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The Evolution of Urban Roadway Design Approaches

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Abstract

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The approach and practice of urban roadway design in North America has evolved on the basis of research and experiences for higher speed rural style highways that form part of a national or regional transportation system. The various design guidelines that have been developed over past decades evolved out of a need to develop efficient, effective and safe highway systems. Early examples of such guidelines (AASHO/AASHTO, CGRA/RTAC/TAC etc.) focused largely on the technical issues of vehicular travel. This led to the use of functional classifications that dictated design speed, design vehicle, access control, levels of service and related design considerations.

From the late 1970s onward, there has been a distinct shift in the approach taken towards roadway design, particularly in increasingly more congested urban areas. Since that time there has been considerable attention paid to a host of factors that had up to that point had been given less attention by roadway designers. This included issues such as noise, air quality, speeding, shortcutting, community severance, other travel modes (transit, pedestrians, and cyclists) as well as urban design, public realm and place-making considerations.

The language of urban road design in 2014 is now permeated by words and phrases like “traffic calming”, “context sensitive design”, “multi-modal design”, “complete streets”, “green roads”, “sustainable transportation” and “pedestrian oriented” design. The general public is demanding much more of transportation engineers than they did in the 60s and 70s. This has led to increased complexity in the design process, its objectives and the design parameters that form part of that process.

This paper describes the evolution in the urban roadway design process and the related parameters. This evolution is described through a comparison of historical approaches with more contemporary practices and attitudes. The paper highlights emergent methodologies that reflect the changes from historical practice and outlines the influences from other jurisdictions and other disciplines.

1.0 INTRODUCTION – SOME HISTORY

This paper describes the evolution of the urban roadway design process and the related parameters. This evolution is described through a comparison of historical approaches with more contemporary practices and attitudes. The paper highlights emergent methodologies that reflect the changes from historical practice and outlines the influences from other jurisdictions and other disciplines

1.1 AASHO/AASHTO

The formal practice of roadway design in North America had its roots with the **American Association of State Highway Officials (AASHO)**, which was formed in 1914. AASHO was renamed in 1973 to the **American Association of State Highway and Transportation Officials (AASHTO)**. The name change was aimed at expanding the organization's breadth and scope to include not only highway design and construction, but also other modes of transportation including rail, air, water and public transportation.

The organization's current mission is to advocate "*transportation-related policies and to provide technical services to support states in their efforts to efficiently and safely move people and goods."(1)*

AASHTO executes its mission in part through research in collaboration with a number of organizations in America. In addition, AASHTO publishes a number of reference books. The most noteworthy of these books is entitled "*A Policy on Geometric Design of Highways and Streets",* which is referred to as "the Green Book". Some previous editions of the green book have had both different colours and tiles:

1.2 CGRA/RTAC/TAC

Canadian roadway design practice had its roots with the **Canadian Good Roads Association (CGRA)** which was formed in 1914 and was instrumental in advocating for the construction of the Trans-Canada Highway. For similar reasons to the name change of its American sister organization, the CGRA was renamed in 1970 to **Roads and Transportation Association of Canada (RTAC)** because of its increasing interest and involvement in other transportation issues beyond rural highway design. This was subsequently shortened to **Transportation Association of Canada (TAC)**.

As with AASHTO, TAC has developed a number of reference publications aimed at promoting excellence in transportation design and operations practices nationwide. The ***Manual of Geometric Design Standards for Canadian Roads and Streets*** was first published in 1963. The first metric edition of the manual emerged in 1976 and subsequent editions added or modified material based on evolving research and experience. Since 1994 this widely followed national reference guide has been known as the ***Geometric Design Guide for Canadian Roads*** *(TAC Design Guide);* it is noteworthy that the words “manual” and “standards” were dropped in favour of the word “guide”.

In addition to the main roadway design guide, TAC has published several other reference reports to guide designers in specific aspects of roadway design, such as road safety, traffic control, bicycle facilities, traffic calming, pavement design, etc.

1.3 Other Organizations

In addition to AASHTO and TAC there are several other North American organizations that have contributed significantly to the practice of roadway design. This includes the Transportation Research Board (TRB), Institute of Transportation Engineers (ITE), Transit Cooperative Research Program and more recently, the National Association of City Transportation Officials (NACTO).

NACTO, founded in 1996, is a non-profit coalition of America’s fifteen largest cities it was founded to enable the "exchange of transportation ideas, insights, and practices among large central cities while fostering a cooperative approach to key national transportation issues". Since its formation NACTO has been involved in various initiatives dealing with surface transportation issue in large cities. In 2013, NACTO has published the **Urban Street Design Guide** (USDG) that is aimed at filling a void in the practice of roadway design by offering guidance on how to design and build streets that satisfy a growing set of needs and wants. The NACTO USDG was developed with input from multiple disciplines and is reflective of the reality that roadways are not only conduits for conveyance of vehicles and goods, but also places of social and economic interaction. The NACTO Guide promotes a context based design approach that differs markedly from the traditional approach undertaken by the roadway design community.

