Effective Speed Management Measures: Methodology and Application in City of Edmonton

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ABSTRACT

Every year, staff and members of Council of communities of all sizes along Canada receive numerous complaints from residents regarding vehicles speeding along residential roads. Although traffic volumes on these types of streets can be considered minor, traffic speeds detected in such types of road are causing a concern. Aside of law enforcement, the most common response to these complaints is the implementation of traffic calming since this type of engineering measure has the potential not only to lessen the direct negative impact of road traffic, but to promote the integration of urban environments in which all modes of transportation can be adequately integrated as part of the roadway network. However, many of these attempts have shown questionable effectiveness in reducing travelling speed “corridor-wide” with a perceived effect limited to the area surrounding a traffic calming device. Through a comprehensive literature search and jurisdiction scan approach; this paper investigates the effectiveness of speed management measures while considering the following factors: 1) self-enforcement measures; 2) corridor-wide effect; 3) before and after study findings; and 4) potential impacts on transit routes, emergency vehicle response time, snow removal activities and pedestrian/cyclists. The results of this investigation are summarized in a selection matrix format for the most effective speed management measures. A methodology for applying these measures on collector roads is introduced by considering the context-sensitive characteristics of the study area and the speed management selection matrix. This methodology is then applied to two case studies on the City of Edmonton roads.
INTRODUCTION

Rationale for Speed Management vs. Traffic Calming
What is referred to as traffic calming and speed management in previous studies often has many synonyms in different countries, cities, and jurisdictions. For example, In San Jose, CA, it is called “neighbourhood traffic management”; in Boulder, CO, it is “traffic mitigation”; in Sarasota, FL, it is traffic abatement, and another common name is “neighborhood traffic control”, ITE/FHWA (1). In many North American (NA) and European cities, the most common names are “traffic calming” and “speed management” (2). In this respect, the subcommittee on Traffic Calming of the Institute of Transportation Engineers (ITE) defined traffic calming as “the combination of mainly physically measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorized street users” (3).

Since traffic calming measures as defined by the ITE subcommittee rely on the laws of physics rather than the human psychology to slow down traffic, it is reasonable to assume that traffic calming refers primarily to measures that affect travel speeds. Traffic management, on the other hand, attempts to control the volume of traffic through the use of regulatory devices such as turn prohibitions or one-way streets. Although these naming conventions may refer to different measures and implementation strategies, these names are used interchangeably in the literature and in practice.

Typical traffic calming measures aim to reduce speed as well as other combinations of volume and collisions. Speed management, on the other hand, goes beyond the localized traffic calming initiatives by managing speeds in a “corridor-wide” environment by deploying physical measures, visual treatments and changing drivers’ habits and enforcement (2). This approach is known as self-explaining roads (SERs) or self-enforcing roads (SERs) which primarily uses road design elements to evoke correct and expected driving behaviour from road users (4). Speed management is now extended to a variety of measures applied to all types of roads, including collector roads and highway as well as urban arterial roads, to cope more safely with increasing flow and speeding traffic.

In the context of this paper, we focus on speed management techniques that have the potential to reduce speeds while harnessing some traffic calming measures that focus on speed reduction and control. While speed management measures aim at reducing speeding and collisions they could also negatively affect the operation of transit vehicle, response time of emergency vehicles, and sometime pedestrians and cyclists; an issue that we discuss in the paper.

Research Motivation and Objectives
Speed management measures have been widely implemented worldwide at different capacities with some successful implementations (mainly reported based on before-and-after studies) but also with some questionable effectiveness of some of these measures. Identifying effective and proven speed management measures adds a number of questions. First, what is the experience of jurisdictions/cities with the measure? Second, what is the effectiveness of the measure when applied along a corridor? Moreover, does the measure introduce a self-enforcement solution while considering the perception of drivers? What are the side effects of implementing the measure? and finally, after identifying effective speed management measures, how these measures could be implemented given the context-sensitive nature of each speeding problem including: roadway features and characteristics, magnitude of reported speed violation, existence of transit service, emergency routes, on-street parking, to name a few.

