Comparative Analysis of the Through-about, Roundabout, and Conventional Signalized Intersection Designs

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ABSTRACT

The modern roundabout has become a very popular alternative intersection design within the United States. As this design becomes a more standard solution in keeping with European practice, we are likely to encounter more frequent occurrences of the through-about intersection, a related design. This design, while not well documented in the literature, occurs on the spectrum of alternative intersection designs.

This paper examines the operational aspects of the through-about intersection design. Comparative analysis of overall intersection delay is conducted using the INTEGRATION traffic microsimulation software package, with data for the conventional intersection verified using the HCM methodology embedded within the macroscopic-based Synchro traffic software. Secondary measures of effectiveness are discussed, including safety, cost, and fuel consumption.

The analysis of this design shows that the through-about may not be successful as a direct competitor for either the modern roundabout design or for the conventional signalized intersection. Instead, this design should be considered as a site-specific solution to achieve effective safety and access considerations where a high-volume arterial intersects with one or more low-volume roads, potentially with large skew angles.
INTRODUCTION

The topic of alternative intersections is becoming one of increasing interest in the United States. With the ongoing integration of the modern roundabout design into the transportation engineering industry, more professionals and researchers are taking note of potential alternatives to the conventional signalized intersection design. There remain few options for analyzing these alternatives short of full micro-simulation, which may be preventing these designs from experiencing more widespread adoption by the industry. A design alternative related to the modern roundabout is the through-about, which includes a circulatory road with signalized through lanes bisecting it to allow for greater throughput on a major arterial.

The purpose of this paper is to assess the value of the through-about intersection design as an alternative option to a conventional signalized intersection design from operational perspective. Analysis considers one major arterial crossing with one minor arterial at a ninety-degree angle, with alternatives including a conventional signalized intersection, a modern roundabout, and a through-about intersection design. Sensitivity analysis is conducted on total volume, percentage of left-turns on the major arterial, and the volume split between the major and minor arterial.

The primary measures of effectiveness (MOE) in traffic operations at intersections include the average delay experienced by all vehicles as they traverse a given facility, measured in seconds, followed by the percentage of potential capacity being utilized. Once operational requirements are established, secondary measures of effectiveness move beyond operations and include an assessment of the safety of a design, access it may or may not provide to adjacent property, expected cost of construction and maintenance, and fuel consumption experienced by vehicles traversing it. This paper will focus primarily on measures of vehicle delay, but will touch upon other MOEs as the data allows.

THROUGH-ABOUT GEOMETRY

The through-about design, sometimes known as the “hamburger” intersection, consists of a circulatory road pierced by a major roadway, with through lanes crossing through the circulator.

As shown in FIGURE 1, traffic in the major roadway maintains through movement using signalized intersection(s), while all turning movements from the major roadway and all traffic movements from the minor crossing roadway utilize the circulator. This configuration allows the signal control to operate with a two-phase signal plan, thus reducing lost time. Left-turns are prohibited from within the middle section of the through lanes, forcing left-turning vehicles from the major approach to use the circulator to access their destination.

There are two mentions of the through-about intersection in recent literature. The first is in the Alternative Intersections and Interchanges Informational Report (AIIR) [1], and the second from a TRB conference paper on a proposed new design, the Reduced Conflict Intersection (RCI) [2]. The material included in the AIIR references a 2004 report from Iowa State [3], though upon reviewing this source material it was found that no reference to either the through-about or the hamburger intersection is made therein. The later publication on the RCI provides more detail on the through-about design than did the AIIR, but it also lists the Iowa publication
as its source material. Further review indicates that the RCI paper combined information provided in the AIIR with information found on the “roundabout” article on Wikipedia [4]. None of the information provided about the design on the Wikipedia page is referenced to an external source.

