UNCONVENTIONAL ARTERIAL DESIGN
Jughandle Intersection Concept for McKnight Boulevard in Calgary

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ABSTRACT: A functional planning study was initiated along McKnight Boulevard by the City of Calgary in response to the growing traffic and peak hour congestion routinely experienced along the corridor. The objective of the study was to identify and define, the most suitable improvements for medium term (2015 horizon) and long-term (2038 horizon) traffic demands, while conforming to a large number of independent constraints. Numerous alternatives were identified, and in due course rejected, due to their inability to adequately address the project requirements or satisfactorily meet stakeholder needs. Ultimately, a conventional intersection design involving widening along the south side of the corridor and the jughandle intersection concept were short listed for further evaluation and comparison. These design alternatives were subjected to a relatively rigorous appraisal that included performance, signing, laning and signalization requirements, property impacts, access and transit requirements, safety considerations, human factors and environmental impacts to name a few. It was found that operationally, the jughandle intersection design has compelling application potential in high volume corridors where local access is required and full grade separation is impractical or too costly. However, the jughandle property acquisition requirements and resulting costs along highly urbanized corridors, combined with their limited implementation experience in North America, can preclude their use in less than optimum circumstances.

1. INTRODUCTION

Arterial roadways are typically designed and built with the intention of providing superior traffic service over collector and local roads (1). Historically, most arterials constructed in urban centres were not structured to accommodate future growth or expansion (2). In numerous Canadian cities, this growth has resulted in commercial, industrial and residential construction developments that are conterminous to these high volume traffic corridors. Right-of-way limitations often constrain the transformation of an arterial to a higher functional classification roadway. This significantly impacts the operational quality of many arterials, including McKnight Boulevard in Calgary.

McKnight Boulevard, a major east west arterial, provides a classic example of a major roadway with a diminished ability to efficiently move traffic. The adjacent developments and restricted right-of-way, limited the range of potential improvements requiring consideration of less conventional designs to service traffic. Only a conventional intersection treatment and jughandle concept design were advanced to facilitate comparison, however, a variety of geometric intersection configurations were considered as potential improvements to the McKnight corridor. These configurations, in conjunction with the inherent design considerations for the improvement, are discussed further in subsequent sections.

1.1 Arterial Capacity Issues

There are many factors that contribute to the operational efficiency of an arterial corridor. These include the frequency of intersections, the number of lanes and turning lanes, traffic volumes, alignment, width of roadway and access management to name a few (2). In addition, operational and control measures for left-turn maneuvers, especially along corridors with high through volumes, are key to maintaining an adequate level of service.

As the volume along an arterial roadway approaches capacity, delay increases. This is especially true at signalized intersections with a significant cross-street volume. This shortcoming is further compounded in areas that also have a relatively high left turn volume. Often, protected signal phasing at these arterial intersections is required adding to the delay experienced by the through traffic. A common countermeasure to intersection delay is to increase the signal cycle lengths. However, when combined with protective turning and pedestrian phases, the result is often unacceptable delay times and longer queue lengths.

This paper describes the functional planning study process for the McKnight Boulevard arterial corridor in Calgary. It highlights some of the challenges associated with upgrading this section of the corridor, documents key features of the intersection alternatives generated, and briefly provides a comparative analysis of two left-turn intersection treatments. These include a conventional widening that provides left-turn lanes and a jughandle treatment that accommodates left-turns through an indirect movement.

2. BACKGROUND AND ANALYSIS

McKnight Boulevard is a 4-lane east-west, signalized urban arterial, which extends 12km from the east City boundary to John Laurie Boulevard in the west as shown in Figure 1. The McKnight Boulevard Functional Planning Study was initiated in response to the growing traffic and peak hour congestion experienced along the corridor on a daily basis. The study was performed to define the most suitable medium-term improvement and the corresponding ultimate design requirements for the corridor.

The Calgary Transportation Plan, approved by City Council in 1995, established the guidance for transportation planning to the 2025 horizon year. The plan classifies the McKnight/John Laurie link in the municipal street network as Expressway/Freeway, except the 1.2km section between Edmonton Trail (4th Street East) and 4th Street West, which is identified as Major Street. This section of McKnight still provides direct access to numerous local streets, lanes, residential and business properties.