2.0 DESIGN PHILOSOPHY

A review of traditional design guides published by AASHTO and TAC reveals that their foundations were mainly in the design of rural highways; roads intended for longer distance, higher speed travel in more rural environments. The early versions of these design reference publications were typically regarded and used as design "manuals" or "standards", to be rigorously followed. As a practical matter, deviation from the specific parameters prescribed in these manuals was and remains difficult for practitioners. In recent years these reference "manuals" and "standards" have been transformed into design "guidelines" or "guides", with greater encouragement for more flexibility, judgment and consideration of context and related trade-offs.

2.1 Standards, Guidelines and Design Domain

The 1999 edition of TAC's Design Guide described the process of roadway design as follows:

"Design is an activity in which judgment and experience play significant roles. Designers choose the features of the road and dimensions of the primary design elements. They may use judgment, technical reference and calculations to assist in selecting the appropriate design elements, but the selection of elements in isolation from each other is not design."

The TAC Guide goes on to distinguish quite effectively between "Guidelines" and "Standards". In fact, TAC goes on to say that:

Design dimensions that do not meet standards do not necessarily result in an unacceptable design – and dimensions that meet standards do not guarantee an acceptable design.

In the latter part of the 20th century, design practitioners became very reliant and dependent on the specific numerical values contained in AASHTO and TAC guides. There was and is reluctance to deviate from the dimensions recommended or stated as being "preferred". The notion that the design process by definition requires the application of judgment and experience remains a challenge amongst practitioners.

In an effort to encourage less "table picking" and greater acceptance of the role of judgment, context, and trade-offs in the design process. The most recent TAC Guide adopted the **"Design Domain Concept"** which offers design practitioners with a range of design parameter choices. TAC's design domain concept is graphically illustrated in Exhibit 1.

