic Simulation of Peanut-Turbo Alternative

SUMMARY AND CONCLUSIONS

Retrofitting existing intersections can present many challenges for both traffic and roadway engineers. Developing a variety of alternatives that minimize impacts may lead to non-standard solutions. Roundabouts offer many potential advantages due to their inherent design features and should be considered when possible. The following bullet points provide a brief summary of this paper.

- Roundabouts offer the designer flexibility, especially when more than four approach legs are required.
- Traffic volumes should be reviewed based on the layout of the roundabout. For example, the peanut-turbo roundabout (as described above) consisted of two roundabouts with three approaches, thus reducing the total number of conflicting vehicles when compared to a signalized intersection or traditional four-legged roundabout.
- The results from SIDRA INTERSECTION Version 4 matched closely with the newly relates roundabout methods included within the HCM 2010. Synchro 8.0 will incorporate the roundabout methodologies of the HCM 2010.
- Traffic simulation should be used in situations where closely-spaced intersections exist or will exist in the future.

ACKNOWLEDGEMENTS

The author would like to thank Christopher Kinzel and James Evans for their assistance and insight.

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