Appendix

Process Notes

Community Workshop

Thursday, May 31, 2007 6 – 8 pm

Visioning Exercise

Participants were asked to write on a 3 x 5 card how they would like highways 70/20 to be in twenty years. Their written comments were:

- Better economic development while still maintaining all the historic buildings and structures
- To be safer and more accessible for people with disabilities
- Marysville: Walkable community that serves as a regional destination where folks can safely enjoy and admire the area and be entertained with live/work situations
- Crosswalks with "chirping" signals for the blind. Bike paths, pedestrian paths. Safe paths of travel for people with disabilities and those who don't drive. Turn outs for bus stops.
- D Street as a pedestrian mall; "complete streets", connected system of bikeways within and without region; retain charm, history, and identity; Human scale; Bikeway over Yuba (Hwy 70); Mixed use
- More residential infill; downtown becoming a "destination," a self contained walkable community; Arts, entertainment, unique shops
- Pedestrian-oriented area with an eclectic mix of shops, dining and entertainment businesses; Drawn from the surrounding residential areas south and west of Marysville and the highway traffic.
- Pedestrian-friendly access to downtown areas; freedom from fear of vehicles; aesthetically pleasing; shaded walkways
- Small business mecca; lots of trees and history
- Well designed gateway into town; tree lined; slower traffic flow; people biking on the street safely – much more community-oriented – not car-oriented
- Yuba River parkway+eastern bypass; 3rd river crossing – south of Marysville; 4th river crossing – north of Marysville
- Vibrant, niche, commercial, business, and residential center devoid of gravel trucks
- 6 lanes on E Street or Maysville bypass and third bridge; more trees

The audience created a list of priorities, then "voted" on their top choices:

Trees	11
Crossings: 9th & D, E Street (all)	10
Pedestrian buffers	10
Fix sidewalks	9
Preserve historic buildings	8
Gateways: 3rd & E; 9th & D	8
Public Art	5
Wayfinding signs	5
Medians on E Street	5
Bike Lanes	5
Enhance Highway 20 Entry	5
Historic look for lighting	4
Highway 70 Tunnel: improve aesthetics	4

Saturday Design Workshop and Walk Audit

Saturday, June 2, 2007

Participants worked in groups to suggest improvements to the study area. The results are summarized below.

Group 1

Ninth Street

- Bulb outs at D Street to shorten side street crossing
- Wayfinding signs on bulb outs
- Clean up next to lake where slope is too steep
- Put in two green buffers on Carl's Junior side - one buffer between parking and sidewalk, and the other between the travel lane and the sidewalk
- On C and 9th, implement a two stage crosswalk. Add flashing warning lights.

E Street

- Keep 4 lanes; incorporate greenscape in center median and along pedestrian walk; put brick in furniture area; take away some parking to include some extra trees between parking bays.
- Define parking along E Street. Keeping parking allows us to incorporate the bump outs, which shorten ped crossings

Other

- Directional signs at key points
- Gateways over key city streets: 3rd, 5th, D both ends
- Signage as you come over the bridge
- Advance markings before crosswalks

They looked at B Street. At 18th near the train crossing there is a pedestrian crosswalk that needs improvement. It is used by the high school. Nearby charter school uses buildings for class; high school kids cross.

Group 2

Built scenario to get rid of on-street parking, 72' curb to curb, 2 lanes each way, continuous two-way or left-turn pocket; islands at intersection; that gained 14 feet on edges, so we looked at putting ; eliminated parking; added buffer tree wells with raised planter to separate from the roadway.

E Street

- Remove median lighting; move lighting to edges of streets; make it similar to the historic lighting that lights both the highway and pedestrian walkways
- Provide 14' pedestrian zone both sides, shoulders, 5 – twelve foot lanes
- Vegetation from 3rd to 9th
- Option 1 buffer: green edges with tree wells
- Option 2 buffer: Raised planers w/integrated benches, trees w/surface grate
- High visibility crosswalks
- Gateway – levee is an opportunity; the drop as you enter off the bridge creates an opportunity for a gateway
- Shoulders

Other

- Double right at 9th and B with signal
- Mid-block crossing refuge in wider intersections
- Playground on island where gazebo is.
- Off 20, visual cue about entering different environment
- Pigmented bike lanes
- Reroute westbound trucks on highway 20 to 14th and E Street

Closing Community Workshop

Wednesday, June 6, 2007

- I like the idea of using colored shoulders
- I like the idea of curb extensions
- An island at the intersection of 9th and E Streets could still be a problem for pedestrians
- For the 2-stage crossing recommended at 9th and C Streets, Check to make sure that's the right location. Make sure it is oriented properly for origins and destinations.
- Personally I don't like roundabouts, but they still work. How do we deal with things like drifters and street racers?
- At 9th and D Streets, for westbound cars will often block the crossing currently there. Also, the timing for pedestrians to cross is too short.
- Who will pay for the maintenance of any improvements?
- Look at one-way versus two-way streets.
- Is there a process for doing quick improvements? Especially with Caltrans?
- Did you look at re-routing trucks around Marysville?
- How about moving Route 20 north of Ellis Lake?
- How about using countdown signals?

Focus Groups

Highlights below include the facilitator question in italics, with bulleted responses from participants.

Thursday, May 31, 2007

Regional Agencies
City Hall, Covillaud Room
10:00 – 11:30 am

Attendees:

- Greg Chew, SACOG
- Keith Martin, Yuba-Sutter Transit
- Jackie Slade,Yuba-Sutter Economic Development Corp.
- John Fleming, Yuba County Economic Development
- Kevin Malley, Yuba County Planning Department

The meeting opened with an overview of the downtown strategic plan that was developed with the help of citizen input two years ago. The downtown is a jewel with great fabric and many amenities. The plan identified ways to revitalize downtown. It looked at the residential market to revitalize area. It identified six catalytic sites; one has already happened, Vicks-Worley. Working on retail but with residential leading. Levees, trail systems, specialty retail.

What issues are most important to address?

- Improving E Street, which is a barrier between residential neighborhoods and downtown.
- Would like to see more green, walkable space. City planned as center of region 150 years ago. Now outskirts are larger than the City and have taken over. How do you keep outskirts connected to Marysville? Lot of traffic from Hwy 20. There have been dreams of a bypass for many years.
- Traffic issues are more than just congestion. Newspaper has ranked Marysville as one of the worst from a traffic standpoint. Now identified as #6 statewide. There are more issues than just traffic movement. Pedestrian, signage and other issues; Marysville ranks as one of 10 worst for traffic issues. Traffic incidents.
- Red light cameras are considered for safety issues. Adding 3 cameras. People staying away from them. Not clear if cameras are doing what you want to help control traffic.
- Issues include the time it takes to get through intersection with delays due to fender benders, crashes, etc.
- If we want to create pedestrian-friendly environment need to look at why Marysville is ranked so high for bad traffic.
- Most traffic just trying to get through town, from Linda to Yuba City. As traffic gets worse you start seeing drivers cut through side streets.
- Do you make it easier for cars to get through or do you keep it a place for people to stop? Eliminate left lanes.
- Traffic congestion is relative. Folks from other areas don't consider it an issue. Locals stay away from downtown, concerned over parking. From a transit perspective the delays are a problem. Most of riders are folks without cars. Lot of non-home work trips.
- 14th is a very busy route but it is the way folks cut through to neighborhoods to west. Folks choose routes based on how many stop signs, etc.

- Now we cram as many people through Marysville as possible and capture some of that traffic in the downtown. That's self-defeating. Might be better to create a more desirable downtown that locals would use. Looking at a Marysville bypass that would relieve truck traffic coming from aggregate, 20, 65 & 70. It would create more free traffic easterly and north/south, avoiding congestion in Marysville. Difficulty with this scenario is it will take 10 years before that could happen. From an economic development standpoint if we want to preserve historic atmosphere downtown, we need to get as much of truck traffic out of the flow of traffic through downtown as possible. Explore ways to make this section a non-truck traffic area.
- There are no alternative routes. Looking at a bypass, maybe not as extensive as originally considered. Would need Caltrans to provide alternate route. County road to east. Are going through project study report for that. It's as real as development in south end of Yuba County because that's how they would be paid. With current development in South County even with bypass there will be more volume through Marysville than today after the bypass is complete.
- Suggest fewer pedestrian crossing locations with more visibility. Right now so many places for folks to cross have made it more of a challenge. More ped friendly crossings.
- E Street and 9th captured about 40% of sales tax revenue for downtown. Auto-oriented, marginal uses, but still brings in significant dollars.
- Proposed bypass is a 4 mile route with 6 intersections, max. Question is whether trucks will choose that option.
- Truck traffic is coming from one direction and cars from another, and all end up on E Street. At 9th & E, trucks continue to go on red lights, which is very tough for peds. Multiple crossings might be an issue. Population of Marysville is only 13,000. That's not enough peple to make downtown work.
- Lot of potential for residential in downtown. Especially east of C Street.
- New development on 9th Street. Café, strip development. Seems to be busy. Hard to find parking space. Only Starbucks in town. Same developer looking at development at 10th and E. Plaza of old Marysville that has become state highway.
- Impact fees, 12,000 for traffic. Caltrans has washed its hands of the bypass. Are selling right of way if bypass is too far out into the future. Widening of 5th Street Bridge might relieve some of the through-traffic.
- Caltrans proposed several years ago that Marysville close every other intersection to cars, not peds. Lots of fatalities. Right now no reason to walk on E Street.
- Residential project on NW of lake blocks views to lake. The new Waterfront Plaza project turns back on lake. Desperation to get development.
- Walgreens another example where there is not a single tree in parking lot.
- Some Chinatown buildings have a lot of potential.
- D Street might be key area.
- Where to focus crossings of pedestrians.
- Hotel project at 5th. 3rd is other key east/west intersection.
- Move Highway 70 east of lake and then open up lake to development.
- First phase of bypass is in 1st tier of Metropolitan Transportation Plan project. Second phase of bypass is in second tier.
- If we turn our back on E Street, then what do you do with great buildings? A parking garage can support other development on E St. SACOG has given $2 million for garage. Would be done as condos with retail on ground floor. Short term stay apartments as well. Senior housing, market rate condos.
- Character of E Street vs. D Street. D is the main street and E is more of the state highway.
- D Street used to be E Street. Wanted both to be main street. Bridge got washed out and shifted it over. E was always stepchild. Always had auto-oriented uses. Ford dealer used to be there. Tire stores. Furniture. Absentee landlords. Very small parcels, very deep, narrow lots.
- Was street always that way? Used to have grassy median. Used to be only two lanes. Had diagonal parking.
- Site of Sutter memorial museum, Chamber of Commerce. Union Lumber.
- Hard to visualize how to make it more walkable.
- Big problem: trucks. 9th Street, trucks shift over.