With these questions in mind, the objectives of this research are structured as follows:

- Conduct a literature search to document the experience of jurisdictions/cities when applying short term or long term speed management measures;
- Evaluate the significance of speed management measures and identify the most effective reported measures in a selection matrix format;
- Identify the side effects of implementing speed management measures;

- Develop a methodology for implementing speed management measures by considering the context-sensitive characteristics of the study area and the speed management selection matrix;
- Implement the speed management methodology on a Case Study.

This research constitutes a comprehensive review and evaluation of effective speed management measures, while applying the results of this evaluation on a case study on the City of Edmonton roads. In this research the authors do not attempt to conduct a before and after study as this has to be contemplated by the City of Edmonton which was not ready at the time of this research.

**COMPREHENSIVE EVALUATION OF SPEED MANAGEMENT MEASURES**

**Literature Search and Jurisdiction Scan Approach**

A number of Canadian municipalities, US cities, and OECD countries with significant traffic calming experience formed the list for literature search on traffic calming and/or speed management policies. In addition, the most common cities cited in the "ITE Canadian Guide to Neighborhood Traffic Calming" (3) Findings from design manuals, guidelines and reports were also used to complement the experience of different cities/jurisdictions with speed management measures (5-8)

Our approach in conducting the literature search and jurisdiction scan focused on evaluating both traffic calming and speed management measures with proven effectiveness for speed reduction using the following criteria:

- Example Installation: cities that have implemented the measure;
- Applicability and Locations to Avoid: applicable (or avoidable) locations and streets;
- Potential Advantages: speed reduction, volume reduction, conflict reduction, environment;
- Potential Disadvantages: emergency response, maintenance and winter, significant disadvantages;
- Jurisdiction Experience and Recommendations; and
- Literature Review Search: guidelines, manuals, scientific papers.

**Effectiveness of Traffic Calming Measures**

The summary shown in Table 1 builds on the findings of the jurisdiction scan and literature search while focusing on measures that shows at least 3kph reported speed reductions.

**TABLE 1 Summary of Significant Speed Reduction Measures**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Studies show potential to reduce speed (in kilometres per hour) or percentage of reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raised Crosswalk</td>
<td>6 to 12 kph</td>
</tr>
<tr>
<td>Rumble Strip</td>
<td>3 to 8 kph</td>
</tr>
<tr>
<td>Speed hump</td>
<td>6 to 25 kph</td>
</tr>
<tr>
<td>Speed Tables</td>
<td>around 11 kph and by up to 60% in countries like China</td>
</tr>
<tr>
<td>Speed Cushions (Lumps)</td>
<td>10% speed reduction</td>
</tr>
<tr>
<td>Chicane</td>
<td>6 to 15 kph and by 26% in some cities</td>
</tr>
<tr>
<td>Curb extension/ neckdown/ chokers</td>
<td>1.5 to 8 kph and by 26% in some cities</td>
</tr>
<tr>
<td>Raised median island</td>
<td>3 to 8 kph</td>
</tr>
<tr>
<td>Traffic circle (sometimes referred to as mini-roundabouts)</td>
<td>6 to 14 kph</td>
</tr>
<tr>
<td>Roadway Narrowing (lane narrowing)</td>
<td>1.5 to 10 kph and by 21% in some cities in England</td>
</tr>
<tr>
<td>Road Diet</td>
<td>5 to 12 kph and by 12%-32% in New Zealand and Vancouver</td>
</tr>
</tbody>
</table>

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Effectiveness of Speed Management Measures

Despite the large number of studies concerning speed management and traffic calming measures, very few reports include results of a systematic evaluation methodology to quantify the effectiveness of such measures. In addition, the majority of studies focused solely on before-and-after analysis without considering other dimensions such as: time of analysis (e.g., off peak vs peak periods), season of analysis (e.g., winter vs summer), location of analysis (spot location, along a corridor, area-wide), active modes of transportation (pedestrians and bicyclists), spatial variation of measures (e.g., influence zone vs spontaneous effect) (9-12).

It is therefore essential to assess the system wide impacts of these measures if applied individually or in combination with other measures. Therefore in this paper close attention was given to review studies that reported reduction in speed using systematic evaluation perspectives, including the following factors: 1) self-enforcement, 2) corridor-wide effect, 3) before and after study findings, and 4) potential impacts.

Self-Enforcement

In accordance with Lockwood (13) the self-enforcement aspect of traffic calming focused on “altering driver behavior” in order to lower speeds, reduce aggressive driving and increase respect for non-motorized users of the streets.