**FIGURE 1** Example Through-about Geometry

**Existing Implementations**

Despite a lack of literature on the design, a number of locations exist where it has been implemented. Without citation, some of the literature cites these designs as being popular solutions in both the United Kingdom and Spain. Within the United States, there are currently three examples documented, though the authors believe that all of these designs date from a time when rotaries were popular, and are not associated with the recent proliferation of the modern roundabout. The differentiation between the designs is well documented in the current state-of-the-practice document: Roundabouts: An Informational Guide (second edition) [5]. The older rotary design is differentiated from the modern roundabout by a larger diameter, often in excess of 300 feet. This large diameter was often set based on the length of weaving section required between intersection legs, and resulted in higher speeds of travel and greater safety concerns than its modern counterpart. Modern roundabouts are designed to maintain lower circulating speeds, with an inscribed diameter between 90 and 180 feet for single lane roundabouts, and 150 to 300 feet for multilane roundabouts. The smaller radii of these designs force drivers to slow their
speed in order to comfortably traverse the curve of the road, with the slower speeds achieved reducing both the frequency and the severity of crashes at the site. Aerial images of the domestic example locations can be seen below in FIGURE 2. These designs are not true circles, but are oblong in shape, with locations that include Fairfax, Virginia with a 200/230 foot inscribed diameter, Everett, Massachusetts with a 400/450 foot inscribed diameter, and Cherry Hill, New Jersey with a 230/330 foot inscribed diameter. It is unclear whether the diameter dimension along the major arterial is governed by the need to provide adequate queuing space or not.

![Aerial Images](image1.jpg)
(a) Fairfax and Old Lee, Fairfax, VA
(b) Revere Beach and Mystic View, Everett, MA
(c) Kaighn Ave and Church Rd, Cherry Hill, NJ

**FIGURE 2** Existing domestic implementations of the through-about. (Source: Google Earth)

Aspects that these locations have in common are the intersection of a major arterial with high through vehicular volumes, and skewed approaches on minor streets. While the Virginia location features only two minor approaches heavily skewed from the primary arterial, the Massachusetts location includes three minor approaches and the New Jersey location includes four. The accommodation of pedestrians and bicyclists are handled differently at each location. In Fairfax, VA, at-grade crossings are provided in all four directions, with north-south movements accommodated on the outer edge of the circulator, and east-west movements accommodated within the green space. The Everett, MA location accommodates pedestrians and
bicycles with grade-separated facilities, maintaining traffic throughput. No accommodation is
provided at the Cherry Hill, NJ location. In general bicycle and pedestrian accommodations are
a site-specific concern, and the analysis of their interaction is not explored herein.

Information was provided by a traffic engineer working for the city of Fairfax, VA regarding
the history of the through-about in their city [6]. The single through-about intersection located in
Fairfax is the last remaining of a number of different locations that have been reconstructed over
the years due to safety concerns. Many of these resulted from the initial construction of rotaries
or traffic circles in the 40’s and 50’s, with through lanes subsequently added in later years to
accommodate growing traffic volumes in the area. Safety concerns arose due to frequent
accidents, largely due to weaving movements with business access points in close vicinity to the
intersection. The remaining location is operating within acceptable mobility and safety
measures, and the cost to reconfigure the junction would not be justified.

EVALUATION APPROACH

Though a number of the alternative intersection designs are being integrated into future iterations
of the Highway Capacity Manual, currently the two analysis methods available for practitioners
are a planning level capacity-based analysis using FHWA’s CAP-X program [7] and full traffic
microsimulation. Many of these designs exhibit benefits to safety or access, but in practice these
become secondary considerations, examined only after capacity and delay measures are satisfied.
The opposite also holds true, that many of these designs have benefits to mobility but the right-
of-way necessary to accommodate large intersection footprints or wide medians is not always
available or cost effective. In evaluating the through-about design, our primary concern will be
measures of delay, with secondary measures of effectiveness investigated as appropriate and
available.

Analysis Methodology

Two software applications were employed to validate the findings included in this paper: the
macroscopic based Synchro software, and the microsimulation based INTEGRATION software
package. The standardized methodology from the Highway Capacity Manual [8] was used to
validate the findings of microsimulation for the conventional signalized intersection using HCM-
2000 methodologies as implemented in Synchro (version 6). Microsimulation results are an
amalgamation of numerous simulation runs, varying the random seeds to achieve significant
confidence in the values presented. Each volume/geometry combination was run for
approximately 20 hours of simulated time, resulting in 95% confidence intervals on average
delay of less than +/- 0.5 seconds for undersaturated traffic conditions.