Friday, June 1, 2007

Business Improvement District Continental Breakfast
The Brick Coffee House Café
7:30 – 9 :00 am

Attendees:
- James and Kara David, Amicus Books
- Ethel and Bill Padgett, Candy Box
- Nancy Duplantis, Posh Décor
- Julie Shackleford, Gold Country Bank

Michael Ronkin opened the meeting by explaining this project focuses on the impact of highway 70 and 20, and how they can become more walkable. He explained this is an opportunity to energize E Street to become a part of the downtown. There are also ways to bring the traffic in, which is so important to the business community. Making it easier to get around without a car.

Mukul provided an overview of the development of the strategic downtown plan. The conclusions included recommended heritage tourism, residential development and strategies to revitalize the downtown. Part of the process helped identify strategic sites, including the theaters. Some improvements have already begun.

What is working for you downtown?
- Storefronts are starting to fill, creating foot traffic. There is nothing to entice you to turn off E Street, so nearby businesses are important. The bank would like to assist with the funding. We have alliance group that does that type of funding. We have 40 people in the building who need to park.
- We agree. Stores fill and so does the parking. Get some business from Caltrans personnel who are walking around during lunch. We need more foot traffic.
- Nancy pointed out new residents benefit her home décor business.
- What works for us is the book store draws people. We need the arts center to draw people. We need more of that. We have had an established business since 1964.
- I agree. Also, the positive businesses nearby let us build on each other. Word of mouth is starting to happen. A new brochure with a map that pinpoints the businesses and points of interest. It is a beautiful place to walk. Parking needs to be addressed.
- City has a parking study, which says there is more of a management issue.
- The marketing plan done two years ago is working for us. Our purpose is to build recognition for literary arts and the possibility of expressing yourself in writing. We were invited here, loved the building, we saw the possibilities. We started projects like the downtown Chautauqua. We started downtown walking tours, which has helped bring people's consciousness to the history of the city, which builds pride. We are walkers; we would like to ride a bike, but it is too dangerous to ride a bike. Crossing E Street to the bank is harrowing. We see the power of building a walking plan in the downtown. When you connect walkability to the downtown marketing plan it is very powerful.
- Although downtown is a commercial district, we see it as the central district. It holds the character of the city. Our business is more of building community than anything else. We create events so people in the community can be included.

What is your anchor? Does Mervyn's anchor downtown?

- People go to Mervyns, then leave downtown. It doesn't draw people into downtown.
- Posh Décor helped create a flow; there is no one anchor.

We are looking primarily at how we can improve walking conditions up and down E Street.
What do you see as the major negatives that need to be addressed?

- It is difficult to find the downtown. There are no directional signs. If you are walking it is hard to find.
- You left out a major portion of new development. Chinatown is rebuilding. It is a tiny little hotspot. People aren't aware of it happening, but people in San Francisco and LA are becoming more and more aware of the revitalization that is going on there.
- Getting across E Street is a problem. If you've been to Spokane, they have walkovers. Perhaps there could be occasional walkovers, say from the lake. Along D Street, starting at 9th, the sidewalks are atrocious. You have to know those sidewalks to walk there. In terms of bicycling, forget it. It is very dangerous in the downtown area. People use the sidewalks; that has become a safety issue. (conflicts with pedestrians)
- The hospital is planning an expansion. It generates walking traffic.
- Towns I've visited had directional signs that show walking routes. I find even in cities like San Francisco there is not enough parking, so traffic is going around and around, so it is dangerous to walk. You have to have a place for people to park. We have brochures that show stores, but we don't have a walking route that will help them feel safer. Just for the people who work here.
- One of the biggest problems in downtown is it shuts down at 6 o'clock.
- Mini strip too hard to get into.
- No lighting downtown. We walk people leaving our business to their cars in the evening. D street is fine; it is the side street.
- There isn't anything to draw anyone's attention. There is no beautification on E Street. It looks like a ghost town. Except by Bank of America it is void of green. Some buildings are eyesores.
- I believe E Street is what is hurting downtown Marysville. Driving through, I would not be tempted to venture off the E Street. It must feel inviting.

What kind of businesses do you think would work on E Street?

- We need more retail specialty shops.
- The beautification is what it takes to get the people there.
- You have to think about the parking issue.
- The loudness of the noise, the smell of the diesel fuel, I have trouble imagining any business that would attract people. It is hard to imagine. Part of the issue is not just walkability, but what the traffic does. A friend rides his bike from Yuba City to Yuba College. He cites the diesel fumes as the biggest danger.
- I could see a travel agent there. That would bring people. Might be able to have a small café. Maybe some kind of a computer store. Actual destinations, not random.
- We're about community. You want to catch someone's attention so people want to go further. Spokane uses public art to draw people into the city. When we travel what we see on the main street is what determines whether or not we get off.

Some cities adopt a theme. What is the first thing people see now? What theme would work?

- The arches. People have talked about putting more arches on E Street. We want people coming in to see there is no other place like Marysville. The arches seem to be a positive attraction.
- Plants or trees, water.
- Bricks. I think of it as a brick city.

- Brick art.
- Brick podium with lights on top. Brick is amazing. We have it indoors. Marysville was once called the brick city. Using brick in flower boxes or whatever. Brick as a line to follow on a walking tour.
- Bricks in sidewalk, bricks in crosswalks.
- C and 2nd, there is a big brick intersection.
- There is no calm when you come over any of the bridges.
- On D Street they have the poles with flags.

Where do your customers come from?

- Chico, San Francisco, Oroville.

Where are your competitors?

- Yuba City. People act like they have to swim across the bridge.
- They come to us for the personal one-on-one service. We know everyone who walks in the bank.
- We are trying to build a concept of the Brick City, but the developers come in and do horrible designs that don't blend into our concept. We would like to see those businesses "brick it up." We would like to incorporate the existing businesses, even if they just add a large brick flower bed.
- Michael explained the idea of form based code.
- We are reactive now. We don't have design guidelines and don't have the funds to develop them now. Form based can be very expensive.
- We can't buy into worrying about internal competition; every new business helps us.
- The concept we are hearing is they want to bring in people with sliding scale rents. These don't help us. We need people who can afford to live in downtown and enjoy the comfort of urban life. I don't understand the concept of low income housing downtown.
- We need a mix of housing, not just low income.

What would entice businesses to move into downtown Marysville?

- Downtown, retail. On edges, doctor offices and services like travel agents.
- A Whole Foods would be good.
- We are looking at marketing B Street property across from the lake. What do we want there? B Street markets to a different clientele.
- We have a high end market in the foothills.
- Every time we put a big business across the lake we ruin the opportunities.
- I would do a gorgeous hotel; beautiful restaurants. The view at the lake is cars and trucks. The beauty it was intended to bring is being etched away with the kind of commercial that is there.
- Smaller scale grocers. Trader Joes.
- There was a pivotal thing that destroyed hope in downtown. The day the RentaCenter went in with the huge signs we walked away.
- If we had a vision of what we would like our city to look like it would help.
- We have a school in our downtown; it is not very walkable.
- There is a massive residential buildup occurring south of town in county area. Plumas Lake, Earl Road, McGowan Road. Nearby residents are asking us to stay open later.

Emergency Responders
City Hall, Covillaud Room
10:00 – 11:00 am

Attendees:

- Jack Beecham, Police Chef
- Joe Hernandez, City Fire Chief
- Aaron Ward, Director, Office of Emergency Services, Yuba County

What issues do you see from your perspective?

- Red light running was worse before the red light cameras were installed. Driving habits have been influenced. They have been a significant help.
- We get gridlock on a regular basis and use the side streets instead.
- Any corridor changes that restrict access across the street are a problem because the hydrants are on one side of the street. So a median design is a problem because we can't drive around and put hose down. Hydrants on both sides would mitigate that problem.
- Yuba City has an Opticom system; Marysville providers weren't able to be part of that grant. They have a switch to operate signals at B and 10th, but it doesn't work well. They would like to be able to have priority at intersections to be able to preempt when crossing E.
- If you add medians, we cannot pass in the middle. Traffic can't pull off to the right, so we can't go down that road. Access is number one concern.
- Cameras are at G, 3rd, 5th. They have slowed people down.
- They also use 14th; wide enough and less congestion.
- Emergency providers have issues during construction.
- Truck traffic is going down side streets including residential.
- A pothole on 10th Street bridge caused one lane to close. It gridlocked the town. I waited 15 minutes.
- We had 180,000 cars a day in 2003. A bypass would solve the problem, but the city might dry up. Most vehicles are going through. We had an OTS grant that funded traffic enforcement; we dropped crashes substantially.
- The problems are deeper than that…this is a poor county. When the grants run out you cut back. I may have to cut traffic officers this year, which is likely to result in increased injury accidents. Whatever could be done in engineering to help would be good.

What kind of injuries are occurring?

- Bicyclists, auto occupants. Both fatalities last year were bicyclists.
- On Highway 70 heading toward Butte I've noticed a reduction in crashes. I attribute it to the halo affect from the red like camera. Highway 70 north of town is very dangerous.
- Truck traffic is a huge issue. There is no place for them to stop, so they just pass through. We've had a couple of cases where we've had major accidents and everything gridlocks. There's been talk of another bridge, and a bypass, for thirty years. I don't see that happening. You are dealing with a depressed area here. If they do anything here it is a result of grants or outside help. But there are developers interested now because of the growth. Schools Focus Group
- Michelle Healy, Senior facilities planner for School District provided information about Covillaud School, which is located near the downtown area. The District has a master plan and is currently renovating buildings. Covillaud is getting a new two story addition.
- Covillaud School; not sure about travel to school or after school programs.
- School does not have facilities used by the community.

- Many parents transport their kids to and from school. There is a lot of chaos when parents drop off and pick up their children. 2:30 release; 8:00 or so start time.
- All of downtown is very business oriented. Very few residences.
- Enrollment is increasing, although more slowly at Covillaud than other schools.
- If you cross the river to Yuba City, there is commercial growth, which generates more tax revenue than property tax. Tax base isn't there to support it [increased enforcement]. We lose the OTS positions in September, plus another two positions will be lost.
- Fire responders are located on 9th near B.
- Caltrans interested in red light program.
- The blocking of the intersections is another problem. We've stepped up enforcement of those, but one judge throws those tickets out. Enforcement seems to make it drop off, but it comes back.
- Emergency service's concern is to support fire and police department needs. Our issues are consistent with those already mentioned. In an evacuation situation (flooding) highway 20, Simpson Lane, and Highway 70 are the only ways to get out of Marysville. Doing that while bringing people in is our concern. Maintain intersection access for purposes of moving people out of here as quickly as possible.
- We have a transient population near the river.
- The lake purpose is flood drainage runoff; occasionally city buys water so they can run new water into the lake; then the water is clear. Only 10 feet deep; not a desirable place to recreate.

Have you considered walking as part of your evacuation plan?

- Yes, we have considered walking to transit locations as part of the plan.
- The size of the incident makes a difference. Very few incidents where everyone has to be evacuated at the same time. We have levels of evacuation.

