Mini-Roundabout Case Studies

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Abstract

Mini-roundabout was invented by Frank Blackmore in 1969 as a way to combat urban street congestion. Although this design has been around for over 40 years and is widely used in European Countries and Australia, it hasn't gained much recognition in the United States. The Federal Highway Administration (FHWA) initiated a study in 2009 aimed at introducing the mini-roundabout design into the U.S. As of December 2013, the FHWA research team has conducted over 40 outreach presentations, provided technical assistance to numerous state and local highway agencies, and evaluated 12 mini-roundabouts in 5 states. Interests in implementing this design for solving various types of traffic operational and safety problems are on a sharp rise, with some local agencies programming 6 to 10 sites in their jurisdictions. FHWA's experiences show that the engineering design and construction of mini-roundabouts are relatively simple and can even be undertaken by in-house staff employed by state or local agencies. Much more efforts had to be devoted to overcoming institutional barriers and convincing the public and elected officials that this intersection design can solve real traffic congestion and safety problems. This paper documents the success stories and the lessons learned from four field evaluation sites. It describes the operational and safety problems at each site, their ranges of traffic demands and construction costs, and then using before/after field data and local business sales data to illustrate the various aspects of mini-roundabout design and to what extent the intended implementation objectives were achieved at each site. All four sites had operational and safety problems for years before the mini-roundabout solution was tried and found successful. The problems that were successfully addressed at these evaluating sites are comprehensive enough to provide ready answers to most of the questions a highway agency may face when evaluating the suitability of mini-roundabout design at particular intersections.

Introduction

By FHWA's definition, mini-roundabout is a single-lane roundabout with an inscribed circular diameter (ICD) between 50 ft to 90 ft. Figure 1 shows a mini-roundabout constructed in August 2012 at the intersection of S. Tollgate Rd and W. MacPhail Rd, Bel Air, MD. Its ICD is 67 ft. A well designed mini-roundabout shall have all the features of a single-lane modern roundabout, plus one additional feature, and that is the central island (as well as part or all of the splitter islands) must be traversable to accommodate large vehicles. For passenger vehicles, the experience of navigating through a mini-roundabout is no difference than navigating through a regular size single lane roundabout. When FHWA initiated the mini-roundabout study in 2009, the intent was to introduce this intersection design to the U.S. and apply it to intersections of high volume collector roads. At that time, very few conforming mini-roundabouts existed in the U.S.; however, small traffic calming circles like the one shown in Figure 2 di exist then. In comparison to mini-roundabouts, traffic calming circles typically have smaller non-traversable landscaped central islands, much wider circulating lanes, and little or no speed reduction treatments to the intersection approaches. For large vehicles, traffic calming circles can become in-escapable traps. They are not suitable for junctions of high volume collector roads. Many people confuse neighborhood traffic calming circle with mini-roundabout, and many transportation agencies are reluctant to try this design at high volume intersections.

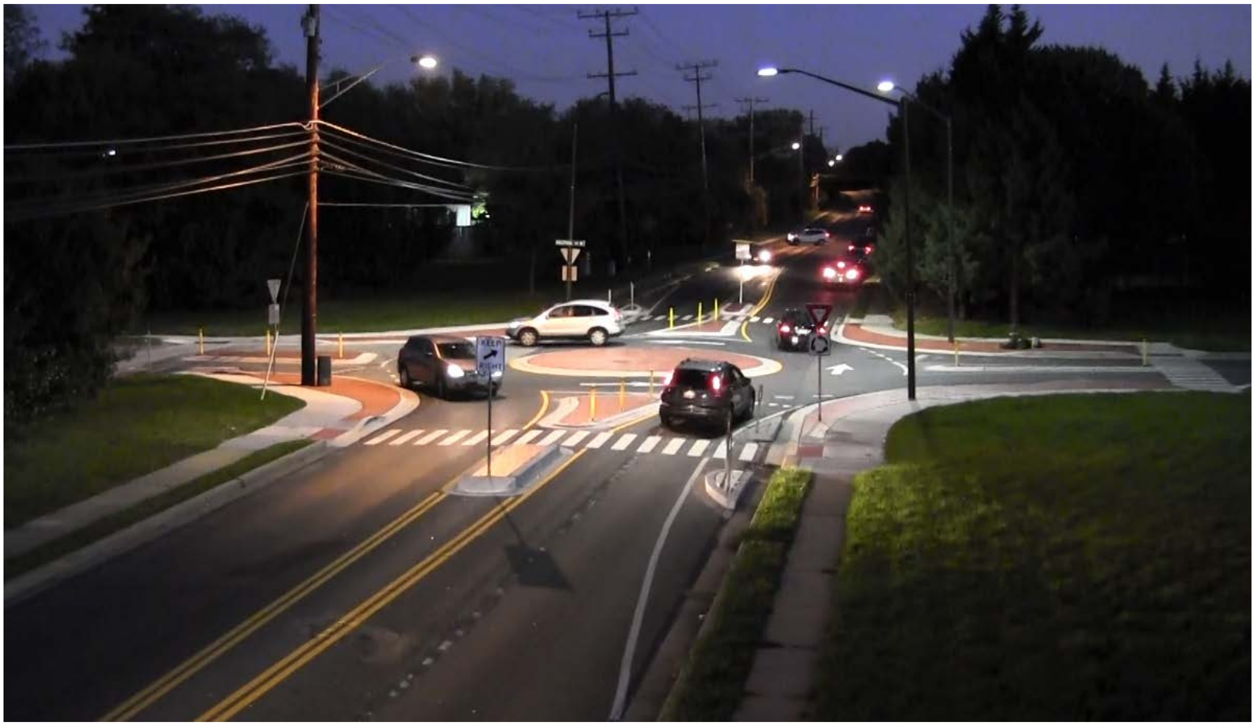

Figure 1. Mini-roundabout at S. Tollgate Rd and W. MacPhail Rd, Bel Air, MD

Figure 2. Neighborhood Traffic Calming Circle at South St and Intervale Rd, Brookline, MA