The use of microsimulation software packages provides the opportunity to optimize signal
timings in real time, however, in the interest of obtaining consistent and repeatable results the
authors developed signal timing schemes for each volume combination and geometry. Critical
lane analysis was used to develop both the natural cycle lengths, using Webster’s method, and
the signal splits for the various phase movements, in accordance with the Traffic Signal Timing
Manual [9]. The natural cycle length was rounded to the nearest ten seconds, and allowed to
vary between 60 and 140 seconds for the four-phase conventional intersection, and between 40 and 120 seconds for the two-phase through-about design. Signal timings were treated as pre-timed non-actuated signals, with a constant timing plan for the duration of the simulation. The modern roundabout design was analyzed as an unsignalized intersection under yield control.

**Measures of Operational Effectiveness**

While control delay is the operational standard by which conventional intersections are measured against each other, alternative intersections often include displaced or rerouted vehicle movements with increased travel length. The preferred methodology used in the literature to provide comparisons between alternative intersections is to hold the limits of the network size standard across each alternative design, and provide comparisons for total travel time [1]. As the delay measure is so critical for transportation engineering practitioners, the authors of this study chose to define a traffic network with origin-destination nodes located equidistant from the centroid of the intersection. In this case, each design was modeled with start/end points located 0.4 km away from the centroid of the intersection. Setting the desired free-flow speed to 40 km/h (approximately 25 mi/h), each of the twelve origin-destination movements travels 0.8 km, with a base theoretical travel time of 72 seconds. Using the average total travel time of vehicles in the network as the output of simulation, a measure of delay can then be used that incorporates both control delay as well as geometric delay for alternative designs.

**Selection of Alternative Geometries for Comparison**

The analysis conducted herein seeks to identify the potential of the through-about intersection design to serve as an alternative solution to a conventional signalized intersection or a modern roundabout design. Decisions about intersection geometry were made in order to provide as equal as possible a comparison between the alternative designs. A visual representation of the geometries simulated is shown below in **FIGURE 3**.
(a) Conventional

(b) Roundabout

(c) Through-about

FIGURE 3 Geometry of (a) conventional, (b) roundabout, and (c) through-about intersections.
Definition of Origin-Destination Demands for Comparative Analysis

Three separate sensitivity analyses are presented herein. The first set of volume combinations varies the total volume on all approaches, while holding other factors constant. The second set varies the percentage of major approach vehicles turning left. The third set varies the percentage of total traffic on the major approach. The volume combinations used are based on engineering judgment.

In conducting sensitivity analysis on the magnitude of volume demands, the total volume on all approaches ranges from 1,200 vehicles (passenger car equivalents) to 4,200 vehicles, with a step size of 600 vehicles. The directional split between the major and minor approaches is 70%/30%. The major approach turn-movement demands are split with 25% left-turning movements, 65% through movements, and 10% right-turning movements. The minor approach turn-movement demands are split with 15% left-turning movements, 70% through movements, and 15% right-turning movements.

In conducting sensitivity analysis on the percentage of left-turning vehicles, the total volume demand on all approaches is held constant at 3,000 vehicles. The minor approach experiences the same turn-movement demand splits for the left-turn analysis as it does with the volume sensitivity analysis. The major approach turn-movement demands hold right-turning movements at 10%, while varying the left/through movements as 10%/80%, 20%/70%, 25%/65%, 30%/60%, and 40%/50%.

In conducting sensitivity analysis on the split between the major and minor approaches, the total volume demand on all approaches is again held constant at 3,000 vehicles. The major and minor approach turn-movement demands experience the same splits as in the volume magnitude analysis. The split between the major/minor approaches varies as 90%/10%, 80%/20%, 70%/30%, 60%/40%, and 50%/50%.

A summary of the volume scenarios used can be seen in TABLE 1.
TABLE 1 Volume scenarios used in sensitivity analysis of (a) volume magnitude, (b) left-turn percentage, and (c) major/minor split.