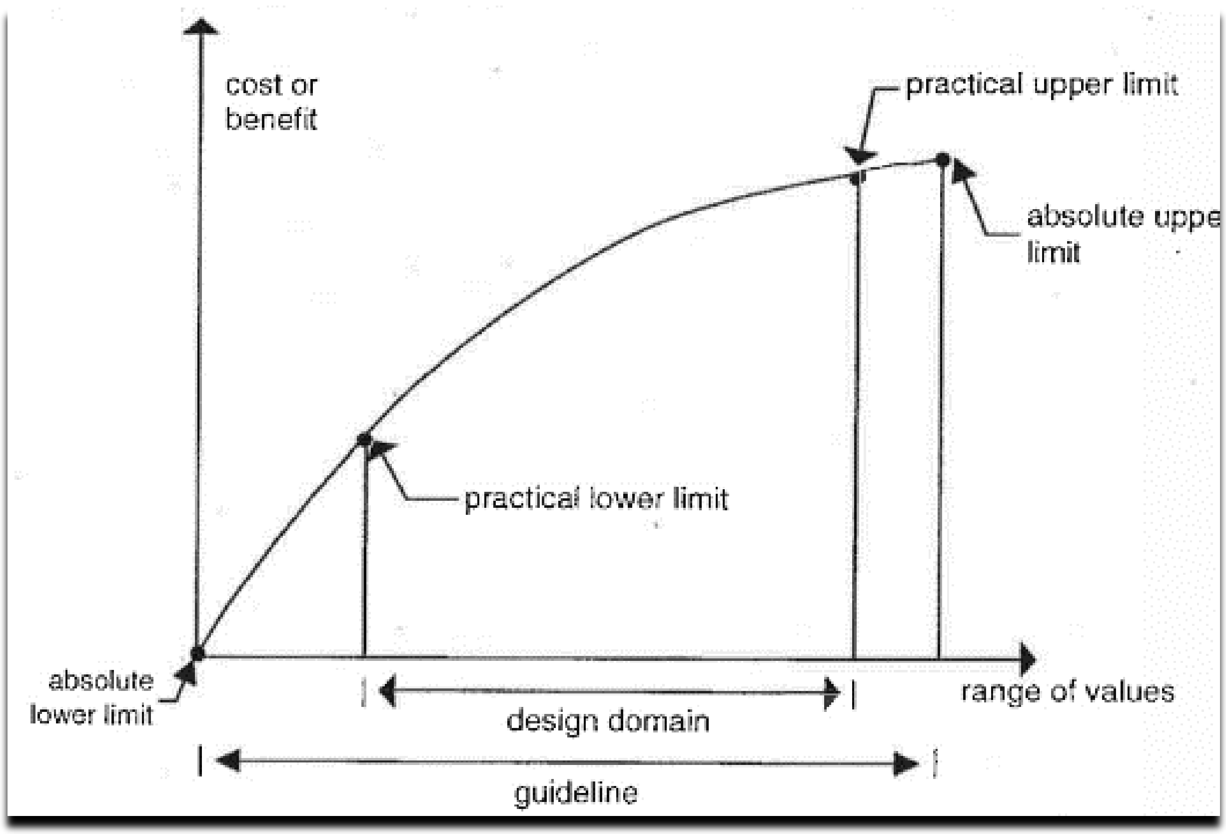


Exhibit 1 – The Design Domain Concept

Source: TAC Geometric Design Guide for Canadian Roads, 1999

2.2 Rural versus Urban Roadway Design

As noted earlier, the practice of roadway design was rooted in design of rural highways; roads intended for longer distance, higher speed travel in more rural environments. In many of the earlier design manuals, urban design was treated as "supplementary". There are instances where practitioners who have responsibilities for both rural and urban conditions, tend to extrapolate their rural design practices to urban situations with less than optimal results. While many of the basic principles of highway design can and should be applied to urban situations, it must be stated that urban roadway design involves a wide variety of elements that rural highway design simply does not address or addresses incompletely or inappropriately. This includes:

- Street Classification or "Typology"
- Context
- Land use and Built Form
- Pedestrians

- Bicycles
- Transit
- Traffic Control
- Pedestrians
- Access Management
- Multi-modal Level of Service
- Community Impact
- Livability
- Place-making
- Public Realm

2.3 Roadway Classification or "Typology"

2.3.1 Classification by Service Function – Traditional Approach

The traditional roadway classification system is centered on the premise that roads exist to perform two functions in various degrees: enable vehicular mobility and enable access to adjacent land. In its earliest and simplest form this classification system has three roadway categories that reflect a trade-off between only two variables: mobility and land access. The three main categories are summarized in Table and the relationship between mobility and access is illustrated conceptually in Exhibit 2.

Table 1: Roadway Classification by Service Function

Roadway Classification	Mobility	Land Access
Arterial (and Freeway)	Primary consideration is vehicular traffic movement	Relatively strict access control
Collector	Traffic movement and land access of equal importance	
Local	Traffic movement is a secondary consideration	Land access is the primary concern

The current TAC version of the functional classification system is represented in Table 2 and acknowledges many elements of the urban environment such as pedestrians, cyclists, transit service and parking. The roadway classification system that relies on service function as its foundation is typically the first step in the traditional design process. Once a roadway's functional classification is determined, the rest of the design process is relatively straight forward and governed by specific design controls that correspond to the chosen functional classification; this includes design speed, design vehicle, alignment controls and cross-section elements.