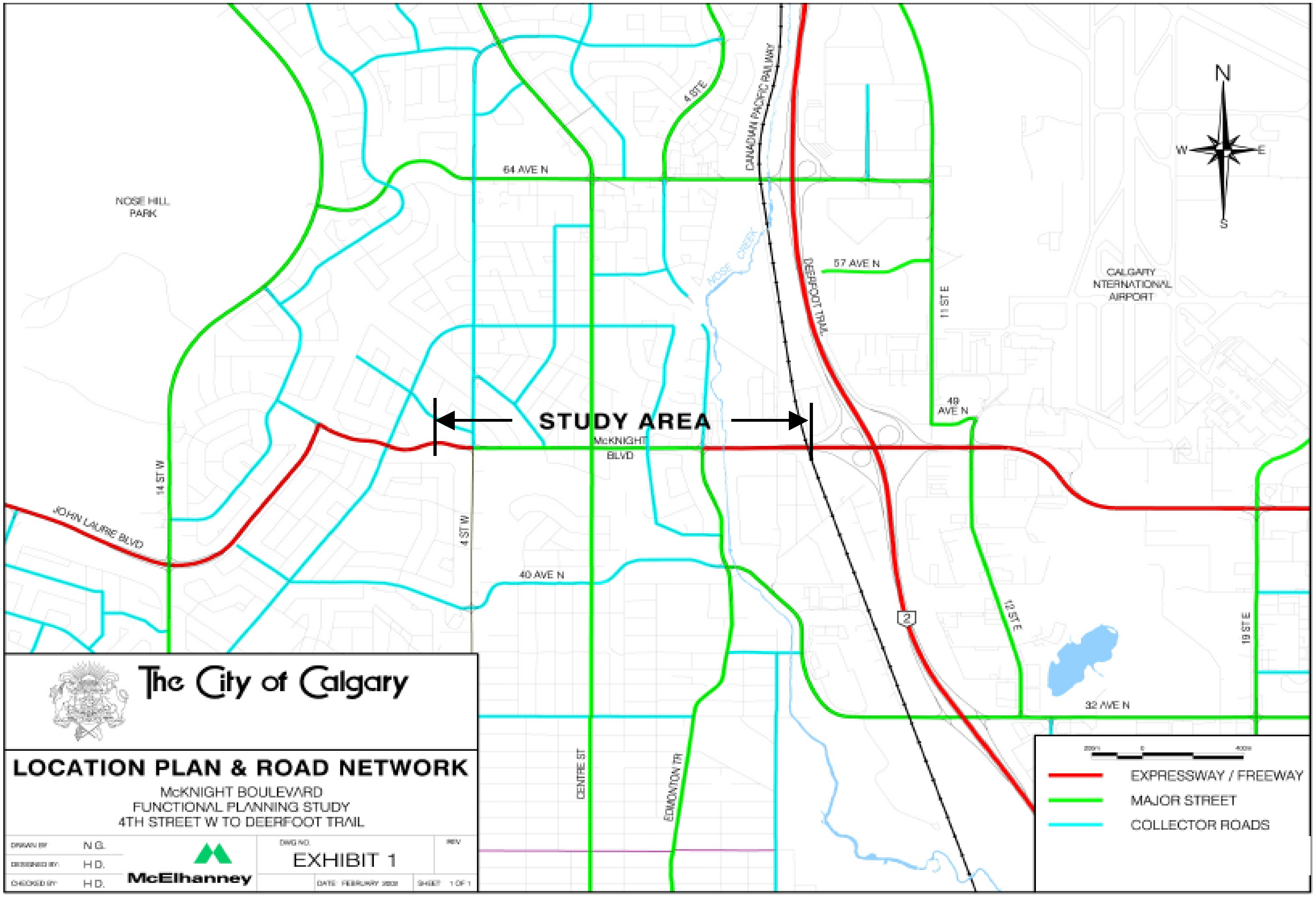


FIGURE 1 – MCKNIGHT BOULEVARD STUDY AREA

Traffic congestion is a daily occurrence along McKnight Boulevard between Deerfoot Trail and 4th Street West. Average annual daily traffic volumes in 1998 of 50,000 vehicles routinely exceeded the capacity of the four-lane roadway, particularly during the peak hours. Westbound PM peak hour traffic approaching Edmonton Trail often backs up across Deerfoot Trail and past Aviation Boulevard. The increased traffic friction associated with this arterial corridor operating at (and occasionally above) capacity results in excessive delay and significant queue lengths.

The 3km of McKnight Boulevard west of Deerfoot Trail, which includes the study area, is a signalized intra-urban arterial, intended to serve local commuters largely traveling between home and work. There is however, some access to industrial lands near Deerfoot Trail. McKnight Boulevard and John Laurie Boulevard form a contiguous east-west arterial, connecting Calgary's future East Freeway with Sarcee Trail in the West. The two nearest alternate east-west routes are Beddington Trail / Country Hills Boulevard, which runs 3.3 to 5.5km to the north, and 16 Avenue (Highway 1), which is 3.2km to the south. The equally congested 16 Avenue presently includes an even longer section of road with multiple traffic signals and poor access control.

Calgary's Transportation Infrastructure Investment Plan (TIIP) has programmed funding for widening this section of McKnight Boulevard from four to six lanes in 2003. Currently forecast traffic growth suggests that a 6-lane roadway may need further improvement by 2015. This was not consistent with the Cities' Transportation Plan, as 2025 horizon year volumes were not adequately accommodated. As a result, alternative improvement strategies were explored to enhance the longer-term requirements while also minimizing the current and future impacts to adjacent residential and business properties.

There were many constraints and secondary objectives also requiring careful consideration during the study to complement the primary improvement objective of enhancing east west service to traffic. In addition to roadway classification and level-of-service objectives, traffic circulation, land use, community access, environmental impacts, and user safety criteria were all important factors that the proposed improvement strategies needed to address. A thorough discussion of these secondary factors as they pertain to the McKnight Boulevard Study, is beyond the scope of this paper. However, subsequent comparisons of the main alternatives will contrast these factors where warranted.