(With permission from Google)

FHWA's first two mini-roundabout sites were on residential streets with peak hour all entering traffic demand in the 200 vph range; the next 3 evaluation sites were installed on previously two--way-stop-control (TWSC) intersections to provide more gap to minor road traffic and pedestrians, and the peak hour traffic demands at these three sites were in the 700 vph range. These first five sites all have short and flush painted splitter islands, rather than the longer and raised splitter islands recommended by FHWA. Among the agencies that FHWA sought partnership with, implementation of mini-roundabout design at high traffic volume and challenging sites started in June 2012 at two intersections next to a shopping center in Lake Stevens, WA. Three months later, a well design mini-roundabout was constructed at a busy and dangerous intersection in Bel Air, MD (Figure 1). In April 2013, another mini-roundabout was installed at a heavily congested all-way-stop-control (AWSC) intersection in Jefferson, GA. Success at these four sites demonstrated the traffic handling capacity of mini-roundabout and generated serious interests in applying this design to solve a host of traffic congestion and safety problems at junctions on 2-lane and 3-lane roads. By late 2013, two more FHWA evaluation sites were completed, one in Baltimore, MD near John Hopkins University, and the other in East Atlanta, GA near the library. In 2014, FHWA expects to get commitments from 3 states to implement mini-roundabout design at 4-5 sites that have high traffic demands (over 1,200 vph), higher speeds, and serious congestion and safety problems.

This paper documents the case studies of the mini-roundabouts in Lake Stevens, WA; Bel Air, MD, and Jefferson, GA (sequenced in their time of project completion). At the time of this writing, after period field data collections at the recently completed mini-roundabouts in Baltimore, MD and East Atlanta, GA have been completed, but not fully analyzed. The mini-roundabouts in Baltimore and East Atlanta are all in urban downtown environment, close to traffic signal, and have high pedestrian traffic. A separate paper will be developed in the near future to document their performances.

Intersection Capacity Description

In the literature, the capacity of roundabout is typically expressed as the entering capacity of one approach under the influence of given circulating traffic flow. Approach capacity doesn't directly reflect the intersection capacity. To make it more intuitive, when discussing the capacity of mini-roundabout, we use the concept of intersection capacity, which incorporates the interactions between different approaches. This concept can be related directly to intersection's turning movement counts, and gives the readers a better picture of the range of intersection traffic demands under which practitioners should feel confident to use mini-roundabout design.

Based on our field experience, intersections controlled by AWSC typically start to experience traffic congestion when the all entering traffic demand exceeds 900 vph, and will experience severe traffic congestion when the demand reaches 1100 vph or above. Zhang, et al estimated that a well-designed mini-roundabout can easily handle up to 1600 vph. This paper chronicled the implementation of 4 mini-roundabouts in 3 states. The objectives of these mini-roundabout projects included eliminating traffic congestion, improving safety, and revitalizing commercial district, etc. The problems encountered at these sites are representative and the solutions implemented at these sites provide ready answers to most issues/concerns that may be asked by the public and elected officials when proposing mini-roundabout design for particular locations.

Case Studies

1. Two Mini-roundabouts at Frontier Village Shopping Center in Lake Stevens, WA

Figure 3 shows the satellite view of Frontier Village Center in Lake Stevens, WA. Intersection #1 (Route 9 and Route 204) is a signalized intersection controlled and maintained by WADOT. Intersections #2 (Vernon Rd and N Davis Rd, previously AWSC) and #3 (N Davis Rd and Shopping Center Dr, previously by TWSC) are maintained by the City of Lake Stevens. At this location, Vernon Rd is a frontage road of Route 9. At intersection #1, the existing geometric layout prohibits vehicles exiting the shopping center from 7th PL NE to access the signalized intersection (#1). As such, Intersection #3 literally became the only exit of the entire shopping center. Drivers seeking to access Route 9 or Route 204 must exit the shopping center from intersection #3, be queued up by the TWSC, and then turn left and be queued up again by the AWSC. These two intersections had problems of traffic congestion and drivers disobeying the STOP sign for many years. On average, the two intersections experiences 5.55 crashes per year with driver failing to yield cited as a main reason. The traffic condition deteriorated to the point that the businesses in the shopping center were feared leaving. The City's Department of Public Works (DPW) was asked for many years to do something to improve the traffic condition at these two intersections.