The most common method to achieve a self-enforcement speed management environment is to locate a series of speed management measures in a sequence that adapts the driver behaviour by generating a smooth “slow-and-go” speed profile as shown in FIGURE 1-a.

In this respect, the most common source of midpoint speeds identified in the literature search is based on the ITE/FHWA “Traffic Calming – State of Practice”, the findings of which indicate that (1):

- Measures such as 22-foot tables and longer tables (raised crosswalks and speed tables), circles (traffic circles), and narrowings (curb extension/neckdown/chokers, sidewalk extension and raised median island) have a proven effect on speed reductions after implementation, and
- A series of those measures adequately located along a corridor will create a self-enforcement environment in which the observed 85th percentile speed between measures may be reduced by a range of 4 - 18 %.

Corridor-Wide Effect

It should be noted that speed reduction obtained after implementation of a series of measures along a corridor depends on: the current prevailing speed, its relation to the desired speed, and the type and location of the selected measures.

Although guidelines and standards of practice such as in (1,3) do not provide explicit details about the expected speed reductions of these types of combined treatments; more recent research discussed the use of 85th percentile speed at midpoints, speed profiles, zone of influence and variation in speed to estimate the scheme-wide effects of traffic calming (14-18). (see FIGURE 1-b).

In addition the distance between measures will directly affect the effectiveness of the selected measures.

If a longer spacing between measures is provided, higher midpoint speeds will be observed (16). Based on the physical relationship between those elements, it is possible to estimate maximum spacing of speed management measures in order to maintain a “desirable speed” between measures and create a “corridor-wide” speed management effect.
FIGURE 1 Zone of Influence and Speed Differential of Multiple Measures for Self-Enforced Roadways.

After considering the approaches/equations for determining the required spacing of speed management measures, it is possible to assume that:

- If the 85th percentile speed of the collector before implementation is available, the equation provided by the City of Anaheim to calculate 85th percentile speed at midpoint after implementation is the most comprehensive (15);
- The location of speed management measures such as raised crosswalks, speed tables and traffic circles can be estimated in order to maintain a “desirable speed” between measures and to create a “corridor-wide” speed management effect; and
- Physical characteristics of these types of measures (speed differential, acceleration/ deceleration ratios and separation between measures) can be estimated to maintain a sustained speed reduction.

Before and After Study Effect

To further investigate the effectiveness of the speed management measures summarized in TABLE 1, an additional review was dedicated to before-and-after study effects by using the following approach:

- Only before and after studies for a series of measures along a corridor with documented before/after dates were reviewed. It should be noted that this requirement drastically narrowed the search space since most before-and-after studies are focused on the effect of a single measure.
- Due to the approach followed by these studies, if a combination of measures was used along the corridor, the results after implementation cannot be pinpointed to a specific type of measure.
- The most recent status of the measures was identified using Google maps search.

The results of this review are summarized in TABLE 2.
TABLE 2 Evaluation of Before and After Studies for Key Speed Management Measures