2.1 Traffic and Operations

Network forecasts for the design year horizons provided by the City of Calgary were reviewed and reassigned to evaluate network operations following implementation of a proposed improvement alternative. Establishing relatively accurate reassignment of traffic volume forecasts is a key step toward the development of feasible network alternatives, intersection configurations, warrants for long term grade separation, laning requirements and access management plans. This assessment included interchange / intersection performance at Edmonton Trail (4^{th} Street East), Centre Street and 4^{th} Street West.

It is well known that care and control in arterial access design is vital in maintaining safety and operational efficiency therefore, the study assessment also incorporated a number of the minor intersections between the three major ones noted above. Many of these minor intersections are right-in / right-out and as a result have a reduced impact on the operational efficiency of the corridor, especially in the competing direction.

Traffic volumes for the Deerfoot Trail / McKnight Boulevard interchange were recorded by the Province of Alberta in May 2001. The results indicated that approximately 60% of the volume approaching Deerfoot Trail from the west along McKnight Boulevard travels east across the interchange, and 30% heads south along Deerfoot. This suggests that the industrial areas east of Deerfoot are a significant source of peak-hour trips for commuters using the McKnight/John Laurie Boulevard corridor.

FIGURE 2 – TYPICAL SECTION ALONG MCKNIGHT BOULEVARD

Figure 2 shows a typical section along McKnight Boulevard looking east towards the Edmonton Trail intersection. The Deerfoot Trail interchange is also visible on the horizon. In 2001, there were more than 50,000 vehicles per day entering or exiting McKnight Boulevard from the east through the Deerfoot Trail interchange area. A significant proportion of these vehicles traverse the corridor to/from John Laurie Boulevard on the west. There were also more than 50,000 vehicles per day entering or crossing the McKnight corridor traveling north-south to downtown Calgary along either Edmonton Trail, Centre Street or 4th Street West. Centre Street and Edmonton Trail carried 20% and 40% more traffic respectively than 4th Street West.

Edmonton Trail is the highest volume intersection, with the greatest number of turning movements, and of the three major intersections, is the only one that is fully channelized. The higher volumes at this intersection may be due to the adjacent industrial parks' access points not found at the other locations. Fifty percent of the traffic on the north leg enters the Skyline Industrial Park and 25% enters the two commercial quadrants. Fourth Street East dead-ends north of McKnight and therefore only 38% of the traffic travels north south through the intersection.

2.2 Existing and Future Traffic

This study used Synchro and Simtraffic software to analyze and design all intersections and/or interchanges along the McKnight Boulevard corridor, and to evaluate performance of the adjacent road network, for the 2003, 2015 and 2038 design horizons.

Table 1 shows a PM peak hour traffic volume comparison at key locations for 2001, existing conditions and for each horizon.

TABLE 1 – TRAFFIC VOLUME COMPARISON – PM PEAK HOUR

Intersection	Location	2-Way Traffic Volume (vph)			
		2001	**2003**	**2015**	**2038**
McKnight Blvd	East of 4 St East	3,827	4,010	5,560	7,230
	West of 4 St West	3,727	4,370	4,590	5,650
Edmonton Tr	North of McKnight	1,590	1,920	2,200	2,370
	South of McKnight	1,530	1,710	1,980	2,480
Centre St	North of McKnight	1,120	1,510	1,560	1,750
	South of McKnight	1,160	1,320	1,860	2,400
4th St West	North of McKnight	1,457	1,550	1,780	2,050
	South of McKnight	1,356	1,460	2,000	2,550
Intersection	**Location**	**Percentage Increase Since 2001**			
		2001	**2003**	**2015**	**2038**
McKnight Blvd	East of 4 St East	-	5%	45%	89%
	West of 4 St West	-	17%	23%	52%
Edmonton Tr	North of McKnight	-	21%	38%	49%
	South of McKnight	-	12%	29%	62%
Centre St	North of McKnight	-	35%	39%	56%
	South of McKnight	-	14%	60%	107%
4th St West	North of McKnight	-	6%	22%	41%
	South of McKnight	-	8%	47%	88%

McKnight Boulevard currently carries approximately 4000 vph during the PM peak hour. Traffic volumes are projected to increase to between 5,650 vph, west of 4th Street West, and over 7,200 vph, east of 4th Street East / Edmonton Trail. In terms of percentage increase, traffic volumes are estimated to increase substantially by 2038, in the order of 50% to 100%. Notwithstanding calculation details, the 2003 level of service for the weekday AM and PM peak hours are shown in Table 2 as are the average delay times experienced at each of the three major intersections.

TABLE 2 – 2003 LEVEL OF SERVICE AND AVERAGE DELAY (SEC/VEH)

Intersection Location	LOS / Delay	
	AM	PM
McKnight / 4^{th} St West	C / 30.7	E / 68.0
McKnight / Centre Street	F / 96.4	E / 56.2
McKnight / Edmonton Trail	E / 70.5	D / 49.1 *

*Some individual movements operating at LOS E or F

The volume-to-capacity (v/c) ratio is another indicator of intersection performance. An intersection with acceptable delay, but high v/c ratio can signify the presence of queues. A v/c ratio above 1.0 for any individual movement indicates that it is operating over capacity. Generally, v/c ratios below 0.90 are considered acceptable. Table 3 presents v/c ratios based on 2003 volumes for the McKnight major intersections. Movements with v/c ratios above 0.90 are highlighted in bold.