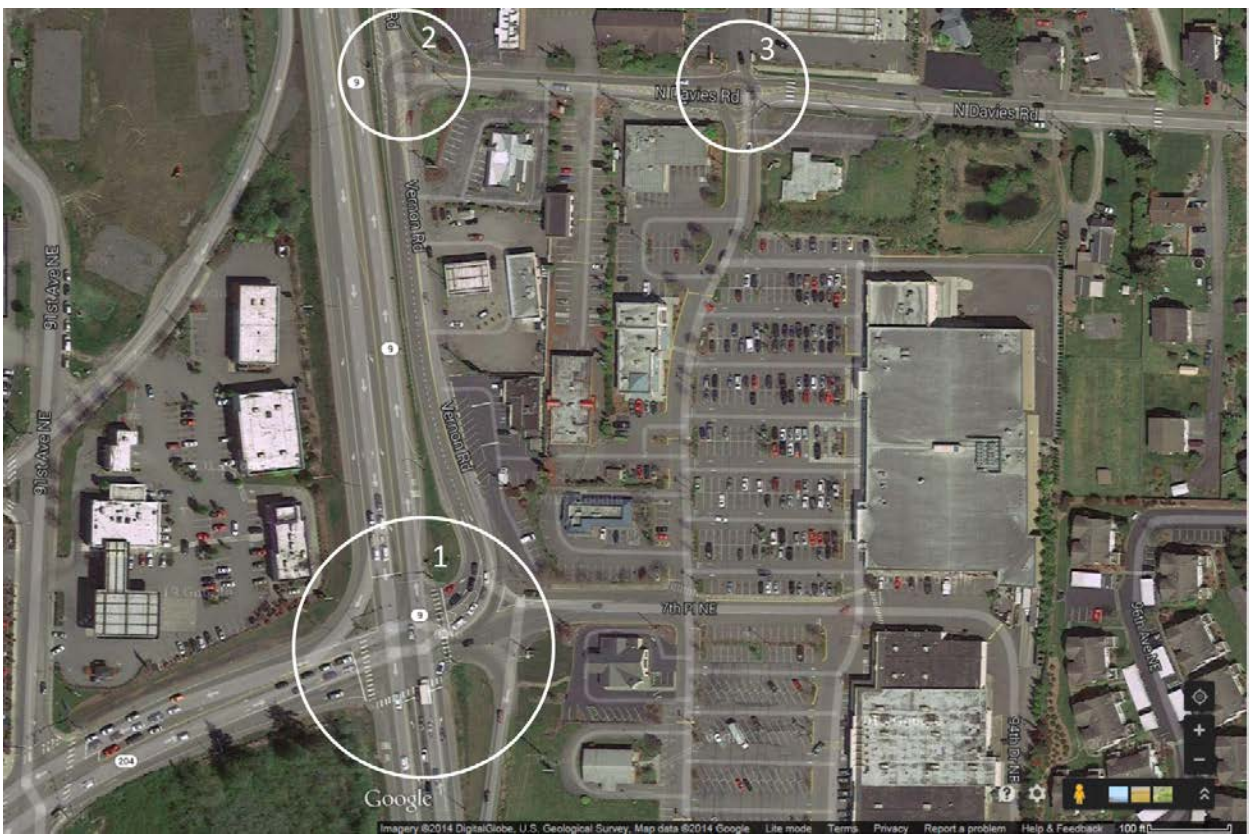

Figure 3. Mini-roundabouts at Vernon Rd & N Davis Rd and N Davis Rd and Shopping Ctr Dr, Lake Stevens, WA

Figure 4 shows the current and future PM peak traffic demands at these two intersections. Each intersection has a gas station nearby. The year 2010 all entering traffic demands were 1141 vph and 985 vhp, respectively. Recurring congestions occurred daily at the two intersections during the PM peak. The city's Public Works Director contacted FHWA researchers in November 2011 about information of mini-roundabouts. At that time, the city had an urgent need to improve these two intersections and revitalize the shopping center, and FHWA had an urgent need to find suitable sites with real congestion and safety problems that couldn't be fixed easily and economically by conventional designs to showcase the mini-roundabout design. The city's capital improvement budget was also very tight. Mutual interests brought FHWA researchers and the City together to find a low cost solution to improve these two intersections.

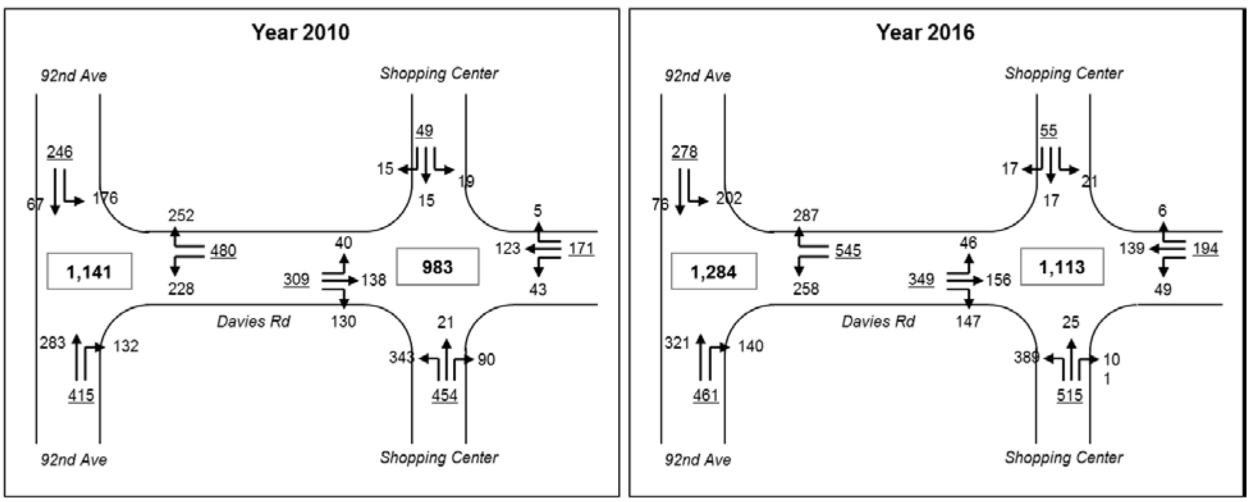

Figure 4. PM Peak traffic demands at Vernon Rd and N Davis Rd, and N Davis Rd and Shopping Center Dr., Lake Stevens, WA

FHWA researchers performed traffic analysis based on the existing (2010) and forecast (2016) peak hour traffic demands and determined that mini-roundabouts would operate at level of service A under both existing and forecast traffic demands. We also conducted emission analyses to estimate the fuel consumptions and emissions of various pollutants under no-build and mini-roundabout scenarios. Snapshots of the traffic conditions and comparisons of fuel consumptions and emissions are shown in Figures 5 and 6, which predicted that congestion would be eliminated and fuel consumption and emissions would be dramatically reduced. FHWA's analyses results and further technical assistance from Gibson Traffic Consultants, a local engineering firm, helped the city's DPW to win funding approval from the city council to test build two mini-roundabouts. The DPW staff worked with the city's fire department to design and test two different curb designs for the central island to ensure the curb would be fully mountable by the fire trucks.

The two mini-roundabouts were constructed in June 2012. For each intersection, the city spent one day to strip the splitter island (contractor work), and one day to install the central island (in-house labor). The cost of each mini-roundabout was about $10,000, excluding the cost of DPW's staff time (estimated at $2,000 per intersection).