<table>
<thead>
<tr>
<th>(a) Volume Magnitude</th>
<th>(b) Left-turn Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume Magnitude</strong></td>
<td><strong>Left-turn Percentage</strong></td>
</tr>
<tr>
<td></td>
<td>Split</td>
</tr>
<tr>
<td>1,200</td>
<td>70</td>
</tr>
<tr>
<td>1,800</td>
<td>70</td>
</tr>
<tr>
<td>2,400</td>
<td>70</td>
</tr>
<tr>
<td>3,000</td>
<td>70</td>
</tr>
<tr>
<td>3,600</td>
<td>70</td>
</tr>
<tr>
<td>4,200</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Volume</th>
<th>Major</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,000</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>3,600</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>4,200</td>
<td>70</td>
<td>30</td>
</tr>
</tbody>
</table>

RESEARCH RESULTS
For the volume combinations examined, in general, the roundabout was found to be the preferred design, performing significantly better than the other alternatives investigated, with the conventional intersection displaying slightly better operational performance than the through-about design at higher volumes. Results of the three sensitivity analyses are found in FIGURES 4-6.

The two-lane roundabout alternative in FIGURE 4 is seen to impart significantly less average delay than the other alternatives prior to 3,600 total vehicles on all approaches, after which the roundabout design experiences oversaturated conditions. The results of microsimulation of the conventional signalized intersection track along with the anticipated results calculated using the macroscopic HCM methodology, but the microsimulation predicts an average vehicle delay of a few seconds more in each case. At lower volume thresholds, the through-about intersection performs slightly better than the conventional signalized intersection, with equal performance in the mid-range volumes and increasingly poorer performance in the high-volume regime.
FIGURE 4 Average delay as a function of total volume on all approaches.

The results shown in FIGURE 5 examine the sensitivity of each design to the percentage of left-turning vehicles. The values displayed at 25% left-turns on the major approach in FIGURE 5 are the base results included at the 3,000 total vehicles level in FIGURE 4. The findings of this research indicate that at this level of volume magnitude, the operational effectiveness of the roundabout design is largely unaffected by the percentage of left-turning vehicles. As the percentage of left-turning vehicles increases, both the conventional signalized intersection and the through-about design degrade in operational effectiveness, though the conventional intersection is seen to be less sensitive to the effects of left-turning vehicles than is the through-about.
The results shown in FIGURE 6 examine the sensitivity of each design regarding the degree to which the major arterial experiences more traffic than the minor arterial. The findings of this research indicate that at this level of volume magnitude, the operational effectiveness of the roundabout design is largely unaffected by major/minor approach split. As the percentage of traffic on the major approach increases, both the conventional signalized intersection and the through-about design improve in operational effectiveness, though the through-about design slightly underperforms the conventional signalized intersection, and neither of these designs comes close to the operational effectiveness of the roundabout.

ANALYSIS OF RESULTS

Reviewing the three sensitivity analyses for the through-about design, there does not appear to be a niche condition under which this design is preferable, based on the volume combinations tested herein. Anecdotal evidence suggests that the existing through-about intersections in use domestically were constructed as a modification to an existing traffic circle, as through-vehicle traffic demands on the main arterial grew too large to be accommodated on the circulator [6]. This may suggest that specific volume combinations with high through-traffic volume on the major arterial, and low volume demands on the major approach turning movements and minor approaches may yield beneficial results.

While overall average delay experienced by vehicles at the through-about design appears to be greater than that of either the roundabout or the conventional signalized intersection, the reduction from four phases to two may reap benefits for this design on the average delay of through-movement vehicles on the major arterial. There are some cases where access is necessary for turning movements and minor approaches, but the maintenance of throughput on the major arterial takes precedence over the overall performance experienced by all vehicles at the intersection. As such, FIGURE 7 seeks to determine if there’s an advantage to the average...
through the major approach through-movement vehicles when examining the results of the total volume sensitivity analysis. The results of this through-movement delay analysis indicate that the advantage of the modern roundabout design tails off as it approaches capacity before the conventional intersection or the through-about design, and that the through-about design consistently serves through-movements better than its conventional intersection counterpart. A question for designers might be the degree to which the through movements on the major arterial might take precedence over the total intersection operations at a given location.