TABLE 3 – MCKNIGHT BOULEVARD INTERSECTION V/C RATIOS

<table>
<tr><th colspan="2" rowspan="3">Intersection Movement</th><th colspan="6">2003 Volume to Capacity Ratios</th></tr>
<tr><th colspan="2">4th St West</th><th colspan="2">Centre</th><th colspan="2">Edmonton</th></tr>
<tr><th>AM</th><th>PM</th><th>AM</th><th>PM</th><th>AM</th><th>PM</th></tr>
<tr><td rowspan="3">Eastbound</td><td>Left</td><td>0.32</td><td>1.23</td><td>0.06</td><td>0.72</td><td>0.70</td><td>0.97</td></tr>
<tr><td>Thru</td><td>1.02</td><td>0.89</td><td rowspan="2">1.39</td><td rowspan="2">1.02</td><td>1.28</td><td>1.08</td></tr>
<tr><td>Right</td><td>0.25</td><td>0.10</td><td>0.31</td><td>0.10</td></tr>
<tr><td rowspan="3">Westbound</td><td>Left</td><td>0.52</td><td>0.76</td><td>0.71</td><td>0.27</td><td>1.13</td><td>1.07</td></tr>
<tr><td>Thru</td><td>0.58</td><td>1.21</td><td rowspan="2">0.56</td><td rowspan="2">1.08</td><td>0.71</td><td>0.95</td></tr>
<tr><td>Right</td><td>0.03</td><td>0.12</td><td>0.44</td><td>0.31</td></tr>
<tr><td rowspan="3">Northbound</td><td>Left</td><td>0.25</td><td>1.31</td><td>0.57</td><td>0.73</td><td>0.32</td><td>0.97</td></tr>
<tr><td>Thru</td><td rowspan="2">0.46</td><td rowspan="2">0.80</td><td rowspan="2">0.39</td><td rowspan="2">1.02</td><td>0.25</td><td>0.74</td></tr>
<tr><td>Right</td><td>0.83</td><td>0.84</td></tr>
<tr><td rowspan="3">Southbound</td><td>Left</td><td>0.44</td><td>0.70</td><td>1.05</td><td>0.80</td><td>1.08</td><td>1.06</td></tr>
<tr><td>Thru</td><td rowspan="2">0.85</td><td rowspan="2">0.80</td><td rowspan="2">1.06</td><td rowspan="2">0.28</td><td>0.37</td><td>0.54</td></tr>
<tr><td>Right</td><td>0.27</td><td>0.96</td></tr>
</table>

Based on the 2003 traffic volume operational analysis, it is easy to surmise that without improvements to the corridor, horizon year levels of service would be unacceptable and average delay times would be excessive.

3. GENERATION OF ALTERNATIVES

A total of six distinct preliminary functional plans were developed within the project scope to ultimately improve corridor mobility. These alternatives evolved and were refined in response to public and stakeholder input. A significant part of this study involved the preparation and implementation of a comprehensive communications plan that included a public consultation program. Details of the process are beyond the scope of this paper, however, through this process, stakeholders had an opportunity to provide feedback on the alternatives and remain appraised of the project developments throughout its duration. The improvement strategies considered were:

1. Do-Minimum Improvement
2. Widening Generally to the North Side
3. Symmetrical Widening
    i. Alternative 3 with Interchange at Centre Street
    ii. Alternative 3 with Transit and Reversible Lanes at Centre Street
4. Widening Generally to the South Side
5. Jughandle Ramps at Key Intersections
6. Interchange / Freeway Option (Functional classification upgrade)

All of the improvement alternatives identified were subjected to a thorough evaluation process. In addition to the primary objective of improving traffic and operations, the alternatives had to be constructible under traffic, address environmental considerations including traffic noise attenuation, and accommodate the Cities' long-range strategic transit plans. Pedestrian and cycling routes, neighbourhood access and circulation, aesthetics, structural widenings or retrofits, socioeconomic considerations, capital cost and right-of-way acquisitions are other factors that were considered during the evaluation of alternatives.

Of the improvement strategies noted above, only Widening Generally to the South Side (No. 4) and Jughandle Ramps at Key Intersections (No. 5) were deemed to be viable alternatives. The widening alternative would generally be considered a conventional improvement while the jughandle ramps option is classified as an unconventional treatment. A comprehensive discussion on unconventional arterial intersection treatments can be found in the literature and will not be repeated here. However, a brief discussion on this topic is warranted so the reasons for not considering other unconventional intersection treatments are clear to the reader.