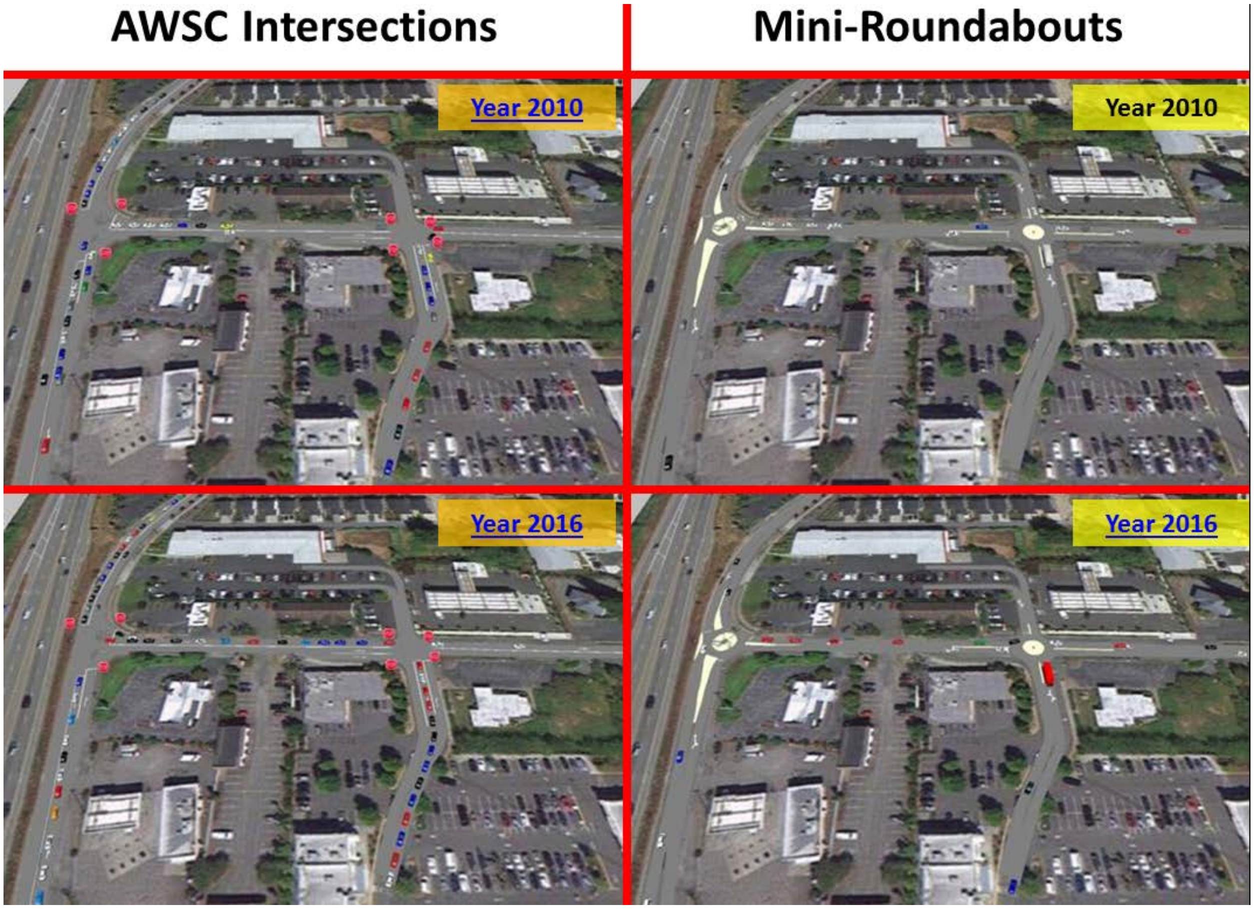

Figure 5. Simulated peak hour traffic condition under no-build and mini-roundabout scenarios