<table>
<thead>
<tr>
<th>Location</th>
<th>Before &amp; After Dates and Applied Measure</th>
<th>Effect and Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Route 116, Amherst (19)</td>
<td>Before: December, 2004 After: October 2005 Measure: (4) Central Narrowing Islands and curb extensions</td>
<td>Data collected at 3 different locations along the State Route 116 corridor (0.33 mile), with two lanes of traffic and parking. Status: Still in place (September 2009)</td>
</tr>
<tr>
<td>Frome Road, North Vancouver (20)</td>
<td>Before: April 2008 After: February 2009 Measure: Curb extensions (bulges) and road narrowing</td>
<td>The 85&lt;sup&gt;th&lt;/sup&gt; percentile speed decreased 4% (from 56 km/h to 54 km/h) Status: Still on trial stage (May 2009)</td>
</tr>
<tr>
<td>Goyder Street, Canberra (21)</td>
<td>Before: 2002 After: 2006 Measure: Wombat (raised) Crossings and Raised Platform</td>
<td>The 85&lt;sup&gt;th&lt;/sup&gt; percentile speed decreased from 65 km/h to 58 km/h. Status: Still in place (December 2009)</td>
</tr>
<tr>
<td>Kihapai Street, Honolulu (22)</td>
<td>Before: 2002 After: 2003 Measure: Chicane (1), Bulbouts (6), Median (3), Speed Tables (4)</td>
<td>Speed reductions between 3 to 9 mph were observed. The variations may be due to differences in the type of devices installed at each location. Status: Chicane was removed in 2004 due to public complains.</td>
</tr>
<tr>
<td>Montanoso Drive, Mission Viejo (23)</td>
<td>Before: 2005 After: 2007 – 2008 Measure: (8) Curb extensions and (3) Partial Raised Median Islands</td>
<td>Montanoso Drive is a 40-foot wide undivided collector street, posted speed of 30 mph. The 85&lt;sup&gt;th&lt;/sup&gt; percentile speed prior to implementation ranged from 34 to 38 mph. Status: Still in Place (September 2011)</td>
</tr>
<tr>
<td>Central Lonsdale West, North Vancouver (24)</td>
<td>Before: 2006 After: Spring-Fall 2009 Area-wide implementation consisting of Speed Humps, Speed Tables, Raised Crosswalks, Traffic Circles, Curb Extensions, and Crosswalks with Flashing Lights.</td>
<td>Traffic speeds decreased by more than 10% in at least one direction in all the 23 tested locations. Although an average speed reduction in traffic speeds of 18% was observed on Mahon Avenue (Traffic Circles location), the City received significant complaints regarding their final implementation. Status: Still in trial phase (May 2009)</td>
</tr>
<tr>
<td>College Terrace, Palo Alto California (25)</td>
<td>Before: May 2005 – May 2006 After: May - October 2007 Area wide implementation of Traffic Circles and Speed Tables</td>
<td>A decrease of overall 85&lt;sup&gt;th&lt;/sup&gt; percentile speeds in the neighborhood of 10%. The City received a petition signed by several residents challenging the effectiveness of traffic circles and requesting their removal. Status: Still in place (March 2011)</td>
</tr>
<tr>
<td>West River Road, Cambridge (26)</td>
<td>Before: 2009 After: 2010 Traffic Circle, Speed Cushions and Pavement Markings</td>
<td>A decrease in vehicle speeds on West River Road of 3 to 8 km per hour. Status: In 2012, the geometric design of the traffic circle was modified to provide access to emergency vehicles.</td>
</tr>
<tr>
<td>City of Portland (27,28)</td>
<td>Before: 1987 -1988 -1989 After: 1991 City-Wide analysis of Traffic Circles Performance</td>
<td>The main focus of this analysis was the determination of change in the distribution of vehicles speed Status: Traffic Calming Measures Installed Between 1996 to 2006</td>
</tr>
</tbody>
</table>

Based on the review of the before-and-after studies presented above, the following findings can be offered:

- A combination of road narrowing measures (i.e. curb extensions and raised median islands) can decrease the observed 85<sup>th</sup> percentile speed between 1 and 7 miles/hour
- A combination of traffic circles with curb extensions can decrease the observed 85<sup>th</sup> percentile speed between 10% and 18%;
A combination of vertical deflection (i.e. raised crosswalks and speed tables) and road narrowing measures (curb extensions) can decrease the 85th percentile speed by approximately 10%; and Effectiveness of short term measures such as line striping are inconsistent and vary from no effect to 1 to 7 miles/hour (similar to other road narrowing measures).

Impacts on Fire and Emergency Services
The ultimate goal of speed management measures devices is to improve pedestrian safety and promote livable communities without compromising response times of emergency vehicles. Achieving effective service levels at an emergency scene directly relates to minimizing response times of emergency personnel. Several published studies have found that a single traffic calming device can delay EMS and Fire vehicle responses by 2 to 10 seconds, depending on the measure and the emergency vehicle response type. In addition, vertical deflection measures have been found to cause injuries to responding emergency personnel (neck, back and head), exacerbate injuries and comfort of a patient being transported to the hospital. As a result, multiple speed management measures along a corridor can cumulatively cause significant delays and can have negative consequences in the emergency outcome (29,30).

Impacts on Transit Services
Due to their dimensions, transit buses are affected by horizontal and vertical deflections. Due to consideration for the comfort and convenience of passengers, as well as the repetitiveness of the bus schedule, horizontal deflection devices are generally preferred over vertical deflections in locations considered as transit routes. However, it should be noted that horizontal measures alone may not always be effective at reducing speeds to the required level.