3.1 Unconventional Intersection Treatments

Many signalized arterial intersections experience delay and long queues as a result of vehicle congestion. Congestion issues are so broad that no single solution is capable of alleviating the problem. Transportation engineers have traditionally focused on treating left turn movement to and from arterial roadways as these movements cause many of the operational and capacity problems on these types of corridors. Multiple left turn lanes, actuated traffic signals, parallel one-way streets and time of day restrictions on certain movements are several methods commonly employed to address these disruptive left turn movements. Unconventional intersection alternatives focus on reducing delay for through movements, reducing intersection conflict points and physically separating the conflict points that remain (5).

The five unconventional treatments that had potential for implementation along the McKnight corridor included median u-turns, bowties, continuous flow intersections, superstreets and jughandle ramps. There are other unconventional intersection treatments documented in the literature. However, the five mentioned have the greatest potential for implementation, and in most cases, are already in limited use in other North American jurisdictions. Table 4 illustrates these alternative intersection treatments.

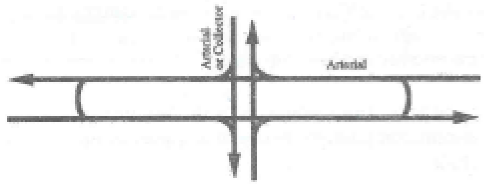
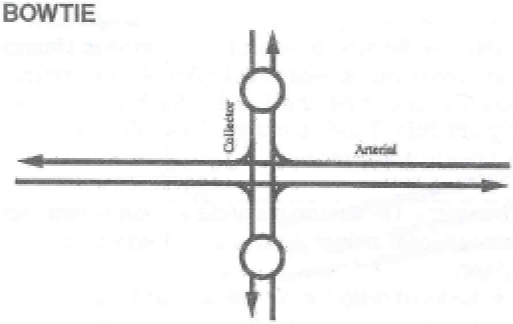
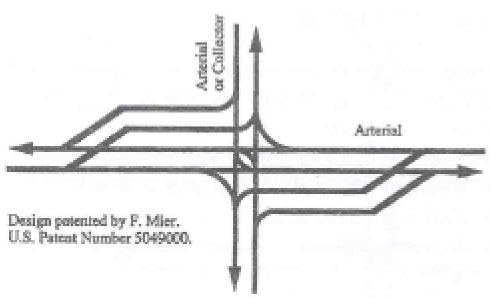
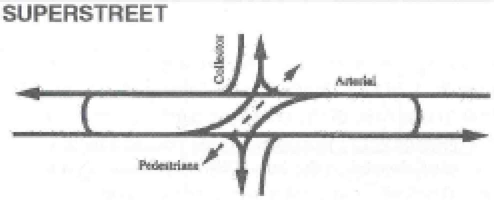
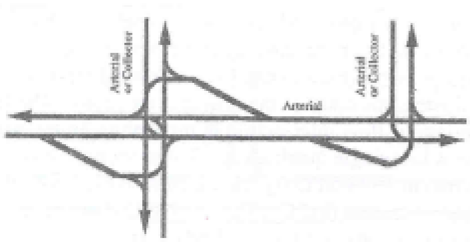
The median U-turn configuration prohibits left turns at the intersections and requires these movements to occur at directional median crossovers. Vehicles wishing to turn left from the main arterial to the minor collector or cross street must first travel through the intersection, make a U-turn at the median crossover and then make a right at the intersection. Vehicles turning left onto the arterial from the cross street first must turn right on the arterial and then utilize the median crossover to reverse direction.

The bowtie alternative also prohibits left turns at the intersection. Vehicles are required to turn right off the main arterial onto the collector, proceed some distance to a roundabout and then reverse back through the arterial intersection. U-turn movements from the main arterial follow a similar path but in addition vehicles would then proceed to the opposing roundabout to reverse directions yet again. Only through and right turn movements are permitted with this configuration requiring vehicles to enter the intersection up to three times in order to make a U-turn from the main arterial.

The continuous flow intersection uses separate ramps to isolate turning movement to and from the main arterial. This design, patented by Francisco Mier, requires considerable right-of-way at the intersection to accommodate the requisite number of parallel lanes.

The superstreet design eliminates through and left turn movements from the minor street to the arterial. These movements are accommodated using directional crossovers along the arterial itself. Left turn movements from the arterial to the minor collector are routed to dedicated ramps. Next to interchanges, the superstreet design provides the most efficient movement of through traffic (3).

TABLE 4 – SEVERAL ALTERNATIVE INTERSECTION TREATMENTS (3)

ALTERNATIVE DESIGNS	WHEN TO CONSIDER
MEDIAN U-TURN 	• On arterials with wide medians • High arterial volumes conflict with low or moderate left turn volumes • On arterials with good prospects for obtaining additional ROW • Minimum potential for driver spillback
BOWTIE 	• High arterial volumes with moderate to low left turn and cross street volumes • On arterials with narrow medians and no prospects for obtaining ROW • When adjacent collectors will not require expansion beyond 2 lanes • Where adjacent collector ROW acquisition possible
CONTINUOUS FLOW INTERSECTION 	• On arterials with high through volumes and little to no U-turn demand • When significant ROW exists at intersections • Access to land adjacent to intersection is not required
SUPERSTREET 	• Where close to 50/50 arterial through traffic splits exist for most of day • On arterials with wide ROW or potential to obtain ROW • On arterials that have an uneven spacing of cross streets
JUGHANDLE 	• On arterials with a narrow ROW • Where high through volumes conflict with low to moderate left turn volumes • Where intersection spacing is large enough to allow savings to offset extra ROW costs.