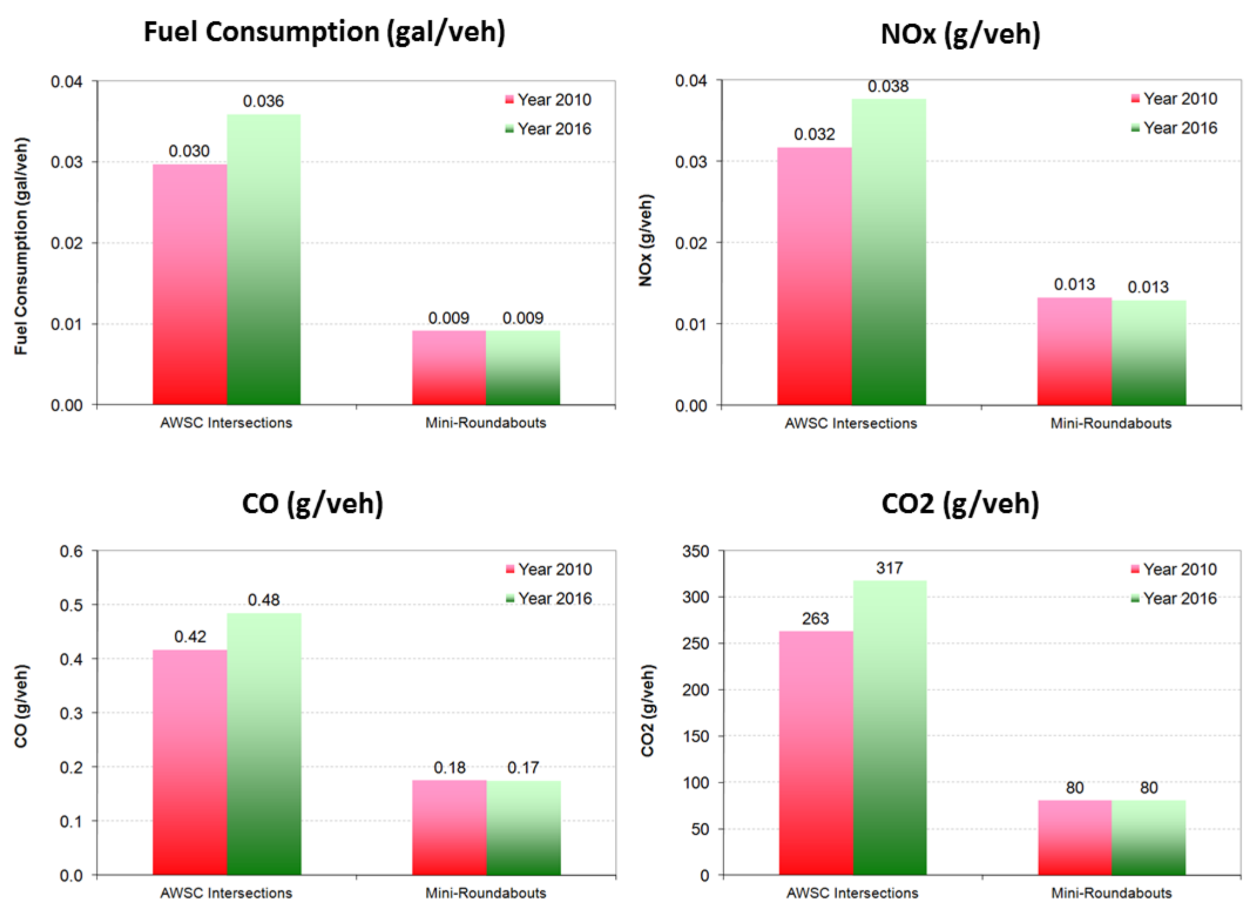

Figure 6. Estimated average fuel consumptions and emissions under no-build and mini-roundabout scenarios

After completion, the two mini-roundabouts eliminated the traffic congestion that used to occur daily during the PM peak. At Intersection 32, (Vernon Rd and N Davis Rd), PM Peak period field video showed that when the intersection was controlled by AWSC, each vehicle arriving at the intersection experienced 10 to 20 seconds delay due to the first come first serve rule of AWSC; after it was converted into a mini-roundabout, most vehicles arriving at the intersection could enter without stopping (particularly the SB approach), which means the intersection control delay has been virtually eliminated. Also, some NB vehicles were observed making U-Turns (easily and effortless from the videos). This means some drivers intending to leave the shopping center to access Route 9 or Route 204, can now exit the shopping center from 7th PL NE, rather than the north exit at Intersection #3, and make a U-Turn back to the signal intersection. This redistribution of exit traffic reduced the NB traffic demand at Intersection #3, (N Davis RD and Shopping Center Dr.), which was the source of congestion (and frustration) that used to block the parking lot of the Safeway Store located just south of Intersection #3.

Anecdotal testimonies suggested the mini-roundabouts performed beyond expectation. Brooke Severns with the Seattle real estate division of Safeway, Inc., said that a manager of the grocery store near the roundabout reported, "There have been absolutely no complaints from our customers, just the opposite; everyone finds the traffic to be moving much smoother in and out of our store parking lot and the surrounding roads." Severns added that “sales at this location had increased. I wouldn't hesitate to say that [the roundabout] contributed to a portion of that increase, I think we would certainly do this in another location after our experience here."

The 6-month sales records from the Safeway Store indicated 10% to 15% increase in sales for 6 consecutive months compared to the before period. Fuel delivery trucks were able to make left-turns by traversing the central island. One un-expected negative outcome was that N Davis Rd was on the bus route of a regional transit company serving multiple cities in the area, and the company has a policy of not permitting its bus drivers to traverse any raised curb. The city didn’t engage the transit company during design phase, and was unable to resolve that issue with the company in time. The transit company ended up changing the bus route.

2. Mini-roundabout in Bel Air, MD

Figure 1 shows the mini-roundabout at S. Tollgate Rd and W. MacPhail Rd in Bel Air, Harford County, MD. Figure 7 shows the satellite view of the mini-roundabout and its nearby properties. At the adjacent intersection to the north sits the county’s first single-lane modern roundabout, which connects to a large shopping center (Home Depot, Target, etc.). One block to the east is a recently expanded hospital. This intersection was controlled by TWSC. The post speed on major road is 25 mph. Before period speed samples indicated that under TWSC condition, 85% of the vehicles on major road went through the intersection at 38 mph. The high speed and high traffic volume on major road created a dangerous condition for minor road drivers and pedestrians to enter the intersection. The intersection had 8 reported traffic crashes between 2008 and 2011, and one fatal incident in 2006.

Figure 7. Satellite view of mini-roundabout at S Tollgate and W MacPhail, Bel Air, MD

Figure 8. Utility pole at NE corner of the intersection of S Tollgate and W MacPhail. (Source Jeff Stratmeyer, Harford County DPW Chief Engineer)

Harford County has over a dozen modern roundabouts, all experienced excellent safety records. The County's DPW staff is capable of designing roundabouts themselves. Their initial answer to the safety problem at intersection of S. Tollgate and W. Macphail was a regular sized single-lane roundabout. That design required enlarging the intersection and relocating a fully loaded utility pole located (Figure 8) on the NE corner of the intersection. After completing the final design and before advertising for bid, the county invited relevant companies to assess the cost of relocating the utility pole. According to Jeff Stratmeyer, Harford County DPW Chief Engineer, the estimated relocation cost was about $400,000, which was too high for the county. The DPW staff went back to work and worked out another solution, which was also a regular size single-lane roundabout. It included the utility pole inside the central island by realigning the north leg. They conducted Internet search and found examples of roundabouts with large poles inside the central island. The revised design was vetoed by Law Department due to safety concern. The project was said to sit on the shelf for 18 months until the DPW staff came across the mini-roundabout concept and the ongoing FHWA field evaluation study of mini-roundabout, which stated that in most cases, mini-roundabouts can fit into the intersection's exist right-of-way. The county's DPW staff eventually produced a mini-roundabout design that possessed most of the desirable features of a conforming mini-roundabout. The detail design is shown in Figure 9, it has an ICD of 67 ft., raised central island and splitter islands, raised bulb-out curb, and pedestrian cross walk on each approach.