**FIGURE 7** Through-movement delay on major arterial.

**Secondary Analysis Metrics**

Though delay is the primary measure of effectiveness used in the comparison of potential improvements for an intersection facility, many other considerations come into play before a final selection is made. No increase in mobility can be justified if the safety of the roadway users is compromised by its construction, designs must be shown to be as safe as the other alternatives under consideration. The cost of each alternative may become a governing factor if the difference is significant; this is particularly true when there is insufficient right-of-way to construct a given design, and additional land must be purchased. Fuel consumption, while a secondary consideration, is also becoming a common metric for evaluation. A final metric that becomes important for the through-about design is the number of minor approaches intersecting at the location, and the relative skew of those approaches. The study results lead the authors to believe that the through-about may serve as an optimal solution in cases where a high-volume major arterial is joined by more than two low-volume approaches, and/or those approaches meet at a highly skewed angle.

One of the primary considerations which must be met when proposing facility improvements is that the safety of the location must not be compromised by any improvement constructed. Though the modern roundabout design provides significant safety improvements over the
conventional signalized intersection design, these improvements are arrived at due to the reduction in the total number of conflict points encountered by vehicles traversing the facility [10], and the reduction in severity of the existing conflicts. The modern roundabout design features only merging and diverging conflicts, with the majority of incidents involving property damage with little in the way of injuries or fatalities. The conventional signalized intersection has higher rates of accidents, injuries, and fatalities, due to the larger number of conflict points, and the fact that a number of these conflicts are the most dangerous crossing type of conflicts. An analysis of the conflict points for the multi-lane designs analyzed in this study can be seen in FIGURE 8. The conventional signalized intersection includes 48 total conflict points, of which 30 are the most-dangerous crossing conflicts. The dual-lane roundabout retains 16 crossing conflicts out of a total of 32 points of conflict. The through-about design shows a slight reduction from the conventional signalized intersection, with 40 total conflict points including 28 crossing conflicts.

![Conventional, Roundabout, Through-about intersection designs](image)

**FIGURE 8** Conflicts created by (a) conventional signalized, (b) roundabout, and (c) through-about intersection designs.

Four factors impacting cost for the alternative designs examined herein include the cost of purchasing right-of-way, the cost of constructing the footprint of the roadway geometry, the cost of constructing signalization and corresponding sensors, and the cost of maintenance for the signalization. These factors can be summarized as shown below in TABLE 2. Although the indicator variables shown are not directly correlated to the overall cost, they give a clear indication that right-of-way is an issue for the through-about design at the central intersection location, and that the modern roundabout design can be expected to incur the lowest total cost for construction. The total asphalt footprint is measured for a 1 kilometer diameter around the centroid of the intersection design, and includes a small paved shoulder beyond the edge of the travelway. These values are not taken to be constant for these designs, but are based on the
geometries used in this study and are meant to be indicative of the relative costs that can be expected.

**TABLE 2** Cost indicators for alternatives analysis.

<table>
<thead>
<tr>
<th>Design</th>
<th>Diameter of Central Area (m)</th>
<th>Width of Major Approach (m)</th>
<th>Width of Minor Approach (m)</th>
<th>Total Asphalt Footprint (m²)</th>
<th>Signal Masts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Signal</td>
<td>42.2</td>
<td>24.0</td>
<td>16.8</td>
<td>25,367</td>
<td>4</td>
</tr>
<tr>
<td>Roundabout</td>
<td>54.4</td>
<td>19.8</td>
<td>19.8</td>
<td>24,900</td>
<td>0</td>
</tr>
<tr>
<td>Through-about</td>
<td>70.8</td>
<td>20.0</td>
<td>12.8</td>
<td>27,364</td>
<td>6</td>
</tr>
</tbody>
</table>

Fuel consumption is becoming a more common secondary measure of effectiveness, and is likely to continue increasing in importance along with the cost of energy. The INTEGRATION traffic microsimulation software package interfaces with the VT-Micro fuel consumption model to provide measures of fuel consumption for the alternatives analyzed [11]. Making use of the total volume sensitivity analysis, **FIGURE 9** shows the relative fuel consumption of the alternative designs for the various volume combinations examined. The results of the fuel consumption analysis indicate that the modern roundabout outperforms the conventional and through-about designs until it approaches capacity, and that fuel consumption for the conventional intersection is consistently better than that for the through-about design, though not to a great degree.