Schools
City Hall, Covillaud Room
3:00 –4:00 pm

Attendee:

- Michal Healy, MJUSD, Senior Facilities Planner

- Covillaud School, which is located near the downtown area. The District has a master plan and is currently renovating buildings. Covillaud is getting a new two story addition; not sure about travel to school or after school programs.
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Street tree palette

TREES

Canopy Trees

Botanical Name	Common Name
Platanus acerifolia	London Plane 'Yarwood'
Quercus lobata	Valley Oak
Quercus wislizenii	Interior Live Oak
Pinus attenuata	Knobcone Pine

Secondary Trees

Botanical Name	Common Name
Acer freemanii	Maple 'Autumn Blaze'
Liriodendron tulipifera	Tulip Tree
Platanus racemosa	California Sycamore
Ulmus wilsoniana	Prospector Elm
Zelkova serrata	Sawleaf Zelkova

Ornamental Trees

Botanical Name	Common Name
Cercis canandensis	Eastern Redbud
Cercis occidentalis	Western Redbud
Lagerstoemia indica	Crepe Myrtle
Malus (various disease resistant species, 15' dia max)	Crabapple
Prunus dulcis	Almond Tree

The above tree list is provided to suggest the scale and character that might be appropriate for planting along State Routes 70/20 in Marysville, and should not be considered an exhaustive list. They are trees typically considered for street settings and the environment found in Marysville. However, final selection should be made by a landscape architect and arborist after careful consideration of soils, drainage, specific location, and other design factors and by consulting Section 500 of the Manual for Encroachment Permits on California State Highways, Caltrans.

Effectiveness of Additional Lanes at Signalized Intersections

IN THIS FEATURE, THE AUTHORS EXPLORE WHETHER INCREASING THE NUMBER OF LANES AT SIGNALIZED INTERSECTIONS COULD BE A SUSTAINABLE APPROACH TO SATISFY TRAFFIC DEMAND ONLY IF LARGER INTERSECTIONS HAD ECONOMIES OF SCALE, OR AT LEAST DID NOT HAVE DISECONOMIES OF SCALE.

BY KORNEL MUCSI AND ATA M. KHAN

INTRODUCTION

Approaches to combat urban traffic congestion span from demand management to physical expansion of road capacity. Attempts to shift a part of peak travel from car to high-quality public transit and to times when roads are relatively less crowded sometimes have been successful.[1,2] Also, intelligent transportation systems (ITS) have the promise to optimize the operation of transportation systems and delay the building of additional lanes.[3]

However, the most common attempt to alleviate traffic congestion at intersections is to provide more road space to vehicles.[4] Since very little or no research exists on the optimum size of intersections, they are often made as large as traffic demand projections require and/or the available right-of-way (ROW) allows. It is often assumed that this approach is both an effective and a sustainable way to provide for growing travel demand. From the technical perspective, increasing the number of lanes could be a sustainable approach to satisfy traffic demand only if the marginal capacity of additional lanes can match the marginal traffic demand increase.

This feature shows that the effectiveness of additional lanes decreases as the size of the intersection increases. Effectiveness is expressed in terms of marginal capacity increase of the additional lanes, vehicle delay and queue lengths.

Typical urban intersections usually are expanded a number of times during a 60- to 80-year span. Evaluating and comparing the operation of a particular intersection during this period is technically infeasible due to changes in the environment and the lack of appropriate historical data. In this feature, measures of effectiveness (MOEs) of a hypothetical intersection during a similar life span are evaluated and compared assuming common traffic engineering procedures are applied as traffic demand grows.

The authors appreciate that adding new traffic lanes is often the only feasible approach to reduce congestion in the short term. However, the objective of the feature is to demonstrate technical reasons why this approach is not sustainable in the long run.

REASONS FOR DIMINISHING MARGINAL CAPACITY BENEFITS

A number of factors affects the marginal capacity of additional lanes. Although all factors are described in traffic-engineering textbooks and routinely utilized in traffic-engineering calculations, the importance of their cumulative and long-term effect usually is not recognized. The importance of these factors depends on the particular intersection configuration, traffic characteristics and types of intersection users. Not all factors are always relevant; however, most intersection expansion projects are affected by some of them.

Lost time due to phase change: From the capacity perspective, every phase change generates some lost time. The total lost time in a cycle increases with the number of phases. Furthermore, additional lanes increase the size of the intersection and, consequently, the clearance intervals, which represent lost time.

Left-turn phasing: The treatment of left turns varies from jurisdiction to jurisdiction. In terms of approach capacity, permissive or protected plus permissive left turns are preferred. This practice is normally allowed as long as it provides safe operation. The implementation of double left turns, however, usually requires the introduction of protected-only left-turn phasing. The additional protected left-turn phase introduces another clearance interval that represents additional lost time and the protected-only phasing eliminates permissive left turns during gaps in the opposing flow.

Provision for pedestrians: At intersections with pedestrian activity, the provi-

Table 1. Default lane-utilization factors.

Movement	Number of lanes	Lane utilization factor
Through or shared	1	1.00
	2	0.95
	3	0.91
Exclusive left turn	1	1.00
	2	0.97

Source: Highway Capacity Manual 2000, *pages 10–26, Exhibit 10-23.*

sion of adequate pedestrian timings may contribute to unutilized vehicular green times and lost vehicular capacity on the conflicting approach. Since the minimum (safe) pedestrian crossing time is directly related to the size of the intersection, under certain circumstances some pedestrian crossings may require more green time than what is needed for the concurrent vehicular movement. Consequently, splits (the allocation of green times between competing vehicular movements) cannot be optimized.

Lane utilization: Due to lane arrangements along an arterial and driver behavior, it is possible that the capacities of all lanes are not fully utilized. To account for this phenomenon, lane-utilization factors are often used in intersection analysis. In the absence of local data, the *Highway Capacity Manual* (HCM) suggests the use of default lane-utilization factors.[5] These are shown in Table 1.

Lane blockages and inadequate queue storage space: Larger intersections usually require longer signal cycles and, therefore, longer queuing space. If the required queuing space is unavailable, the potential capacity benefits of additional lanes will be reduced.

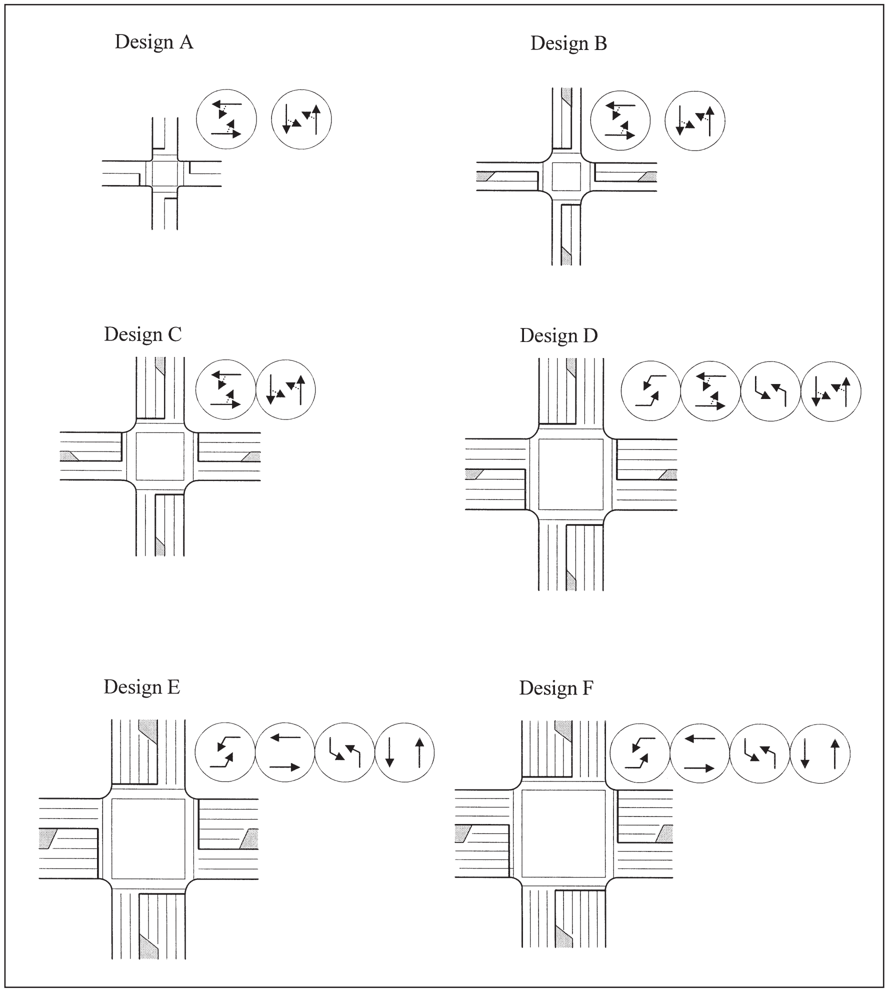

Figure 1. Intersection designs.

DESIGN AND ANALYSIS

The analysis of a signalized intersection has been carried out as the intersection goes through a series of expansions. As is common practice, intersection development is in the form of adding straight-through (ST) and left-turning (LT) lanes to accommodate growing traffic demand (Figure 1). This process resembles the most common approach to the urban traffic growth problem, particularly in locations on the fringes of the central business district and in suburban areas.

To keep the analysis relatively simple and straightforward, only some of the factors contributing to the diminishing capacity of the additional lanes were included in the analysis. These included the lane-utilization, left-turn arrangements and the lost time due to the increased number of signal phases. The selected factors may not be the most important in all cases. However, the objective of the provided analysis is not to quantify the exact reduction of lane capacity due to the relevant factors but to demonstrate the phenomenon of diminishing marginal benefits and its long-term consequences.

To ensure that results are not affected by uncontrolled circumstances, the following assumptions were made:

- There are no right turns, or no special provision is made for right turns;
- The left-turn bays are always of sufficient length to prevent queue blockage;
- The proportion of LT and ST movements remains constant; and
- The approach volumes are the same for all four approaches.