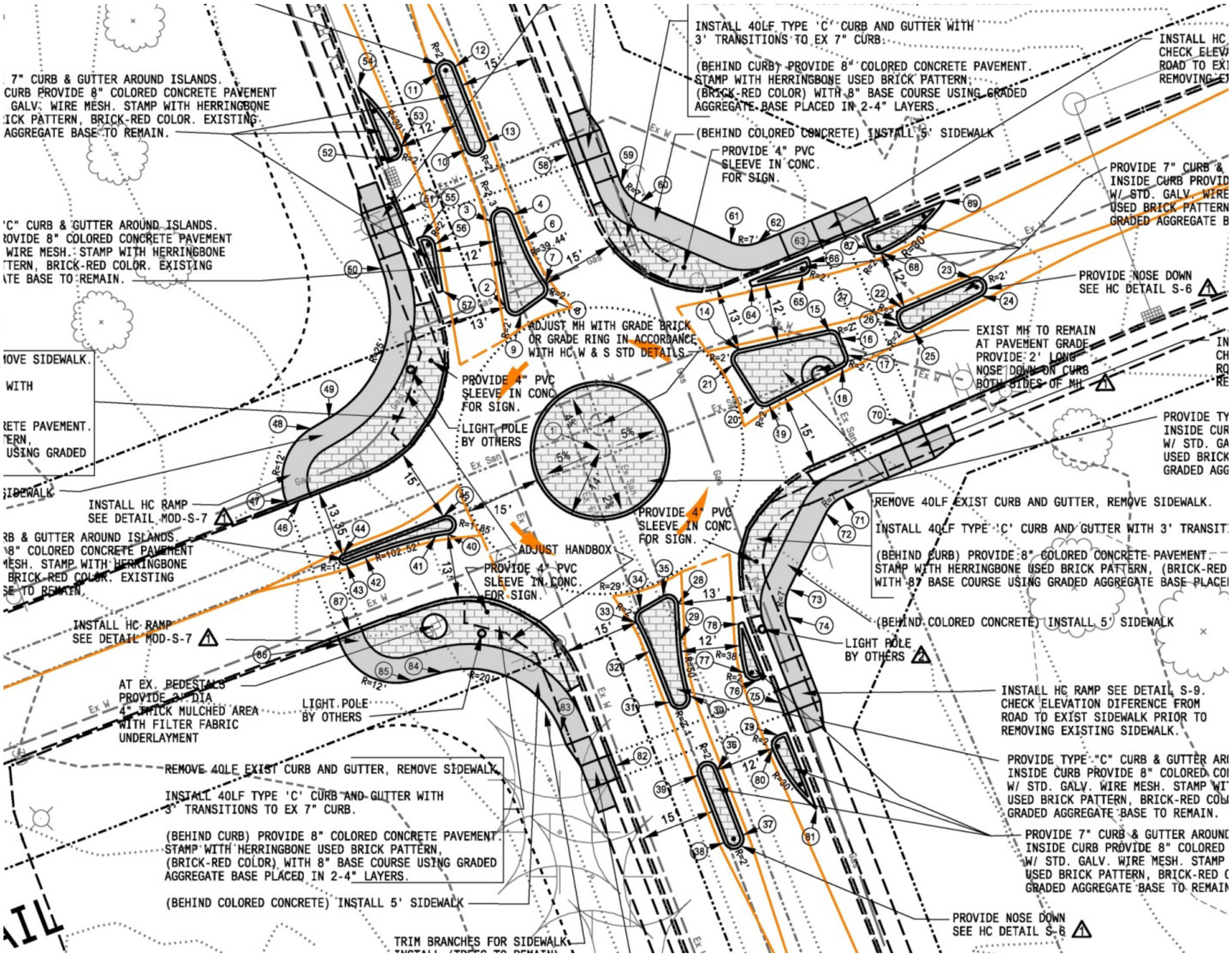

Figure 9. Detail design of the mini-roundabout at S Tollgate and W Macphail, Bel Air, MD (Source, Jeff Stratmeyer)

The mini-roundabout shown in Figure 1 is the completed product. The construction took 3 weeks and was finished in August 2012 before the start of public schools. The county paid about $175,000 including the installation of 3 LED lights at the intersection.

After completion, the mini-roundabout has been performing well. A local citizen wrote to the local newspaper expressing her appreciation to the DPW staff, said she found it much safer and easier to enter the intersection after the TWSC was converted into mini-roundabout. Figure 10 shows the speed distributions collected by FHWA research team. The speed sensors (Hi-Star) were installed at locations 100 ft from the entrance. One can see from Figure 10 that at speed sensor locations, the speeds of 90% of the vehicles were reduced to 25 mph (compare to 38 mph on major road in before condition). In their last 100 ft to the entrance, their speeds would be further reduced to 15 mph. The field video showed the brake lights of virtually every vehicle were on after passing the speed sensor location, indicating drivers were reducing speeds during the last 100 ft to the entrance. Many meaningful traffic scenes were recorded from this site, including vehicle safely yielding to pedestrian and left turns by large truck, school bus, and ambulance at the intersection, as shown in Figure 11.