The jughandle intersection eliminates all turns to the minor arterial or collector at the main intersection. Drivers attempting to make a left or right turn on to the minor street must use the right hand ramp before the intersection. Left turn vehicles proceed to the end of the ramp, turn left on to the collector street and proceed through the main arterial intersection. Vehicles turning right exit on the right hand ramp and continue right.

Although not as enigmatic as some of the alternatives identified above, roundabouts are still relative newcomers as far as intersection treatments. Under certain conditions, roundabouts offer significant operational advantages over conventional signalized intersections and are quickly gaining popularity in many jurisdictions. The McKnight corridor volumes were however, higher than could be satisfactorily serviced with roundabouts at the main intersections and they were therefore not considered in detail.

When considering implementation of a relatively new or innovative design, concerns ultimately arise regarding driver understanding and expectancy. All of the unconventional design configurations identified above requires the driver to navigate through 'unnatural' movements to which they are currently not accustomed. Thompson and Hummer (2001) evaluated vehicle movements on these unconventional intersection treatments and compared them to four types of conventional intersections. They found that next to the conventional intersections, the jughandle contained the least number of unnatural movements compared to the other designs.

These alternative intersection designs can potentially reduce congestions along arterial corridors but only if the drivers understand how to properly use the configurations. Public information and education campaigns have been used by jurisdictions where these designs have been implemented including Michigan, New Jersey, Texas and North Carolina to name a few. These campaigns have helped drivers understand the operations of these unconventional designs before they are constructed minimizing the length of time required for driver adaptation (4).   It is also advantageous when considering implementation of an unconventional configuration, to use them contiguously at more than one location on the corridor.   This further promotes driver adaptation and works to improve driver expectancy (5).

Due to the limited right-of-way width on McKnight combined with reduced and separated conflict points provided by the jughandle design, it was determined that this alternate type of intersection could potentially meet the project objectives in a satisfactory manner. Jughandle alternatives have already been implemented effectively, both in Canada and the USA as documented in the following section. It should be noted that the pedantic review of unconventional intersections presented in this section was not documented in the original study and has only been included to benefit the reader.

3.2 Jughandle Experience in Other Jurisdictions

<u>State of New Jersey</u>

Jughandle intersections have been used by the NJDOT for a number of decades, and are generally located in rural or semi-urban settings. New Jersey uses several different types of jughandles, as follows:

- Forward, Upstream, Near Side
- Reverse, Downstream, Far Side
- U-Turn
- Around the Block
- Divided or Undivided

The NJDOT has found the advantages using a jughandle design are:

- High-speed traffic keeps left, lower speed differential is safer.
- Fewer traffic signal phases, greater capacity and less delay.
- Fewer conflict points, greater safety.
- Provides area for landscaping, drainage detention and water quality enhancement.
- Compliments median barrier designs on urban streets.

The NJDOT has found the disadvantages using a jughandle design are:

- Require more right-of-way, costly in an urban setting.
- Increases travel distances for some movements.
- Some vehicles have to go through a signal more than once.
- Unfamiliar to some drivers; however careful signing and an education program can address this.

The NJDOT has found that jughandle designs generally improve intersection safety, capacity and travel time. The alternative proposed for the McKnight corridor was a Forward or Upstream jughandle design.

City of Edmonton

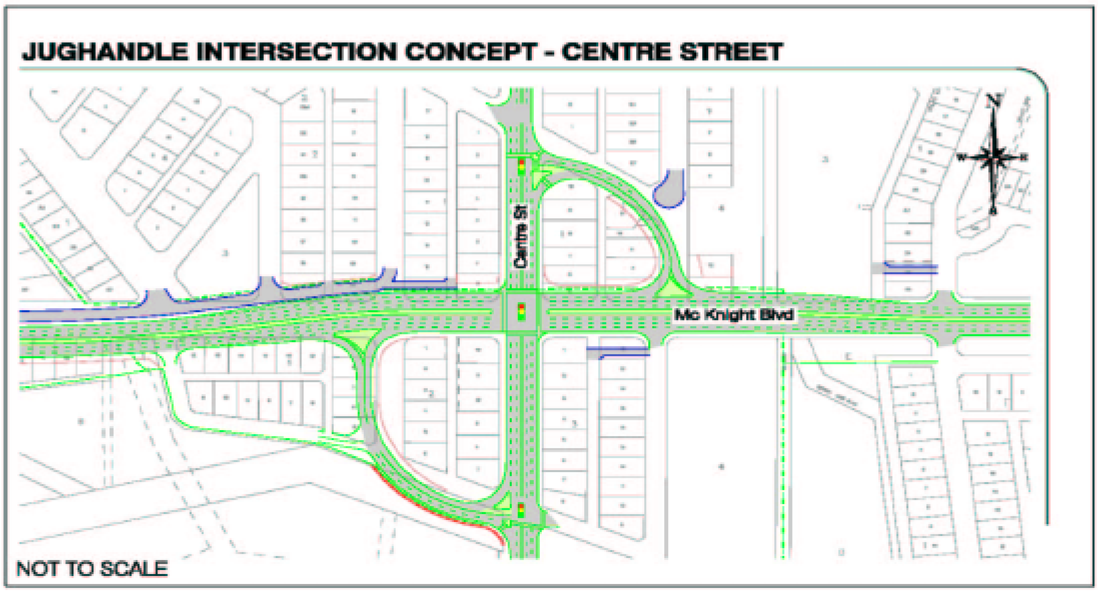
The City of Edmonton operates jughandle intersections in four locations. Some have been in place for several years. The intersections are all around-the-block designs with a loop movement exiting right on the far side of the intersection. There are development and access points along each of the jughandle loops. The loops are all retrofit designs, located on busy city arterials near commercial and industrial areas and all accommodate truck flows. Only one is located near a residential area; therefore the retrofit applications, which required little new right-of-way, encountered minimal community objection.