Although the above assumptions significantly oversimplify real-world traffic and geometric conditions at most locations, the nature of conclusions is not affected by the assumptions. The law of diminishing marginal benefits of additional lanes applies to all geometric and traffic conditions because the reasons for the diminishing benefits are always present, although the exact numerical values are certainly different. It is very likely that for traffic and geometric conditions, which are less ideal than the conditions defined in the assumptions (e.g., queue blockage due to short left-turn lanes, interference with right-turning vehicles,

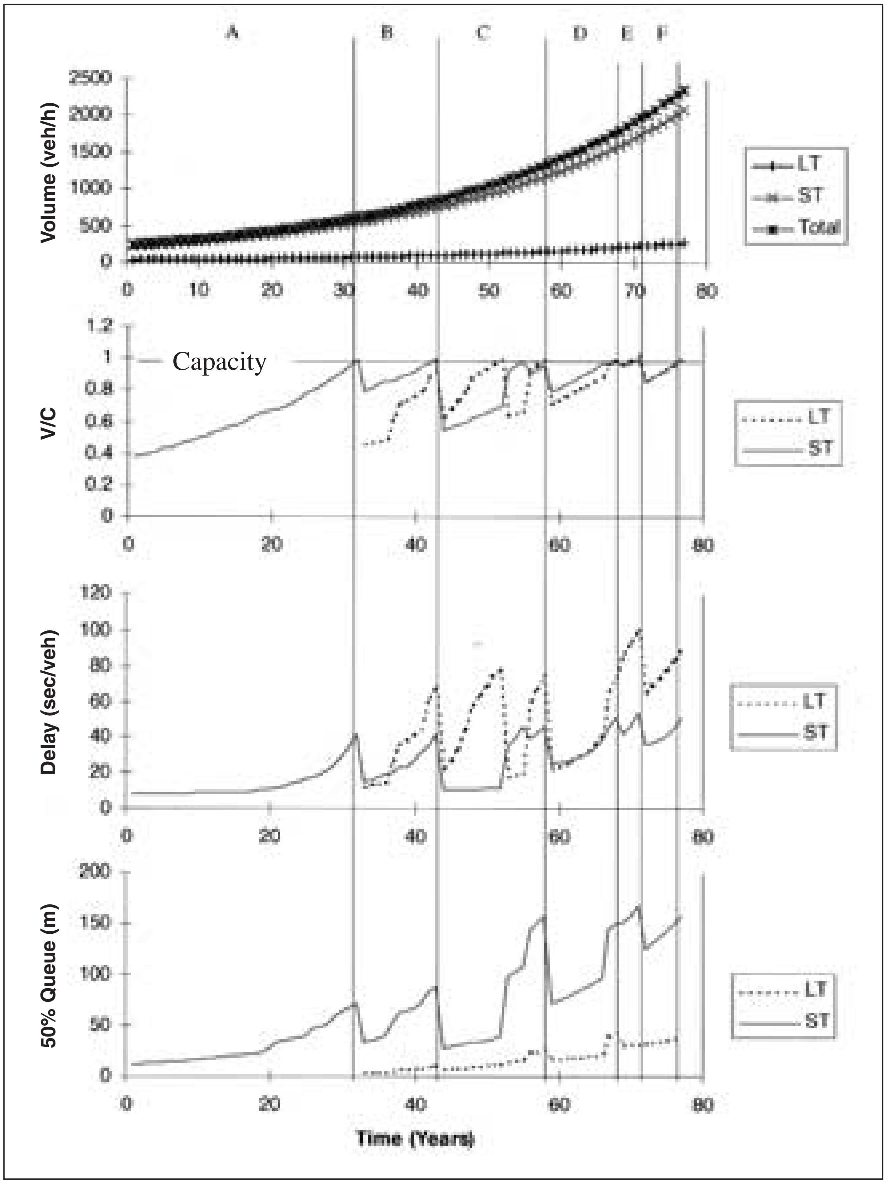

Figure 2. MOEs for the six stages of intersection capacity expansion.

different approach volumes), the rate of diminishing marginal benefits is even more dramatic (see Figure 1).

At the outset, the intersection has one shared LT and ST lane at all four approaches (Design A in Figure 1). Expansion of the intersection occurs when the volume/capacity (V/C) ratio of either the LT or the ST movement reaches its saturation. The expansion is in the form of adding one lane to each of the four approaches—either to the LT or the ST movements. Signal timing is modified to keep the V/C ratio of the ST and LT lanes in balance and identical at all four approaches.

The cycle length is optimized to provide minimum delay and queue lengths, but it is not increased beyond 120 seconds (sec.). Theoretically, longer cycle lengths provide more capacity because the proportion of lost time decreases and the proportion of green time increases. However, there is a practical limit to increasing the cycle length above 120 to 140 sec. due to the decreasing saturation flow rate during long phase times and due to long queues associated with longer cycle lengths.

To calculate the number of years before the intersection reaches capacity, a 3 percent annual traffic growth is assumed. However, a sensitivity analysis for other growth rates is also provided. Three MOEs, namely the V/C ratio, vehicular delay and average queue length, are calculated for each year. A widely used traffic signal optimization package, Synchro, marketed by Trafficware, was used for signal optimization and the calculation of factors shown in Figure 2.[6] However, any other software package with comparable features could be employed for these tasks.

Design A

As noted earlier, this is the starting point of the analysis and represents an intersection with one shared ST and LT lane per approach. It is assumed that traffic volumes in year one satisfy the minimum volume requirements for signalization.

The increase of traffic volumes and the corresponding MOEs, including the V/C ratio, vehicle delay and average queue length, are presented in Figure 2. Signals are operated in two phases (Figure 1), and there is no special provision for left turns; left turns are made during gaps in the opposing flow and during the clearance interval.

The cycle length starts at 40 sec. and increases to 60 sec. Higher cycle lengths do not provide more capacity because a significant proportion of LT is accommodated at the phase change interval and longer cycle lengths decrease the number of these opportunities.

The V/C ratio reaches one in approximately 32 years (Figure 2). While the V/C ratio is a good indication of the demand-supply balance, the vehicular delay shows that as the volume approaches capacity, vehicular delay increases exponentially.

As expected, the queue length increases with the increase of volume and cycle length.

Design B

When Design A reaches saturation, an LT lane is added to each of the four approaches. The additional ROW is approximately 4 meters (m). The two-phase signal control is retained because it provides the highest capacity for both the LT and the ST movements. Although a protected plus permissive LT phasing normally would improve the LT V/C ratio and delay, it also increases the V/C ratio and delay of the opposing ST movement. In this particular example, the gain to LTs is less than the loss to the ST movement.

Table 2. Comparison of intersection designs at traffic growth rate of 3 percent/year.

Design	Lifetime (years)	Additional lane	Additional ROW (m)
A	32	—	—
B	11	1 LT lane	4
C	15	1 ST lane	8
D	10	1 ST lane	8
E	3	1 LT lane	4
F	6	1 ST lane	8

Table 3. The marginal capacity of additional lanes.

Additional lane	Designs compared	Additional ST + LT capacity per approach (veh/h)
1st LT	A to B	240
2nd LT	D to E	168
1st ST (base)	A (base)	625
2nd ST	B to C	483
3rd ST	C to D	463
4th ST	E to F	385

The cycle length increases from 40 to 60 sec. The LT V/C ratio and delay change abruptly with the change of the cycle length. These effects can be noticed in Figure 2.

The lifetime of Design B is approximately 11 years. The loss of efficiency, expressed in delay per vehicle as volume increases, is evident. Vehicular delay at the beginning of the observation period for Design B (year 33) is not more than 15 sec. At the end of the period (year 43), it increases to approximately 68 and 42 sec. for the LT and ST movements, respectively (Figure 2).

Design C

This design evolved from Design B with the addition of a second ST lane. To keep average vehicular delay at a minimum, the LT operates as a permissive turn during the first nine years. However, due to insufficient opportunities for making left turns, a protected plus permissive left-turn phasing is introduced. This change significantly improves the LT V/C ratio and delay at the expense of the ST V/C ratio and delay. The introduction of the protected LT phase requires increasing the cycle length from 50 to 90 sec. This increase contributes to longer delay and queue length. In year 56, the cycle length is increased again to 120 sec. and the jump in delay and LT queue length is evident.

It takes approximately 15 years for Design C to become saturated. Although the lifetime of Design C is longer than the lifetime of Design B, in terms of the total road space requirement, Design B required only one additional lane because the two left turns are "back-to-back," while Design C required two additional lanes or approximately 8 m of additional road space (Table 2).

Design D

This design has one LT lane and 3 ST lanes (one more than Design C). The left-turn phasing is protected plus permissive. The cycle length starts from 85 sec. and increases to 120 sec. The cycle length increase provides additional capacity. However, this additional capacity is sufficient for only three more years. The cycle length increase causes a jump in delay and queue lengths. In terms of the marginal increase of the ROW requirement, both Design C and Design D needed 8 m of additional space. However, the lifetime of Design D is only 10 years compared to the 15 years of Design C (Table 2).

Design E

This design has an additional LT lane (two LTs per approach). It is assumed that double lefts require protected LT phasing due to safety reasons. In terms of signal operation, there is very little flexibility. The cycle length must be relatively long—120 sec.

The lifetime of the design is approximately three years compared to the 11 years of Design B that had the same marginal increase of ROW (Table 2).

Design F

This design has two LT lanes and one more ST lane than the previous design. Signal phasing is similar to the previous design. The lifetime of the design is six years. This is significantly less than the 10 and 15 years of Designs D and C that required the same marginal increase (8 m) of ROW (Table 2).

DISCUSSION OF RESULTS

By comparing the capacity of Designs A to F, it can be seen that the marginal capacity increase of additional lanes decreases as the size of the intersection increases. The single approach lane of Design A accommodates 625 vehicles per hour (veh/h). However, the second, third and fourth lanes add only 483, 463 and 385 veh/h, respectively. A similar trend could be observed for the LT movement as well (see Table 3). It is recognized that the total volume moved increases in absolute terms. However, it is clear that every new ST (or LT) lane provides less additional capacity than the previous ST (or LT) lane did.

While the marginal capacity of additional lanes decreases, the constant annual traffic growth results in more additional traffic each year in absolute terms. The combination of the increasing number of vehicles (in absolute terms) on the intersection approach and the decreasing marginal capacity of additional lanes results in a dramatic reduction in the uncongested lifetime of subsequent intersection designs. The 3 percent growth used in the calculations was chosen for illustration purposes. Developing areas, however, do experience traffic growth that is significantly more than 3 percent.

Sensitivity Analysis of Uncongested Lifetime

The above reported information corresponds to 3 percent per year growth in traffic. A sensitivity analysis was carried out to show the trend in the uncongested lifetime of intersection designs for traffic growth at 5 percent and 7 percent per year. The estimated lifetime values for the various growth factors are provided in Table 4. The results clearly show similar trends in the uncongested lifetime of intersection designs.

OTHER CONSIDERATIONS

In addition to decreasing marginal capacity, larger intersections function less efficiently. One measure of the loss of efficiency is the increased vehicular delay. The average delay of Design A at capacity is approximately 42 sec. per vehicle, which increases to 100 sec. and 52 sec. for the LT and ST movements, respectively, in Design F (Figure 2).

At low volumes, which could prevail for most parts of the day except the peak hours, large intersections with pedestrian activity and protected left-turn phasing could be even more inefficient (in terms of delay) compared to smaller intersections due to the restricted left-turn phasing, long pedestrian crossing times and the resulting relatively long minimum cycle lengths.