Therefore, to maximize the benefits of a speed management scheme and to minimize the effects on transit services, several sources (31-33) suggested taking into consideration the following factors:

- The proposed speed management scheme (number of measures and location) should avoid a substantial increase in travel time;
- A recommended operational speed of 25 kph or less when crossing traffic calming measures;
- The proposed speed management scheme should not include more than five (5) vertical deflection measures per transit route; and
- The flat surface of speed tables and raised crosswalks should be a minimum of 6 metres long.

Impacts on Snow Maintenance
Although very few studies reported a quantitative impact of speed management strategies on snow removal activities, it is expected that reducing speed would have an impact on snow removal and response times. Therefore, measures should be clearly identified and equipment operators made aware of these types of measures. This will improve the snow removal operation and help prevent damage to the snow removal equipment or the measure itself. In some cases the snow and ice removal equipment are at capacity. In such cases the current fleet of snow removal might not cope with any additional delays imposed by speed management treatments - in response to major winter events.

Impacts on Pedestrians and Cyclists
Physical measures (either horizontal or vertical) could address the issue of speeding on roadways but could easily jeopardize the accessibility and safety of pedestrians and bicyclists. Therefore, design standards for physical treatments should accommodate the minimum requirements for bicyclists and pedestrians. In some cases, there is a contradiction between the introduced speed management measure and bicyclists and/or pedestrians. The following discussion highlights important considerations of a few measures for illustration purposes and is not meant to comprehend all speed management measures (34):

- Vertical speed management measures are not conducive to bicycle travel in general; therefore, they should be used carefully, especially for heavy travelled bicycle routes;
- Horizontal measures should be clearly marked to enable bicyclists to identify and anticipate them. To reduce the risk of bicyclists’ being squeezed, horizontal measures should generally be used in conjunction with other speed control devices such as speed tables at the narrowing;
- Medians and refuge islands are most valuable on major corridors that present safety problems for bicyclists and pedestrians wishing to cross. A minimum central refuge width should be maintained for safe use by those with wheelchairs, bicycles, baby strollers, etc.; and
- Road narrowing and road diets are among the few speed management measures that have the potential to control speed, while at the same time creating enough room for bicyclists.

As discussed above, finding the balance between improving the level of safety for pedestrians/cyclists in a livable community and maintaining timely snow removal and emergency response services is not insurmountable. It is therefore important to involve all the stakeholders and the public to understand the benefits of implementing speed management strategies and the potential impact on snow removal services.

After considering the results summarized in TABLE 1, the potential of speed management measures in creating a self-enforcement solution along a corridor (i.e., not a single measure/point), the findings from before-and-after studies; and the potential impact on transit/emergency/snow removal services; the following key speed management measures can be recommended for implementation as part of a corridor-wide speed management plan:

1. Raised Crosswalk
2. Speed Tables
3. Curb Extension/Neckdown/Chokers
4. Raised Median Islands
5. Traffic Circles

METHODOLOGY FOR THE IMPLEMENTATION OF KEY SPEED MANAGEMENT MEASURES

Concept of Context-Zones
The use of the “Context Zone” concept as a way to define the specific characteristics of an urban area was initially presented by Andres Duany in 2001, as part of the Smart Code alternative to zoning (35). In this concept, a “transect” or cross-section similar to the one depicted in FIGURE 2-a, is used to identify the type of urban environments that compose a community from the downtown core to the rural areas surrounding the community. This concept was later integrated into the ITE recommended practice as a tool for “designing urban streets that are compatible with and supportive of the surrounding context and community” (36).

ITE suggested the use of four context zones (suburban, general urban, urban center and urban core) to describe how context varies around a community. Following this approach to urban characterization, the geographic location and specific characteristics of the roadway network can be directly related to each type of Context Zone as shown in FIGURE 2-b.