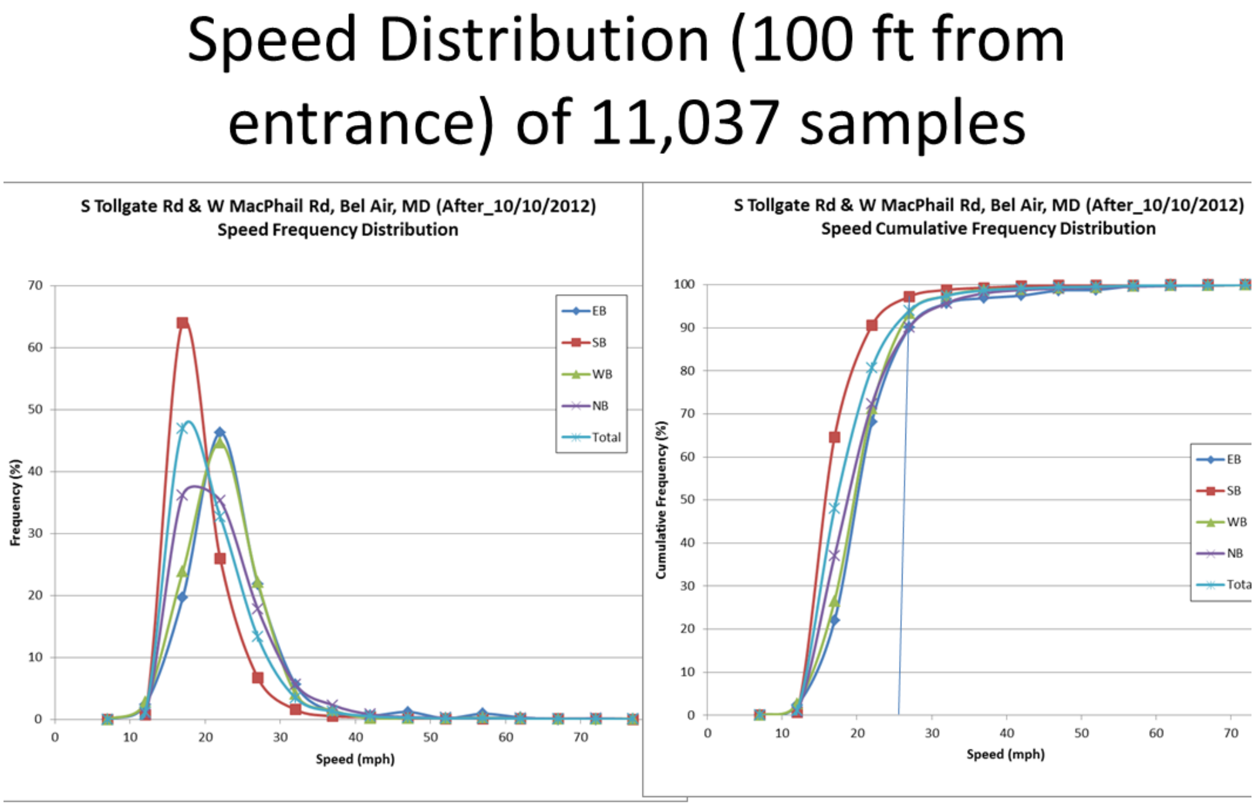

Figure 10. Vehicles approaching speed distribution at mini-roundabout at S Tollgate and W MacPhail, Bel Air, MD

The field measured peak hour traffic count was 1158 vph (PM Peak). Youtube field videos of this site can be viewed through the following link:

https://www.youtube.com/watch?v=3KLbr1awEbk&feature=youtube_gdata_player

Figure 11. Traffic scenes observed (vehicles yield to pedestrian, left turn by truck, school bus, and ambulance).

3. Mini-roundabout in Jefferson, GA

Figure 12 shows the satellite view of the intersection of Winder Hwy, or State Route 11 (SR 11) and Galilee Church Rd, or SR 124, in Jefferson, GA. The intersection was controlled by AWSC. There is an Exxon gas station at the SW quadrant. Both roads are state routes with post speed of 55 mph. This is not a typical location that one would recommend a mini-roundabout design. However, comparing to the existing AWSC, which required vehicles to reduce speed from 55 mph to 0 mph, the magnitude of speed reduction required by a mini-roundabout, from 55 mph to 15 mph, is less dramatic. According to Scott Zehngraff, the then GADOT District Traffic Engineer, the mini-roundabout project started like this: one afternoon the GADOT District Engineer drove through this intersection and observed a roughly 50-car queue (about 1250 ft, or one quarter mile) on the WB approach. This turned out to be a recurring congestion during the PM peak. The District Engineer demanded the traffic engineering staff to do something to fix the problem. Scott and his staff performed internal traffic study and determined a mini-roundabout would be able to handle the traffic demand. They presented the idea to the city's mayor, and secured the city's endorsement. They then developed the detail design and used GADOT district maintain crew to construct the mini-roundabout.

Figure 13 shows the construction scenes of transforming the intersection from AWSC into a mini-roundabout. The finished mini-roundabout has an ICD of 90 ft. According to Scott's account, the engineering design took 4 days, construction took 9 days (actually 7.5 days), and the project was completed in 7.5 weeks after receiving request from the GADOT District Engineer. The total project cost was $63,353, including $3,510 for curbing, $19,490 for labor, $9,897 for equipment, and $40,474 for material.

Figure 12. Satellite view of Winder Hwy (State Route 11) and Galilee Church Rd (State Route 124), Jefferson, GA

This mini-roundabout eliminated the quarter mile long queue that used to form on the WB approach during PM peak. The reason why AWSC caused such bad congestion and mini-roundabout delivered such a dramatic operational improvement at this intersection can be explained by observing the peak hour traffic demand patterns shown in Figure 14. One can see the all entering traffic demand was 1247 vph during morning peak; and 1037 vph during afternoon peak. In the morning, traffic demands from EB, SB, and WB approaches were evenly distributed (393 vph, 371, vph, and 420 vph), but in the afternoon, traffic demands from WB approach (535 vph) far exceeded traffic demands from EB (271 vph) and SB (195 vph) approaches. Demand from NB approach was always low (63 vph during AM peak, and 36 vph during PM peak). When the intersection was controlled by AWSC, which provides true equal access of right-of-way to all approaches, due to the first come first serve rule, vehicles arriving from any approach would increase the intersection control delay of all other approaches. When the intersecting roads both have high speeds and no capacity constrain along its way, vehicles will arrive at the AWSC intersection faster and queue up longer. This is why AWSC caused such bad congestions and longer queue on the WB approach during the PM peak even though the total traffic demand during PM peak was lower than AM peak. After the intersection was converted into a mini-roundabout, which provides equal access of gap to all approaches, the conflicts faced by WB approach in the circulating lane (come from EB left turn and SB through and left turn) become very low (32 vph during AM peak, and 31 vph during PM peak), which provides plenty of gaps for the WB traffic to enter the intersection (refer to the roundabout entrance capacity chart shown in NCHRP 672).