The cost of capacity expansion is an important consideration in decision-making. While the benefits of additional lanes diminish, the cost of additional lanes usually increases exponentially with increased intersection size due to space constraints in urban areas.

CONCLUSIONS

While roads are an essential part of every urban transportation network, limits to their capacity expansion do exist. As intersections grow, they become less effective in providing additional capacity. The loss of effectiveness is reflected in the reduced uncongested lifetime of larger intersections due to increasing marginal demand for capacity and the decreasing marginal capacity of additional lanes.

This does not mean that roads should not be built. However, expanding intersections above a certain size, especially in locations where traffic growth is high, may be an expensive, ineffective and short-lived solution to the traffic-congestion problem. The recognition of the fact that every new additional lane has less capacity than the previous additional lane should be a strong incentive for transportation professionals to seek other approaches to solve the traffic-congestion problem.

Table 4. Uncongested lifetime at various traffic-growth rates.

	Uncongested lifetime (years) for different annual growths		
Design	**3%**	**5%**	**7%**
A	32	19	14
B	11	7	5
C	15	9	7
D	10	6	4
E	3	2	1
F	6	4	3

ACKNOWLEDGMENTS

This feature is based on a research project carried out at Carleton University. The use of the City of Ottawa's software and financial support by the Natural Sciences and Engineering Research Council are acknowledged. The views are those of the authors. ■

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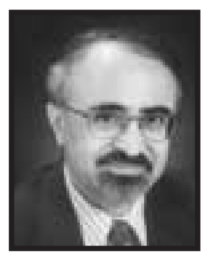
KORNEL MUCSI, *P.Eng., is a traffic engineer with the City of Ottawa, Canada. He has a BSc degree in Transportation Engineering from the University of Novi Sad, Yugoslavia and masters' degrees in transportation planning/management and engineering from the University of Westminster, London, England and the University of Toronto, Canada. Mucsi is an associate member of ITE.*



ATA M. KHAN, *P.Eng., is a professor at and director of the Transportation Research Centre, Department of Civil and Environmental Engineering, Carleton University, Ottawa, Canada. Khan received his bachelor's and master's degrees from the American University of Beirut and his Ph.D. in civil engineering (transportation) from the University of Waterloo, Canada. Khan is a member of ITE.*

The Conversion of Four-Lane Undivided Urban Roadways to Three-Lane Facilities

THOMAS M. WELCH
Director, Office of Transportation Safety
Engineering Division
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010
twelch@iadot.e-mail.com

ABSTRACT

In recent years, many traffic engineers have advocated converting four-lane undivided urban streets to three-lane two-way left-turn facilities. A number of these conversions have been successfully implemented. Accident rates have decreased while corridor and intersection levels of service remained acceptable. This conversion concept is yet another viable alternative "tool" to place in our urban safety/congestion toolbox.

BACKGROUND

Prior to the mid 1980s, it was common practice in Iowa to widen an existing two-lane urban roadway to a four-lane undivided facility if traffic volumes were in excess of 6,000 vehicles per day (vpd). Further, if a four-lane undivided roadway was experiencing an unacceptable accident rate, either a four-lane divided or five-lane two-way left-turn lane (TWLTL) facility was proposed to improve safety along the corridor. Each of these proposals was generally opposed by most property owners adjacent to the roadway because of the right-of-way impacts and/or the changes in access control.

At public hearings, project engineers would state that corridor safety would improve if the two-lane roadway were widened to a four lane undivided roadway. Graphics would be shown to illustrate that additional acceptable gaps in the traffic stream would result, and motorists could avoid rear-end collisions by changing lanes, etc. Those in opposition to the widening would argue that travel speeds would increase, pedestrians would have to cross a wider street, and noise would increase. In most cases, however, the four-lane undivided cross-section was selected as the preferred alternative because the only other alternative was generally to do nothing (i.e., the roadway remains a two-lane facility).

I conducted a 2-year before and after study on US-61 through Ft. Madison, Iowa (*1*) to assist in identifying the road-user benefits and noise impacts of widening an urban two-lane roadway to a four-lane undivided facility. US-61 was widened from two to four lanes in 1983 and had an average daily traffic volume between 10,000 and 14,000 vpd. Table 1 is a summary of the before and after data.

During this same time period, the Iowa Department of Transportation (DOT) authorized the re-stripping of several wide (40–42 feet) two-lane urban roadways to three-lane two-way left-turn lane facilities. The collision rates on the first seven conversions,

TABLE 1 Changes After Highway Widened from Two to Four Lanes (US-61 at Ft. Madison, Iowa)

Corridor Element	Change
• Traffic Volume	Increased 4 percent
• Corridor Travel Delay	Increased 4 percent
• Mid-block 85th% Speed	Increased 2.5 mph
• Traffic Traveling More Than 5 mph Over Speed Limit	Increased from 0.5 percent to 4.2 percent
• Accident Rate	Increased 14 percent
• Injury Rate	Increased 88 percent
• Total Value Loss	Increased 280 percent

which had Average Daily Traffic (ADT) volumes from 5,400 to 13,500 vpd, decreased an average of 40 percent (23 percent to 48 percent) (*2*). Because of the results in Ft. Madison and the success of our two-lane to three-lane conversions, I began a search to determine if anyone had converted a four-lane undivided urban roadway to a three-lane two-way left-turn facility. My search led me to Billings, Montana.

The City of Billings had restripped 17th Street West from a four-lane undivided roadway to a three-lane two-way left-turn lane facility in 1979. 17th Street West is 40 feet wide with an ADT range of 9,200–10,000 vpd and a posted speed limit of 35 mph. City Traffic Engineer Pierre Jomini, P.E., reported that the number of reported accidents decreased from 37 in the 20 months before to 14 in the 20 months after the conversion. He further stated that there was "no increase in traffic delay (*3*)."

I began to look for a candidate roadway to propose a four- to three-lane conversion. The Iowa DOT management staff had only recently accepted the concept of three-lane two-way left-turn lane facilities and was apprehensive about *decreasing* the number of traffic lanes on a state primary highway. However, I was able to convince the City of Storm Lake, Iowa, to convert a portion of existing US-71 after the DOT built a US-71 bypass and transferred jurisdiction of existing US-71 to the City of Storm Lake. Old US-71, Flindt Drive, is 40 feet wide and has an ADT of 8,500 vpd. The roadway was converted to a three-lane facility in 1996. Clyde Bartel, Iowa DOT Resident Engineer, reports that there has been a "very positive community reaction" to the conversion. The city is very pleased with the traffic operations and improvement in safety. At about the same time, a similar conversion was also made on Clay Street in Muscatine, Iowa. Ray Childs, City Engineer, reported "an immediate large reduction in accidents."

The Iowa DOT Office of Transportation Safety has recently begun to actively promote the conversion of other four-lane undivided urban roadways to three-lane two-way left-turn lane facilities when a concern about safety along the existing highway is expressed to the Iowa DOT. Several of these roadways under consideration are 48 feet wide and have traffic volumes in excess of 13,000 vpd. The recommendation to convert to a three-lane facility on these 48-foot-wide roadways is often met with apprehension by the local community and other engineers. As a result, additional inquiries were made around the country about the experience others have had with this concept. I found a number of states discouraged the construction of new four-lane undivided roadways and that those who had experience with the conversion concept had a very positive experience with it.

One example provided was an urban primary highway (US-12) in Helena, Montana. It is a 48-foot-wide, 35-mph roadway with an ADT of 18,000. The roadway did not have a high collision rate but it did have a high percentage of rear-end and sideswipe accidents. It is located in a commercial area with numerous commercial access points. Montana State Traffic Engineer Don Dusek proposed restripping the roadway to a three-lane facility. Both the city staff and other state staff engineers were apprehensive at first, but after observing the improvement in traffic operations and reduction in accidents they support the conversion. They also have received numerous complimentary remarks from city residents about the conversion. Don Dusek stated that the "number of accidents decreased, good traffic flow was maintained, and community residents prefer the three-lane facility over the former four-lane roadway." The roadway cross section was marked with 5-12-14-12-5 foot lanes which meets AASHTO standards to accommodate bikes along a roadway. However, they do not designate the five-foot lanes as a bike path.

In a study conducted for the Minnesota DOT, Howard Preston, BRW Inc., found that the highest urban corridor accident rates were found on four-lane undivided roadways. In fact, the collision rate on four-lane undivided roadways was 35% higher than on urban three-lane roadways (*4*). The study found three-lane roadways in Minnesota with ADTs as high as 20,000 vpd. Mr. Preston stated he would convert most four-lane undivided urban roadways with ADTs less than 20,000 vpd to three lane facilities "in a heart beat."

A good example of a change in community attitude toward the four- to three-lane conversion is the conversion of 21st Ave. East in Duluth, Minnesota. (ADT is 17,000 vpd.) Prior to the conversion many in the community opposed decreasing the number of traffic lanes. A *Duluth News-Tribune* article pleaded "Don't limit 21st Ave. East" and "it's not too late to keep [it] a four-lane street." However, after the conversion, a *Duluth News-Tribune* staff editorial (*5*) stated the following:

> Admit it, 21st East Works
>
> When Duluth officials announced they would convert busy 21st Avenue East between London Road and Woodland Avenue from four lanes to two, with a turn lane in the middle, some armchair analysts predicted it wouldn't work. The News-Tribune Opinion page was among them. Well, it works. About everyone agrees—from city traffic officials to neighbors—that the change has eased congestion and reduced drivers' speed making it safer for pedestrians, and it hasn't caused problems in winter. Traffic moves steadily up and down the hill even though the volume is up. Cutting available traffic lanes by 50 percent on the already heavily used stretch carrying vehicles between the I-35 exit at 21st Avenue East at London Road and the Hunters Park and Woodland neighborhoods did not seem like a good prospect when it was done last May. Initiated at the end of the academic year, many believed that, when the University of Minnesota–Duluth and St. Scholastica resumed classes in the fall, the thoroughfare wouldn't be able to handle the traffic. And winter . . . well, it would be a disaster, we doomsayers predicted. None of it happened. Now the city is planning to repaint the lanes and keep the pattern on 21st indefinitely—as well it should.

ADVANTAGES

Improved Safety

At first glance, it is difficult for most, including many transportation engineers and planners, to accept that, in urban corridors with less than 20,000 vpd, reducing the number of traffic lanes will improve traffic safety and maintain an acceptable level of service. The substantial reduction in accident rates is primarily the result of the reduction in conflict points and improved sight distance for turning and crossing traffic along the corridor. See Figures 1 and 2 for examples of reductions in traffic conflict points along a three-lane corridor. Figure 3 illustrates the improved intersection sight distance.

The three-lane facility is also much more user friendly to elderly drivers. Fewer decisions and judgments have to be made to enter or cross a three-lane facility. Iowa has the third highest percentage of elderly drivers in the country and is making an effort to better accommodate this growing segment of the population on its roadways.