**Development of Selection Matrix**

TABLE 1 forms a comprehensive list of all potential speed management measures. However, for the development of a selection matrix that maps the roadway characteristics to the recommended speed management measures, the five (5) key speed management measures described above were evaluated against the roadway characteristics to include only the speed management measures that are applicable to the type of collector roads present within the different context zones. The evaluation criteria shown in TABLE 3 considered the following factors:

- Anticipated speed/speed limit for which the speed management measure is warranted
- Recommended volume for different types of roads
- Land use purpose and the surrounding area of the studied corridor
- Cross section and right-of-way recommendations
- Availability of parking and the effect of the speed management measure on parking
- Availability of pedestrian infrastructure (e.g., sidewalk) and its effect on the choice of the speed management measure
- Availability of a bike lane and its effect on the choice of the speed management measure
- Availability of a transit route and its effect on the choice of the speed management measure

**FIGURE 2 Context Zone Concept.**

(a) Context Zone Concept

(b) Development of Selection Matrix
### TABLE 3 Speed Management Measures – Selection Matrix

<table>
<thead>
<tr>
<th>Measure</th>
<th>Raised Crosswalk</th>
<th>Speed Tables</th>
<th>Curb Extension/ Neckdown/ Chokers</th>
<th>Raised Median Island</th>
<th>Traffic Circle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Operating Speed (at the measure)</td>
<td>25 - 35 km/h</td>
<td>25 - 35 km/h</td>
<td>35 - 45 km/h</td>
<td>35 - 45 km/h</td>
<td></td>
</tr>
<tr>
<td>$85^{th}$ percentile speed at midpoint after the measure</td>
<td>47 km/h</td>
<td>47 km/h</td>
<td>50 km/h</td>
<td>50 km/h</td>
<td>47 km/h</td>
</tr>
<tr>
<td>Traffic volumes (vehicles per day)</td>
<td>1,500 to 5,000</td>
<td>1,500 to 5,000</td>
<td>1,500 to 10,000</td>
<td>&gt; 10,000</td>
<td>1,500 to 10,000 vpd.</td>
</tr>
<tr>
<td>Cross Section (ROW)</td>
<td>Not recommended in Limited ROW and preferred for local collectors</td>
<td>Recommended for minor collector and local roads</td>
<td>All roadways</td>
<td>May require additional ROW for narrow sections.</td>
<td>Require specific ROW and adequate space for large vehicles manoeuvres</td>
</tr>
<tr>
<td>Pedestrian infrastructure (sidewalk)</td>
<td>There must be at least one sidewalk</td>
<td>Could be used as raised sidewalk at the crossings</td>
<td>Improve pedestrian safety</td>
<td>Can be used as refuge island in wide crossings</td>
<td>Not recommended with area with high pedestrian volumes</td>
</tr>
<tr>
<td>Availability of Parking</td>
<td>-</td>
<td>-</td>
<td>Requires the removal of on-street parking</td>
<td>May require the removal of some on-street parking</td>
<td>May require the removal of on-street parking</td>
</tr>
<tr>
<td>Bike Route</td>
<td>No effect on bicycles at moderate speed</td>
<td>Minor impact on bike lanes</td>
<td>Potential impact on cyclists</td>
<td>Potential impact on cyclists</td>
<td>Potential impact on cyclists</td>
</tr>
<tr>
<td>Transit or Emergency Service Route</td>
<td>Only be considered if desired speed cannot be accomplished by other measures.</td>
<td>Only be considered if desired speed cannot be accomplished by other measures.</td>
<td>Should allow space for large vehicles to pass. Should be located at bus stops.</td>
<td>No effect on transit and emergency vehicles if adequate clearance is provided.</td>
<td>Should not be used on transit routes or emergency service routes unless designed as mountable.</td>
</tr>
</tbody>
</table>

Where: $V = 95^{th}$ percentile speed (km/h) of through vehicles in the traffic circle, $R =$ radius of the centreline of the vehicle’s path (m) at that point, $S =$ sight distance correction factor, (1.0 for good and 0.00 for poor sight distance) (9).

### Implementation of the Selection Matrix

In order to implement any measures form the selection matrix, a number of steps has to performed first as explained below. A graphic representation of these steps is presented in FIGURE 3.

- **Identify the local characteristics of the selected collector road:** The context zone and the roadway configuration can provide an insight about the type of neighbourhood, land use and urban characteristics present along the selected collector.

- **Identify Infrastructure Availability:** Specific information about the selected roadway such as: location and extend of parking and/or bicycle lanes, signalized intersections and the use of portions or the full length of the selected collector as transit and/or emergency service route will narrow the locations in which a speed management measures can or cannot be implemented.
- Confirm if the selected collect is considered part of a transit and/or emergency service route: Due to the limitations imposed by Transit and Fire Department, any proposed speed management measures must limit the negative effects of horizontal and vertical deflections.