The City of Edmonton receives few complaints regarding these intersections. Drivers understand their use and there is no notable accident experience attributable to the jughandle designs. Intersection capacity and safety improved at these locations due to the implementation of these designs.

For these documented reasons, and given that jughandle intersections have been successfully utilized in other jurisdictions, the design team was compelled to consider the jughandle as an alternate intersection treatment for the McKnight corridor. The conventional south side widening option and the jughandle treatments designs were developed further and subjected to a performance comparison to help determine the most applicable solution in easing the existing and horizon year congestion along McKnight Boulevard.

4. COMPARISON OF ALTERNATIVES

Figure 3 shows the two typical intersection concepts considered for the major crossings along McKnight. The geometry shown is for the Centre Street / McKnight Intersection.



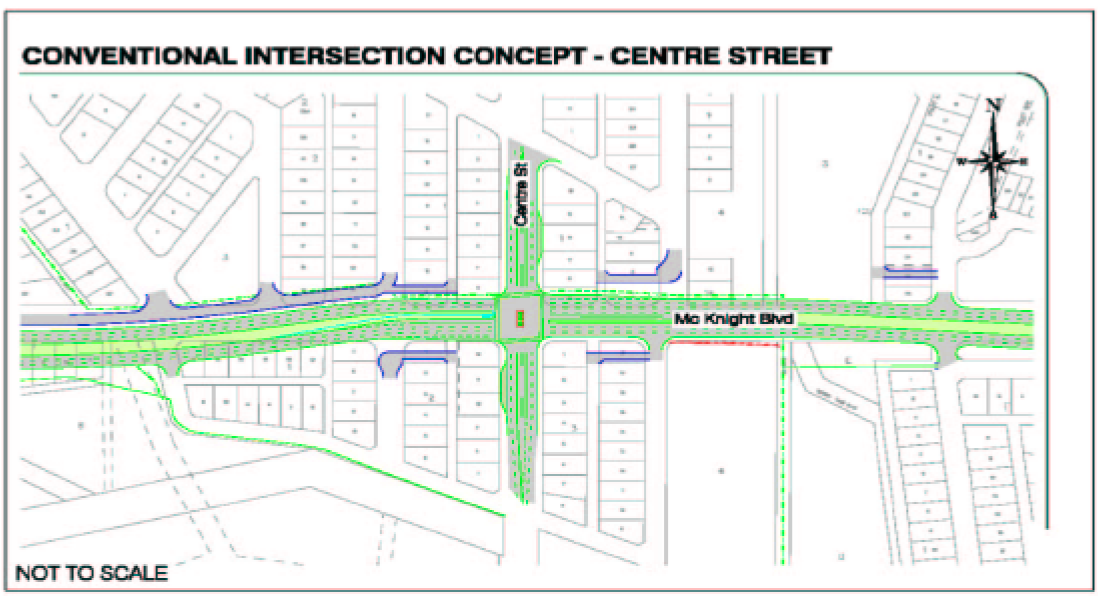


FIGURE 3 – CONVENTIONAL AND JUGHANDLE INTERSECTION CONCEPTS

Both intersection concepts were reviewed for property impacts, level of service, constructability and capital cost to help identify which treatment was most consistent with the project objectives. In addition, they were also subjected to a human factors and safety audit review to further flesh out the most viable improvement strategy.

4.1 Travel Times and Level of Service

Table 4 compares travel times for east west through traffic along McKnight Boulevard during the peak hours for the two options. Travel times using the jughandle intersections is nearly half of those with the conventional intersections for the 2015 horizon and is estimated to be even greater in 2038. The reduced 2015 jughandle travel times are realized despite requiring two less lanes than the conventional alternate.