Table 2 shows the 3-year before and after midblock and nonsignalized intersection crash information for a four-to-three-lane conversion project on Minnesota Trunk Highway 49 (Rice Street) in Ramsey County, Minnesota (Figure 4) (*6*). The ADT on Rice Street during the after period was 16,400 vpd. Table 3 reflects data from several street conversions in Seattle, Washington (*7*). It appears a 20 to 30% reduction in crashes would be a reasonable estimate of the potential safety improvement of a four-to-three-lane conversion.

Improved Pedestrian Safety

For pedestrians, the three-lane facility can on occasion provide a pedestrian refuge allowing pedestrians to focus on one lane of traffic at a time. If necessary, elderly and

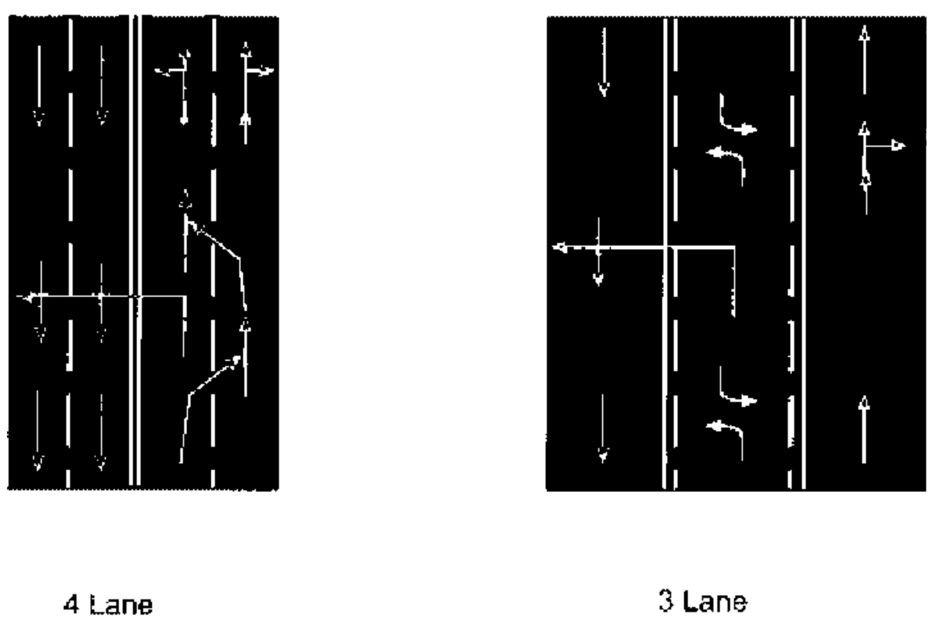
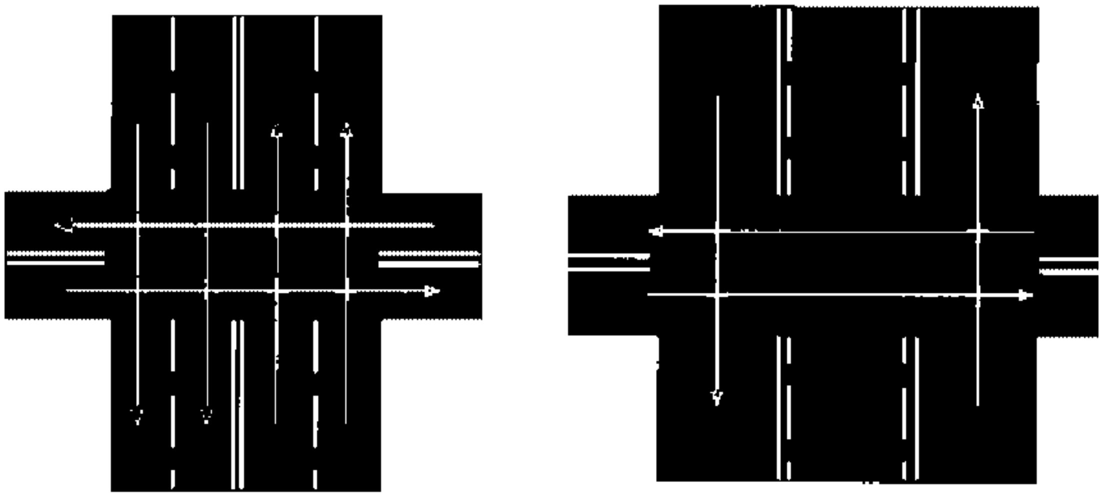
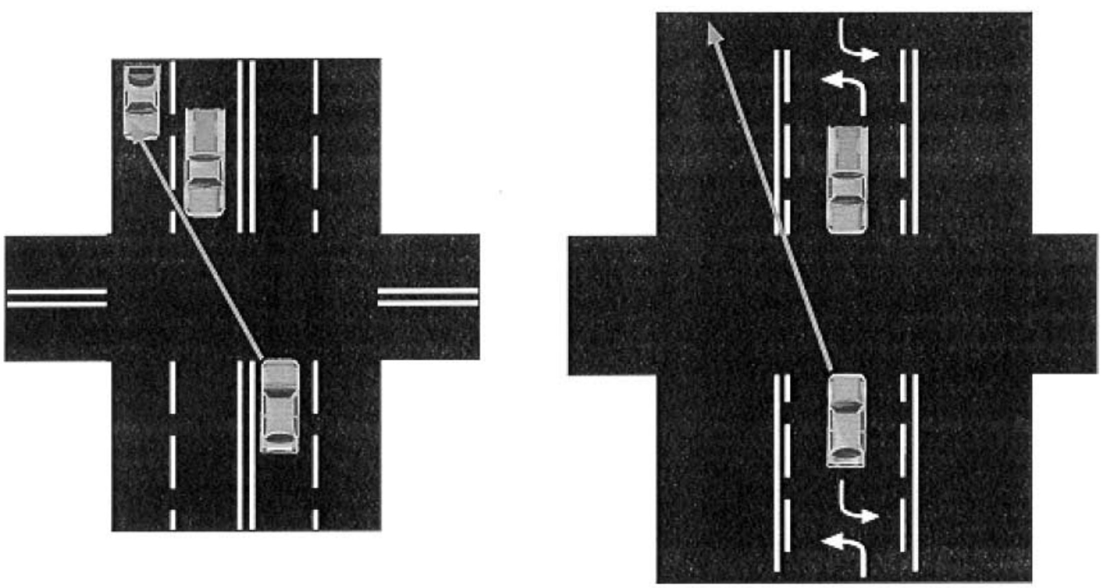


FIGURE 1 Midblock conflict points.



4 Lane   3 Lane

FIGURE 2 Cross-traffic conflict points.



4 Lane   3 Lane

FIGURE 3 Intersection sight distance.

TABLE 2 Collisions Before and After Three-to-Four-Lane Conversion

Corridor Element	Change
• Traffic Volume	Increased 4 percent
• Corridor Travel Delay	Increased 4 percent
• Mid-block 85th% Speed	Increased 2.5 mph
• Traffic Traveling More than 5 mph Over Speed Limit	Increased from 0.5 percent to 4.2 percent
• Accident Rate	Increased 14 percent
• Injury Rate	Increased 88 percent
• Total Value Loss	Increased 280 percent

young pedestrians can stop in the two-way left turn lane, an option not available on four-lane undivided roadways. While the center lane is an active traffic lane, it would have a lower volume of traffic and slower vehicle speeds. Often this lane would be unoccupied by vehicles.

Traffic Calming

Another attribute of the three-lane facility is the traffic calming effect it has on the traffic flow. Aggressive motorists can not travel along three-lane corridors at excessive speeds making multiple lane changes. The three-lane concept also reduces the variability of travel speeds along the corridor, which helps reduce possible collisions. On a four-lane roadway crossing traffic must not only find a gap in four traffic lanes but must also make a judgment on the approach speed of four different vehicles. This is very difficult to do, particularly for elderly drivers and pedestrians.

Improved Emergency Response Time

Emergency vehicles often find it difficult to travel down four-lane urban roadways. Waiting for all the traffic to move over to the curb lane can cause delays to emergency vehicles. The center two-way left-turn lane can be used as a lower-conflict access route along the roadway corridor (Figure 5).

DISADVANTAGES

Increased Travel Delay

Increased travel delay along the corridor is the primary concern many have with converting a four-lane roadway to a three-lane facility. Many assume there will be a 50% reduction in corridor capacity because the number of “through lanes” is reduced by half.

Before

After

FIGURE 4 Four-to-three-lane conversion, Minnesota Trunk Highway 49 (Rice Street), Ramsey County, Minnesota.

TABLE 3 Changes in Traffic Volume and Collisions After Roadways Changed from Four Lanes to Two Lanes plus TWLTL (Seattle, Wash.)

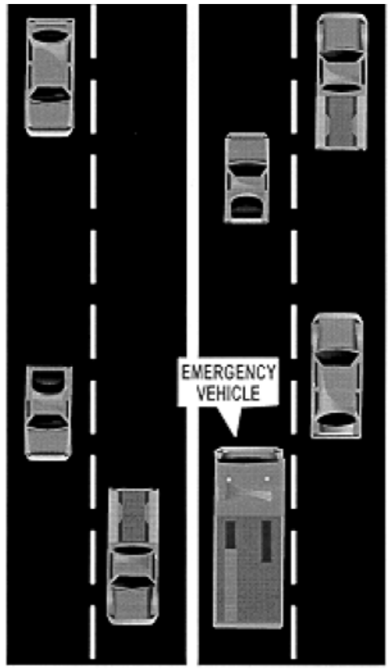
ROADWAY SECTION	DATE CHANGE	ADT (BEFORE)	ADT (AFTER)	CHANGE	COLLISION REDUCTION
Greenwood Ave. N, from N 80th St. to N 50th St.	April 1995	11872	12427	4 lanes to 2 lanes plus TWLTL plus bike lanes	24 to 10 58%
N 45th Street in Wallingford Area	December 1972	19421	20274	4 lanes to 2 lanes plus TWLTL	45 to 23 49%
8th Ave. NW in Ballard Area	January 1994	10549	11858	4 lanes to 2 lanes plus planted median with turn pockets as needed	18 to 7 61%
Martin Luther King Jr. Way, north of I-90	January 1994	12336	13161	4 lanes to 2 lanes plus TWLTL plus bike lanes	15 to 6 60%
Dexter Ave. N, East side of Queen Anne Area	June 1991	13606	14949	4 lanes to 2 lanes plus TWLTL plus bike lanes	19 to 16 59%
24th Ave. NW, from NW 85th St. to NW 65th St.	October 1995	9727	9754	4 lanes to 2 lanes plus TWLTL	14 to 10 28%
Madison St., from 7th Ave. to Broadway	July 1994	16969	18075	4 lanes to 2 lanes plus TWLTL	28 to 28 0%
W Government Way/Gilman Ave. W, from W Ruffner St. to 31st. Ave. W	June 1991	12916	14286	4 lanes to 2 lanes plus TWLTL plus bike lanes	6 to 6 0%
12th Ave., from Yesler Way to John St.	March 1995	11751	12557	4 lanes to 2 lanes plus TWLTL plus bike lanes	16 to 16 0%
				Total	185 to 122 34%

In reality the capacity of a three-lane facility is very near that of a four-lane undivided roadway. Envision a four-lane undivided roadway in a commercial area during the peak hour of the day. Drivers who want to travel through the corridor generally stay in the outside curb lane to avoid getting caught behind mid-block left-turning vehicles. During these peak hours the inside lanes are generally used by left-turning vehicles and very few through trips are made in those lanes. As such, only one lane in each direction is accommodating most of the through trips—which is similar to a three-lane facility.