- Use the Selection Matrix to select the most suitable short or long term speed management measure for each location along the selected corridor: Relate the local characteristics of the selected collector road with the road characteristics presented on the Selection Matrix to identify which type of speed management measures can be implemented along the selected collector taking into consideration the implementation time (short or long term).

**FIGURE 3** Graphical Representation of the Selection Matrix Implementation.

**APPLICATION ON CITY OF EDMONTON COLLECTOR ROADS**

**Selection of Corridors and Site Characteristics**

To demonstrate the use of the selection matrix summarized in TABLE 3, two representative collectors were selected in the City of Edmonton: 9th Avenue (From 119 St NW to 111 St NW) and 122 Avenue (From 107 St NW to Fort Rd). The methodology for implementing the selected speed management measures shown in FIGURE 3 is applied in this section to recommend the speed management measures along the two corridors. In preparation to implement the selection matrix defined above, TABLE 4 summarizes the main corridor characteristics and the context zone analysis for 9th Avenue and 122 Avenue.
TABLE 4 Corridor Characteristics and Context Zone Analysis

<table>
<thead>
<tr>
<th>Implementation Steps</th>
<th>Corridor</th>
<th>Context Zone Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Characteristics</td>
<td>9th Avenue</td>
<td>Length: 1.6 km, Cross-Section: 4 lanes, Width: 13 m, Access Points: 20 local streets and Cul-de sac areas; all of them have yield signs, with average 105 m distance between access points. Control: Only one signalized intersection and one stop control sign. Infrastructure and services: Transit route with 12 bus stops, no bike lanes, no emergency service route, snow route. Speed and Traffic Volume: speed limit is 50 kph, spot speed studies indicate that 60–80% of drivers exceeded the posted speed limit and that the 85th percentile speed was around 73 kph. AADT≈ 1800.</td>
</tr>
<tr>
<td></td>
<td>122 Avenue</td>
<td>Length: 3 km; Cross-Section: 4 lanes; Width: 13 m; Access Points: 28 access points with average of 112 m between access points; Control: 2 signalized intersections, 26 stop controlled. Infrastructure and services: two transit routes, no bike lanes, no emergency service route, snow route, on-street parking. Speed and Traffic Volume: speed limit is 50 kph, 2 spot speed studies indicate that drivers exceeded the posted speed limit by around 10 kph, , AADT_first location ≈ 1800, AADT_second location ≈ 2300.</td>
</tr>
</tbody>
</table>

Recommended Corridor-Wide Speed Management Scheme

Given the local characteristics and the context zone analysis summarized in TABLE 4, the next step is to determine the appropriate spacing between measures to maintain a prevailing speed along the corridor while considering the zone of influence of each measure. Since the 85th percentile speed is a common result of speed studies conducted by the City of Edmonton, the City of Anaheim (15) formula defining the relationship between the speed reduction and separation between measures was used in this paper:

\[
85^{th}_{\text{midpoint}(mph)} = 85^{th}_{\text{slow point}(mph)} + (85^{th}_{\text{street}(mph)} - 85^{th}_{\text{slow point}(mph)}) \times 0.56 \times (1 - e^{-0.004 \times \text{spacing(feet)}})
\]

where \(85^{th}_{\text{midpoint}(mph)}\), \(85^{th}_{\text{slow point}(mph)}\), \(85^{th}_{\text{street}(mph)}\) are the resulting 85th percentile speed at midpoint after implementation, at the measure, and before implementation, respectively.

The \(85^{th}_{\text{midpoint}(mph)}\) value depends on the specific measure as shown in TABLE 3, resulting in the following midpoint speeds:

- Raised Crosswalk, Speed Table, Traffic Circle = 47 kph = 29.2 mph
- Curb Extension/Neckdown/Chokers, Raised Median= 50 kph / 1.609 = 31 mph
The 85th percentile speed (mph) value also depends on the specific measure as shown in TABLE 3, resulting in the following slow point speeds:

- Raised Crosswalk = 30 kph = 19 mph
- Curb Extension / Neckdown / Chokers = 40 kph = 24 mph
- Speed Table = 30 kph = 19 mph
- Raised Median = 40 kph = 24 mph
- Traffic Circle = 30 kph = 19 mph

9th Avenue Most Suitable Corridor-Wide Speed Management Scheme

The 85th percentile speed along 9th Avenue was recorded at 73 kph (above speed limit by 23 kph). This indicates a serious speeding problem along the residential area.