Table 4 – EAST WEST TRAVEL TIMES ALONG MCKNIGHT

Direction		Eastbound AM Peak Hour			Westbound PM Peak Hour		
Attribute		Signal Delay	Travel Time	Average Speed	Signal Delay	Travel Time	Average Speed
		(sec.)	(sec.)	(km/h)	(sec.)	(sec.)	(km/h)
Existing Conditions		139	265	20	140	287	23
2015	Conventional 6 lanes	142	235	23	153	263	25
	Jughandle 4 lanes	33	126	43	45	154	42
2038	Conventional 6 lanes	246	339	16	198	307	21
	Jughandle 6 lanes	46	140	39	38	147	44

Table 5 – 2038 LEVEL OF SERVICE AND MOVEMENT SUMMARY

Intersection along McKnight	4th Street West		Centre Street		Edmonton Trail	
	AM LOS	PM LOS	AM LOS	PM LOS	AM LOS	PM LOS
Conventional	F	D	F	E	F	E
Jughandle	C	B	B	B	B	B
Movement Summary	**No. of Failing Movements / Total No. of Movements**					
Conventional	4 / 12	6 / 12	7 / 10	4 / 12	4 / 12	5 / 12
Jughandle	0 / 4	0 / 4	0 / 4	0 / 4	2 / 6	1 / 6

Table 5 presents a level of service summary for the corridor using 2038 traffic volumes. Also shown are the total number of movements for each intersection and intersection type as well as the number of failing movements out of total movements at each location. Project objectives dictated a level of service ‘E’ or better at the 2038 horizon year.

The jughandle concept provides a superior level of service compared to the conventional intersections even at the 2038 horizon. In addition, the turning movement summary shows that only the Edmonton Trail / McKnight intersection will experience isolated failure at 2038 using jughandles (2 / 6 = 33% max.). Every conventional intersection would have 33% to 70% of their total movements failing by the 2038 horizon.

4.2 Other Considerations

Although the jughandle design offers the greatest long-term improvement in level of service and is the only alternative that accommodates future Express Transit Service along Centre Street (a secondary project objective) it does have its disadvantages. This concept would be introducing a new untried intersection configuration in the City of Calgary. It also incurs a significant property impact compared to the conventional design alternative. The larger property impact associated with the jughandle design translates to an increased capital cost due to additional right of way acquisition requirements.

Moreover, jughandle intersections have laning requirements that are quite different from conventional intersections. They also have more complex signing requirements and due to their somewhat limited use as yet in North America, have a potential to violate driver expectancy. This may increase the probability of driver error and response times. These shortcomings however, can be readily overcome through the design and placement of sign information. Sign design and placement should be dictated by following the principles of Positive Guidance. These include primacy (placement), spreading (multiple signs), coding (colour and shape), redundancy (need repetitiveness), and driver expectancy.

Signalization requirements at the jughandle ramp terminals (along the minor arterial or collector) are another factor requiring consideration. It is anticipated that the jughandle left turn movements at the cross streets will be stop sign controlled and the major intersections will be signalized. As turning and through volumes increase it will be necessary to signalize some of the jughandle terminals. Signalization requirements summarized in Table 6 for each of traffic forecast horizons are based on the results of the traffic simulations.

TABLE 6 – JUGHANDLE CONCEPT SIGNALIZATION REQUIREMENTS

Crossing Street	Jughandle Terminal Intersections	Traffic Control Device Design Horizon		
		2003	2015	2038
4 Street NW	Thornhill Dr. McKnight Blvd. SW jughandle	Signalize*	- Signalize	Signalize - -
Centre Street	NW jughandle McKnight Blvd. Laycock Dr.	Signalize*	-	Signalize - Signalize
Edmonton Trail	Goddard Ave McKnight Blvd. SW jughandle	Signalize* Signalize*	- - Signalize	- - -

* Indicates location of existing traffic signals

The presence of three closely spaced intersections controlled by traffic signals on the north south streets is likely an unexpected situation in the minds of most drivers. Concerns were raised that drivers may be unaware of the situation and that they may attend to a signal further upstream when approaching the nearest signal. This potentially problematic situation could only occur if the minor street signals were not properly synchronized. Moreover, as shown in Table 6, three closely spaced signalized intersections at all locations would not be required until 2038 allowing ample time for driver familiarization with the jughandle operations, notwithstanding their potential implementation in other locations and jurisdictions by that time.

5. SUMMARY

The jughandle intersection alternative was identified as the preferred technical option.

Pros

- Left-turn movements are removed from both the main and intersecting roadways.
- Signal phasing is simplified and green time is maximized.
- Peak-hour performance improved by increased capacity & reduced accident potential.
- Lower costs and impacts than full freeway design.
- Accommodates secondary project objectives such as future north south transit and efficient pedestrian movements

Cons

- Potentially there are three closely spaced signals on the intersecting roadways.
- Higher costs and property impacts than conventional intersection design.

TABLE 7 – OVERVIEW COMPARISON OF INTERSECTION ALTERNATIVES

Attribute	Intersection Alternative	
	Conventional Intersections Widen to South	Jughandle Ramps at Key Intersections
Basic Lanes	6	6
Cost	$24M	$36M
Constructability (detour impacts)	Moderate	Moderate
Service Life to Next Upgrade	No more than 10 years	30 years
Operation	Conventional Design	New Concept
Access Management	Good	Good
Houses Acquired	29	67
Businesses Acquired	4	4
Neighbourhood Disruption	Moderate	High

Table 7 provides an overview of the two intersection alternatives considered for the McKnight corridor. The unconventional jughandle intersection design has compelling application potential in high volume corridors where local access is required and full grade separation is impractical or too costly.

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