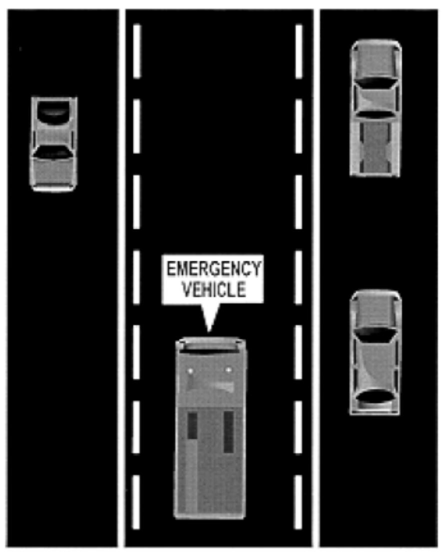
Further, the actual capacity of a corridor is controlled by the signalized intersections. These intersections generally have high volumes of left-turning traffic. As such, once again most of the through traffic is carried in one lane—the outside curb lane.

The following is an example corridor level of service analysis performed on a proposed high-volume roadway in Iowa. Table 4 is an arterial level of service analysis for a section of US-75 through the central business district of Sioux Center, Iowa (population 5,100) (*8*). The ADT on US-75 is 14,500 vpd with 9 percent trucks.

Table 5 is the intersection level of service analysis for the signalized intersection along a proposed conversion of US-65 in Iowa Falls, Iowa (population 5,500) (*9*). The 1996 ADT on US-65 was 8,700 vpd with 8 percent trucks and on Brooks Road the ADT was 1,600 vpd. This is an example of a typical intersection along a three-lane roadway corridor in Iowa.



(a)



(b)

FIGURE 5 Emergency vehicle access (a) on four-lane road; (b) on three-lane road.

As shown, while travel delay increases, an acceptable level of service would be maintained if these four-lane undivided roadways were converted to a three-lane two-way left-turn lane facility. Travel delay along these corridors could be further reduced if right-turn lanes were constructed at major intersections and high-volume commercial entrances. In addition larger turning radii at other driveways will help right-turn traffic exit the roadway quicker, reducing travel delay and the potential for rear-end accidents.

TABLE 4 Arterial Level of Service (LOS) Analysis for Proposed High Volume Roadway[1]

Cross Section	Total Corridor Travel Delay	Average Travel Speed	LOS
Four lane undivided	20.5 secs	16.0 mph	C
Three lane alternative	29.4 secs	14.3 mph	C
Five lane alternative	15.8 secs	17.1 mph	C

[1] U.S. Highway 75 corridor, 1st St. to N. 4th St., Sioux Center, Iowa.

TABLE 5 Intersection Level of Service (LOS) Analysis for Proposed Conversion of a Signalized Intersection[1]

Existing 4 lane undivided							
	Lane Mvmts	v/c Ratio	g/C Ratio	Mvmt: Delay	LOS	Approach: Delay	Approach: LOS
EB	LTR	0.356	0.314	12.2	B	12.2	B
WB	LTR	0.379	0.314	12.4	B	12.4	B
NB	LTR	0.342	0.600	4.6	A	4.6	A
SB	LTR	0.293	0.600	4.4	A	4.6	A
Intersection Delay = 6.2 sec/veh						Intersection LOS = B	

Proposed 3-lane with TWLT Lane							
	Lane Mvmts	v/c Ratio	g/C Ratio	Mvmt: Delay	LOS	Approach: Delay	Approach: LOS
EB	LTR	0.356	0.134	12.2	B	12.2	B
WB	LTR	0.379	0.314	12.4	B	12.4	B
NB	L	0.234	0.600	4.3	A	5.1	B
	TR	0.457	0.600	5.2	B		
SB	L	0.139	0.600	4.0	A	5.0	A
	TR	0.438	0.600	5.1	B		
Intersection Delay = 6.7 sec/veh						Intersection LOS = B	

L = Left, T = Through, R = Right.
[1] U.S. Highway 65 at Brooks Road, Iowa Falls, Iowa.

However, this is not recommended if large volumes of pedestrians are present on adjacent sidewalks.

Increased Delay at Driveways

Often when this concept is proposed through a residential area, residents will express concerns about increased difficulty in backing out of their driveways. Granted, conversion to a three-lane roadway will result in fewer gaps in the traffic stream and motorists will have to be more patient. However, backing onto a four-lane undivided highway and into a traffic lane is a high-risk traffic maneuver. The three-lane concept can enhance the safety of this traffic maneuver by allowing motorists to back across the traffic lane into the unoccupied center lane, and then proceed to enter the traffic lanes in either direction. The center lane also provides a low-risk escape lane for motorists who need to avoid a potential collision with a vehicle backing into the roadway.

Loss of Passing Opportunities

A concern often heard is from aggressive motorists who do not want to lose the opportunity to pass vehicles along the corridor. As previously discussed, that disadvantage provides a benefit to pedestrians and other motorists trying to enter or cross the roadway.

Some are of the opinion that aggressive drivers will use the center lane as a passing lane. While this does occur occasionally it has not been a problem in Iowa on three-lane facilities.

Also, in Iowa slow-moving agriculture vehicles commonly travel on these urban roadways to either grain elevators or implement dealers. There is concern that removing a through lane in each direction will result in motorists illegally passing these agriculture vehicles. This likely will happen just as it occurs on two-lane roadways through a community. While this potential conflict may occur several hundred times each year, this disadvantage must be put in the proper perspective. The safety advantages the three-lane facility provides are to the thousands of vehicles which try to cross and turn left onto or off of the highway each day.

ACCESS CONTROL

Opportunities for eliminating, consolidating and relocating driveways should be investigated during the study analysis. Particular attention should be made to ensure high-volume access points on opposite sides of the roadway are not offset in the wrong direction, which could result in "gridlock" in the center turn lane.

Turbulent traffic flow along the corridor can be reduced by constructing right-turn lanes at signalized intersections and constructing larger turning radii at high-volume commercial driveways.

FACTORS TO CONSIDER

A number of factors should be considered before this type of conversion is made. They include roadway function and access control; total traffic volume; turning volumes and 85 percent speed; accident type and patterns; pedestrian and bike activity; and right-of-way availability and cost. A qualitative discussion of each factor and the changes it may experience due to a conversion are being documented in a follow-up report to be presented at the 1999 Institute of Transportation Engineers Annual Conference (*10*).

CONCLUSIONS

Most of Iowa's four-lane undivided urban roadways are providing both an acceptable level of service and safety to the local community because of the relatively low volume of traffic they carry. However, when safety concerns are expressed about one of these corridors, we have another "tool" in our traffic safety tool box we can consider to address these concerns. This "tool" can be implemented quickly, at a very low cost and with less right-of-way, environmental impact (i.e., tree removal), and other controversy associated with improvement alternatives.

Along four-lane undivided corridors, where it is not acceptable to add more lanes or a median, the key question to answer during an evaluation of alternatives is: What is the primary need in the corridor under study? Is it to move high volumes of traffic as quickly as possible? Or is it to improve corridor safety for motorists and pedestrians, while providing an acceptable level of service to corridor traffic? The answers to these questions will determine if converting to a three-lane facility is a viable alternative to include in your study. There is a need to perform a comprehensive before and after study on this concept. However, the positive community reactions to the past conversions and the fact that none of the previous conversions has been converted back to a four-lane undivided roadway support placing this tool in your traffic safety "tool box."

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Alternate Street Design, P.A.
1516 Plainfield Avenue, Orange Park, Florida 32073-3925
904-269-1851, Fax 904-278-4996, Email: mjwallwork@comcast.net

November 6, 2007

Sue Newberry
Community Partners LLC
218 Carville Circle
Carson City NV 89703

RE: E Street and 9th Street Intersection, Marysville

Dear Sue:

As requested I have undertaken a series of capacity analyses for the above intersection to determine its expected operation if the intersection was controlled by a roundabout. Attached are the capacity analysis summary sheets that show the expected operation for a multi-lane roundabout at this intersection.

The proposed roundabout used in the analysis was a roundabout that uses two lanes north and south along E Street with a right turn lane on E street south and single entry lane on 9th Street west and a left /through and right turn slip lane on the east approach. The total number of entry lanes is eight.

The traffic volumes used in the analysis were the existing traffic volumes from a report prepared by KD Anderson Transportation Engineers report dated 3/14/2006.

As a direct comparison the intersection was analyzed as a signalized intersection using the same capacity analysis program, SIDRA 3.1, using the proposed lane arrangement. The result showed that a signalized intersection is expected to have a poorer level-of-service than a roundabout even though several movements that restrict circulation and access to properties were banned under signal. Furthermore, the signalized intersection had 12 entry lanes, 50 percent more lanes than the roundabout. Even with the extra lanes and prohibited movements the 95th percentile queues at the signalized intersection are longer than the expected vehicle queues at the roundabout.

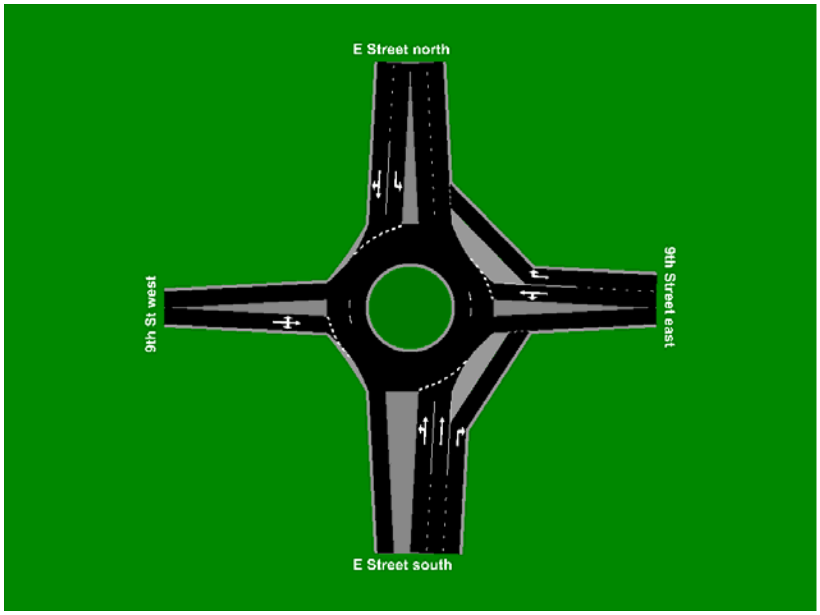
In summary, a two lane/one lane roundabout with eight entry lanes with no restricted vehicle movements provides better operation than the signalized intersection with 50 percent more lanes.