**FIGURE 9** Fuel consumption measures from volume magnitude sensitivity analysis.
The existing implementations of the through-about design domestically all have minor approaches with significant skew angles as they meet the major arterial. Two of the three locations additionally have more than two minor approach spokes at the junction, with the circulator road providing access to multiple points along the circumference. Combined with the microsimulation results of delay measures, the existing implementations as previously shown in **FIGURE 2** would indicate that this design is useful as a solution to a unique geometric condition, and not necessarily useful as a direct competitor to other alternative intersection designs.

**LIMITATIONS OF THE CURRENT RESEARCH**

The authors believe that there exist specific conditions under which this design becomes the preferred choice for construction, but that the conditions necessary for this may be more related to site-specific space constraints than superiority in operational analysis. As an example, all of the domestic implementations of this design exist with large skew angles on the minor approaches, and two of the three locations have more than two minor approaches coming together at the junction. Additionally, there may be a set of turning-movement volumes which indicate the through-about as the appropriate choice from an operational perspective, but the volume combinations tested herein did not include such a scenario.

**CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH**

Three sensitivity analyses were conducted for the research presented herein, with a primary focus on the average delay of vehicles. The first analysis on total volume of all approaches indicates that the roundabout intersection design outperforms the conventional signal and through-about designs up until the roundabout reaches capacity, at which point the conventional signalized intersection has a slight advantage over the through-about design. The second analysis on the percentage of left-turning vehicles indicates that the through-about design is more susceptible to performance degradation at high percentages of left-turning vehicles than is the conventional signalized design, but that the modern roundabout design outperforms both by a significant margin, and is relatively insensitive to the percentage of left-turning vehicles. The third analysis on the major/minor approach split resulted in very similar findings to the second - the through-about design is more susceptible to performance degradation at high levels of minor-approach traffic volumes than is the conventional signalized design, but that the modern roundabout design outperforms both by a significant margin, and is relatively insensitive to higher volumes of minor-street traffic.

Though the through-about intersection design was not able to show significant improvements over the alternatives in terms of overall intersection delay, a number of secondary measures of effectiveness were investigated. From a safety perspective the vehicle-path conflicts produced by the through-about intersection are anticipated to be on-par with those of a conventional signalized intersection, with the modern roundabout experiencing significant improvements to safety over both. From a cost perspective, the conventional signalized intersection is anticipated
to need the least amount of right-of-way for construction, with the roundabout expected to have
the lowest long-term costs due to the lack of signals and corresponding maintenance – the
through-about intersection requires significantly more right-of-way, and is likely to be
considered only on the occasion of retrofitting an existing traffic circle or rotary installation. In
terms of fuel consumption, the vehicle trajectories associated with the roundabout design
provided significant benefits over either the conventional signalized intersection or the through-
about design. Finally, it was discussed that a primary benefit of the through-about is its ability to
safely accommodate a larger number of minor street approaches than the other designs, as well
as approaches that have large skew angles.

The authors propose that future analysis of this alternative intersection design may be
conducted using the Monte Carlo method of experiment design, randomly sampling from a wide
variety of volume combinations to seek out the outlier conditions under which this design
outperforms the competing geometries. Unfortunately, this type of analysis requires a widely-
expanded set of volume combinations in order to achieve significant variety from the sample
population, with a corresponding increase in computer processing time for traffic
microsimulation software. The potential exists that sub-regimes of traffic may be pre-identified
as potentially benefited by this design, with higher weights provided to volume combinations in
this regime when selecting the random samples.

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