The field measured daily traffic count at this intersection was 10809 vpd. From the over 10,000 speed samples collected on all approaches, 90% were travelling at 30 mph or less at 100 ft upstream of the intersection. Judging from the brake lights visible in the field video, almost all drivers were seen to continue decelerating during the last 100 ft to the intersection. The visibility of the curbs may not be ideal at night, which can cause some drivers to approach the intersection at high speed under low light condition. This problem can be mitigated by using lighted material to delineate the approach curbs and central island curb. FHWA researchers are aware of several products (retro reflective pavement markers and lighted bollards) that can enhance the visibility of splitter islands and central island curbs.

This intersection used to experience 7 to 8 crashes (including 2-3 injury crashes) per year under AWSC, during the 1-year of mini-roundabout operation, the total number of crashes was 7, but there were all property damage only crashes. In other word, the severity of crashes was reduced.

Figure 13. Before, during construction, and after states of the mini-roundabout at SR 11 and SR 124, Jefferson, GA

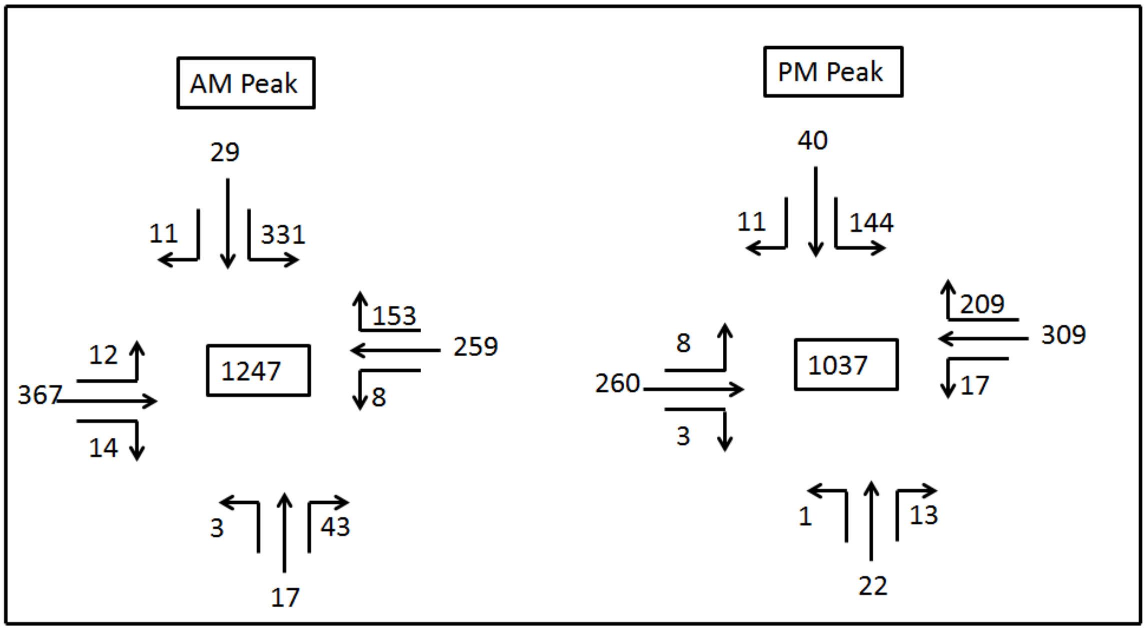

Figure 14. Field measured peak hour traffic counts at SR 11 and SR 124, Jefferson, GA

Discussions

Each of the four mini-roundabouts described above delivered dramatic improvements in operation and safety after project completion. The problems solved include eliminating traffic congestion at previous AWSC intersections, providing more gaps and improving safety for minor road drivers and pedestrians at previous TWSC, and revitalizing a shopping center. For Bel Air mini-roundabout, even though the county had the budget to construct a full size roundabout, the excessive potential cost of relocating the utility pole forced the county to settle with a lite version design, a mini-roundabout, which performed equally well but cost only a fraction of a regular sized single-lane roundabout. The objectives of other FHWA mini-roundabout evaluation sites included making the intersection safer to encourage school children to walk to school, beautifying the intersection to preserving the values of nearby properties, and consolidating traffic flow of complex intersections, etc. The field videos and traffic data collected from these evaluation sites provide convincing evidences of the superior traffic handling capacity of the mini-roundabout design, and the types of the operational and safety problems that can be successfully addressed by mini-roundabout. They also provide ready answers to most of the questions and concerns that the general public and elected officials may ask when considering mini-roundabout design for specific intersections.

Conclusions

At intersections on 2-lane and 3-lane road, when the traffic demand exceeds 950 vph (estimate), stop controlled intersections will start experiencing operational and safety challenges, under such circumstance, mini-roundabout design can be considered for solve the following types of problems:

1. Eliminate traffic congestion at AWSC intersection

2. Provide more gaps to minor road drivers at TWSC intersections.
3. Improve safety for pedestrian traffic
4. Revitalize commercial district
5. Avoid the need of relocating utility poles and storm drains

Acknowledgement:

The authors wish to thank the following individuals for their collaboration in advancing mini-roundabout implementations:

Mick Monken, P.E., Director of Public Works, City of Lake Stevens, WA, for advocating the mini-roundabout design in his city, and working with the private sector to develop innovative curbing designs for use on the central island and splitter island.

Jeff Stratmeyer, Chief Engineer, Department of Public Works, Harford County, MD, for promoting the mini-roundabout design by giving presentations at various conferences, and answering inquiries from different qgencies.

Scott Zehngraff, P.E., Assistant State Traffic Engineer, GADOT, for promoting and implementing mini-roundabout design in Georgia.

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