Sincerely,
Alternate Street Design, P.A.

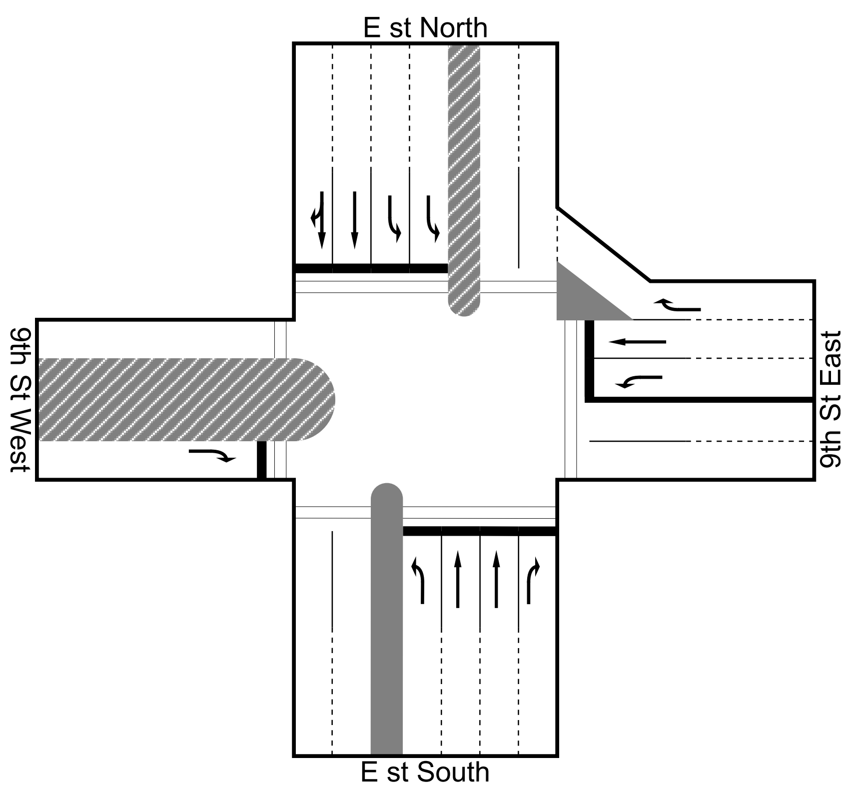
M J Wallwork

Michael J. Wallwork, P.E.
President

Lane arrangement for the roundabout analysis



Lane arrangement for the traffic signal analysis



SIDRA INTERSECTION

Movement Summary

E and 9th

AM Peak

Roundabout

Vehicle Movements

Mov ID	Turn	Dem Flow (veh/h)	%HV	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (ft)	Prop. Queued	Eff. Stop Rate	Aver Speed (mph)
E st South										
3L	L	43	2.3	0.419	15.4	LOS B	103	0.80	0.82	27.9
8T	T	852	2.0	0.418	7.3	LOS A	115	0.79	0.63	30.9
8R	R	340	2.1	0.370	9.1	LOS A	89	0.77	0.75	30.4
Approach		**1236**	**2.0**	**0.418**	**8.1**	**LOS A**	**115**	**0.79**	**0.67**	**30.6**
9th St East										
1L	L	420	1.9	0.756	20.9	LOS C	194	0.89	1.11	25.6
6T	T	63	1.6	0.759	13.8	LOS B	194	0.89	1.08	28.5
6R	R	502	2.0	0.567	10.3	LOS B	129	0.82	0.90	30.2
Approach		**984**	**1.9**	**0.757**	**15.1**	**LOS B**	**194**	**0.85**	**1.00**	**27.8**
E st North										
7L	L	509	2.0	0.664	20.0	LOS C	221	0.93	1.02	26.0
4T	T	584	2.1	0.697	12.8	LOS B	255	0.95	1.01	29.1
4R	R	11	8.3	0.706	14.3	LOS B	255	0.95	1.02	28.2
Approach		**1105**	**2.1**	**0.697**	**16.2**	**LOS B**	**255**	**0.94**	**1.01**	**27.5**
9th St West										
5L	L	5	16.7	0.222	21.2	LOS C	35	0.82	0.95	25.5
2T	T	11	8.3	0.222	13.6	LOS B	35	0.82	0.89	28.7
2R	R	50	2.0	0.224	15.0	LOS B	35	0.82	0.86	27.8
Approach		**68**	**4.4**	**0.224**	**15.3**	**LOS B**	**35**	**0.82**	**0.87**	**27.7**
All Vehicles		**3393**	**2.1**	**0.759**	**12.9**	**LOS B**	**255**	**0.86**	**0.88**	**28.7**

Symbols which may appear in this table:

Following Degree of Saturation
x = 1.00 for Short Lane with resulting Excess Flow
* x = 1.00 due to minimum capacity

Following LOS
- Based on density for continuous movements

Following Queue

SIDRA INTERSECTION

Movement Summary

E and 9th

PM Peak

Roundabout

Vehicle Movements

Mov ID	Turn	Dem Flow (veh/h)	%HV	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (ft)	Prop. Queued	Eff. Stop Rate	Aver Speed (mph)
E st South										
3L	L	45	2.2	0.703	22.7	LOS C	245	0.99	1.13	24.8
8T	T	980	2.0	0.705	14.5	LOS B	268	1.00	1.10	28.1
8R	R	482	2.1	0.609	12.4	LOS B	199	0.96	0.99	29.4
Approach		**1508**	**2.1**	**0.705**	**14.1**	**LOS B**	**268**	**0.99**	**1.06**	**28.4**
9th St East										
1L	L	364	1.9	0.997	47.9	LOS D	427	1.00	1.56	17.4
6T	T	77	2.6	1.000	40.8	LOS D	427	1.00	1.56	18.3
6R	R	617	1.9	0.325	5.8	LOS B#	16#	0.00	0.48	34.3
Approach		**1059**	**2.0**	**0.998**	**22.8**	**LOS C**	**427**	**0.42**	**0.93**	**24.3**
E st North										
7L	L	633	2.1	0.717	19.7	LOS B	273	0.96	1.01	26.1
4T	T	557	2.0	0.703	13.1	LOS B	254	0.95	1.01	29.0
4R	R	4	20.0	0.714	14.5	LOS B	254	0.95	1.05	28.1
Approach		**1194**	**2.1**	**0.717**	**16.6**	**LOS B**	**273**	**0.95**	**1.01**	**27.3**
9th St West										
5L	L	5	16.7	0.231	21.1	LOS C	36	0.83	0.95	25.6
2T	T	11	8.3	0.235	13.5	LOS B	36	0.83	0.90	28.7
2R	R	50	2.0	0.234	14.9	LOS B	36	0.83	0.87	27.9
Approach		**68**	**4.4**	**0.233**	**15.2**	**LOS B**	**36**	**0.83**	**0.88**	**27.8**
All Vehicles		**3829**	**2.1**	**1.000**	**17.3**	**LOS B**	**427**	**0.82**	**1.01**	**26.8**

Symbols which may appear in this table:

Following Degree of Saturation
x = 1.00 for Short Lane with resulting Excess Flow
* x = 1.00 due to minimum capacity

Following LOS
- Based on density for continuous movements

Following Queue

SIDRA INTERSECTION

Movement Summary

E and 9th Signalized

PM Peak

Signalised - Pretimed **Cycle Time = 100 seconds**

Vehicle Movements

Mov ID	Turn	Dem Flow (veh/h)	%HV	Deg of Satn (v/c)	Aver Delay (sec)	Level of Service	95% Back of Queue (ft)	Prop. Queued	Eff. Stop Rate	Aver Speed (mph)
E st South										
3L	L	45	2.2	0.117	41.5	LOS D	67	0.84	0.74	18.0
8T	T	980	2.0	0.850	47.4	LOS D	681	1.00	0.99	16.7
8R	R	482	2.1	0.466	14.0	LOS B	275	0.43	0.78	28.3
Approach		**1508**	**2.1**	**0.850**	**36.6**	**LOS D**	**681**	**0.81**	**0.91**	**19.3**
9th St East										
1L	L	364	1.9	0.587	38.6	LOS D	373	0.88	0.95	18.9
6T	T	77	2.6	0.151	28.4	LOS C	105	0.80	0.62	21.8
6R	R	617	1.9	0.407	9.5	LOS A	126	0.14	0.66	31.4
Approach		**1059**	**2.0**	**0.587**	**20.9**	**LOS C**	**373**	**0.44**	**0.76**	**24.9**
E st North										
7L	L	633	2.1	0.823	64.3	LOS E	467	1.00	0.96	13.9
4T	T	557	2.0	0.486	31.3	LOS C	334	0.87	0.74	20.9
4R	R	4	20.0	0.480	39.8	LOS D	332	0.87	0.83	18.4
Approach		**1194**	**2.1**	**0.823**	**48.8**	**LOS D**	**467**	**0.94**	**0.85**	**16.5**
9th St West										
2R	R	50	2.0	0.066	10.1	LOS B	17	0.19	0.71	30.8
Approach		**50**	**2.0**	**0.066**	**10.1**	**LOS B**	**17**	**0.19**	**0.71**	**30.8**
All Vehicles		**3811**	**2.0**	**0.850**	**35.7**	**LOS D**	**681**	**0.74**	**0.85**	**19.6**

Pedestrian Movements

Mov ID	Dem Flow (ped/h)	Aver Delay (sec)	Level of Service	95% Back of Queue (ft)	Prop. Queued	Eff. Stop Rate
P1	54	41.4	LOS E	0	0.91	0.91
P3	5	30.4	LOS D	0	0.78	0.78
P5	5	38.7	LOS D	0	0.88	0.88
P7	5	25.9	LOS C	0	0.72	0.72
All Peds	**69**	**39.3**	**LOS D**	**0**	**0.88**	**0.88**

Symbols which may appear in this table:

Following Degree of Saturation
x = 1.00 for Short Lane with resulting Excess Flow
* x = 1.00 due to minimum capacity

Following LOS
- Based on density for continuous movements

Following Queue
- Density for continuous movement

SIDRA SOLUTIONS

Site: Signalized 9th and E PM
E:\Project files\Marysville\E and 9th.aap
Processed Nov 06, 2007 08:59:55AM

A0172, Alternate Street Design, Small Office
Produced by SIDRA Intersection 3.2.0.1455

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