85th percentile (mph) = 73 kph / 1.609 = 45 mph

By applying the City of Anaheim equation the minimum spacing between measures is defined below:

- Raised Crosswalk Spacing = 95 m
- Speed Table = 95 m
- Curb Extension / Neckdown / Chokers = 70 m
- Raised Median = 70 m
- Traffic Circle = 95 m

By considering 1) the local characteristics of 9th Ave, 2) the available infrastructure, and 3) the calculated spacing between measures, the recommended measures are shown in FIGURE 4 that summarizes the speed management measures on a map with the distances between the measures.
122 Avenue Most Suitable Corridor-Wide Speed Management Scheme

The 85th percentile speed along 122 Avenue was recorded at 63 kph (above speed limit by 13 kph).

\[ 85^{\text{th}} \text{ street(mph)} = 63 \text{ kph} / 1.609 = 39 \text{ mph} \]

By applying the City of Anaheim equation the minimum spacing between measures is defined below:

- Raised Crosswalk = 180 m
- Speed Table = 180 m
- Curb Extension / Neckdown / Chokers = 140 m
- Raised Median = 140 m
- Traffic Circle = 180 m

The spacing calculated above is to maintain a speed of 47 kph for Raised Crosswalk, Speed Table, and Traffic Circle, and a speed of 50 kph for raised median and curb extension. As discussed above, the average distance between intersections along 122 Ave is around 112 m, which implies – if following the above calculated spacing- the implementation of one measure at each intersection resulting in 27 measures along the 3 km corridor. If the spacing between measures is around 111 m, this will result in 85th midpoint (mph) of 44 kph which is somewhat lower than the speed limit (50 kph). Therefore, we recommend allowing an 85th midpoint (mph) of 48 kph for the raised crosswalk, speed table, and traffic circles, which will result in a spacing of 250 m for each of these measures.

By considering 1) the local characteristics of 122 Ave, 2) the available infrastructure, and 3) the calculated spacing between measures, the recommended measures are shown in FIGURE 5 that summarizes the speed management measures on a map with the distances between the measures.

FIGURE 5 Identification and Location of Speed Management Measures along 122 Avenue.
It is worth noting that the location of traffic circles has to comply with the existing corridor alignment and roadway intersections; and has to be mountable to facilitate the maneuver of large vehicles. Also the City has expressed a concern on the implementation of corridor-wide vertical deflection measures; therefore their implementation is kept to a minimum to minimize the impact on Fire and Transit services.

SUMMARY AND CONCLUSIONS

A comprehensive literature review of technical papers, manuals, guidelines and reports related to the selection, implementation and effects of speed management measures suggested that although several devices currently in use on North America can affect the observed speed along a specific corridor; in most cases their effect is not long-standing and localized only in the immediate vicinity of the device. Furthermore, the process followed for the selection of these devices does not consider the cumulative effect of several devices at the “corridor-level”.

The results of our review suggested that the selection of a series of traffic calming devices based on factors such as 1) self-enforcement, 2) corridor-wide effect, 3) before and after study findings, and 4) potential impacts, can support the design of a methodology for the implementation of a corridor-wide speed management strategy. This methodology included the development of a selection matrix for the most effective speed management measures and presented its applicability to selected corridors according to the context-zone characteristics of these corridors.

The usefulness of the proposed methodology under practical conditions was tested using two representative collector roads in the City of Edmonton: 9th Avenue (From 119 St NW to 111 St NW) and 122 Avenue (From 107 St NW to Fort Rd). Data on the local characteristics and available infrastructure on the two corridors were collected to assist in the selection matrix and context-zone analysis; and a set of speed management measures were distributed along the collector roads to maintain the 85th percentile speed along the collectors under the corridor-wide preferred posted speed.

The results of this practical study indicate that the proposed methodology can be easily followed and implemented by practitioners using information that is commonly available. It is expected that in this particular test case, the City of Edmonton may contemplate the implementation of the recommended speed management measures.
REFERENCES