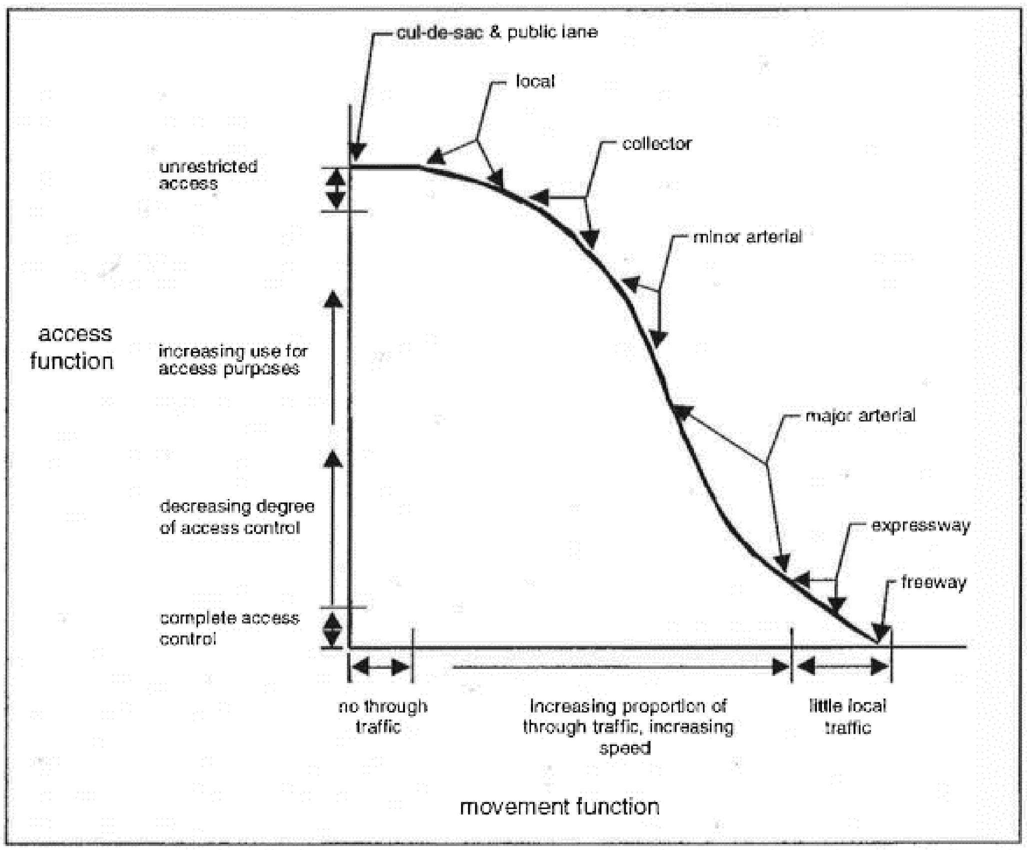


Exhibit 2: Service Function - Mobility versus Land Access
Source: TAC Geometric Design Guide for Canadian Roads, 1999

The traditional classification system is narrowly focused on the transportation and land access functions of roadways and does little to acknowledge other important roles for streets in the urban context. These other roles for streets have been defined by segments of society that see streets as performing a wider array of functions than simply as conveyors of traffic and enablers of vehicular land access. This has led to an evolution of roadway design practices that are founded on more complex classifications than the mobility and access based paradigm that the engineering profession has historically relied on.

2.3.2 Classification or Typology related to Context

In the last two decades or so, there has been increasing societal pressure to plan and design streets in urban settings for more than just moving traffic and providing driveway access. This changing paradigm is leading to alternative classifications of our roadway networks. More and more, streets are as classified by, or performing functions that are more closely related to the surrounding environment. This in turn has lead streets referred to by names such as:

- Downtown Street,
- Neighbourhood Street
- Transit Corridor
- Main Street
- Shared Street
- Boulevard
- Gateway
- Parkway

While these labels are typically not familiar to roadway design engineers, the nomenclature does convey something about the nature, character and context of the street that goes well beyond the mobility and access functions that have normally governed the design.

When roadway design is governed by a classification that is context driven, the design process can and usually will result in a very different end product that meets a wider5 set of community objectives. A roadway design that is achieved by way of a context sensitive design approach will typically follow the following steps:

1. Reviewing or Developing an Area-wide Transportation Plan
2. Understanding of the community vision, goals and objectives
3. Identifying the context zone(s) through which the roadway passes and identify roadway types that may fit the context(s)
4. Developing and testing initial design concepts against the contextual realities and broader network goals
5. Developing the roadway design

Whereas the traditional design approaches relies on the service functional classification to determine design parameters, the context sensitive design approach relies on a roadway typology (and design parameters) that is related to the context or character that is desired in the area through which it passes. While context sensitive design is encouraged to varying degrees in North America, the practice is not common place and in many cases not given much validity. This is in stark contrast to European practice where design to context is common place.

2.3.3 Complete Streets Approach

The “complete streets” design approach is in many respects quite similar to the context sensitive design approach. Specifically, the complete streets approach is predicated upon the notion that in an urban environment streets should be designed to cater to a variety of travel modes and that greater equity should be provided between all modes in the allocation of space within a transportation corridor. Furthermore, the complete streets approach treats streets as both links between destinations as well as social places that enable a relationship with the places that people live, work and play in. As with the context sensitive design approach, European practice is far more advanced than North American applications.

3.0 SPECIFIC DESIGN CONTROLS

Roadway design practice has traditionally relied on selection of a number of critical design controls that then determine the road's various geometric attributes, such as horizontal and vertical alignment, number of through and turning lanes, lane widths, corner radii, intersection spacing, and pedestrian accommodation. These key controls include:

- Design Speed
- Design Vehicle
- Human factors
- Traffic Volume
- Capacity and Level of Service
- Pedestrians and Cyclists
- Intersection spacing and Access control

It is beyond the scope of this paper to delve into the treatment of all of these design controls under evolving design practices. However, attention will be paid to five from the above list.

3.1 Design Speed

Speed is arguably the most important element in the design of roadways be they rural or urban. The speed at which vehicle travel is significantly influenced by the design and has significant consequences on the safety of roadway users regardless of their mode of travel, but particularly on vulnerable users such as pedestrians and cyclists. Exhibitss 3 illustrates the effects of speed on the probability of fatalities

Historically, the design community has tended to lean towards higher rather than lower designs speeds; this is consistent with a design paradigm that is focused on ensuring high levels of vehicular mobility. Roadway designers traditionally select a **design speed** based on the functional classification of the roadway. The design speed is then used as the basis for determining the appropriate geometric design elements of a roadway segment. Typical North American practice has been to establish design speeds and set posted speeds at values that are 10 to 20 km/hour lower than the established design speed.

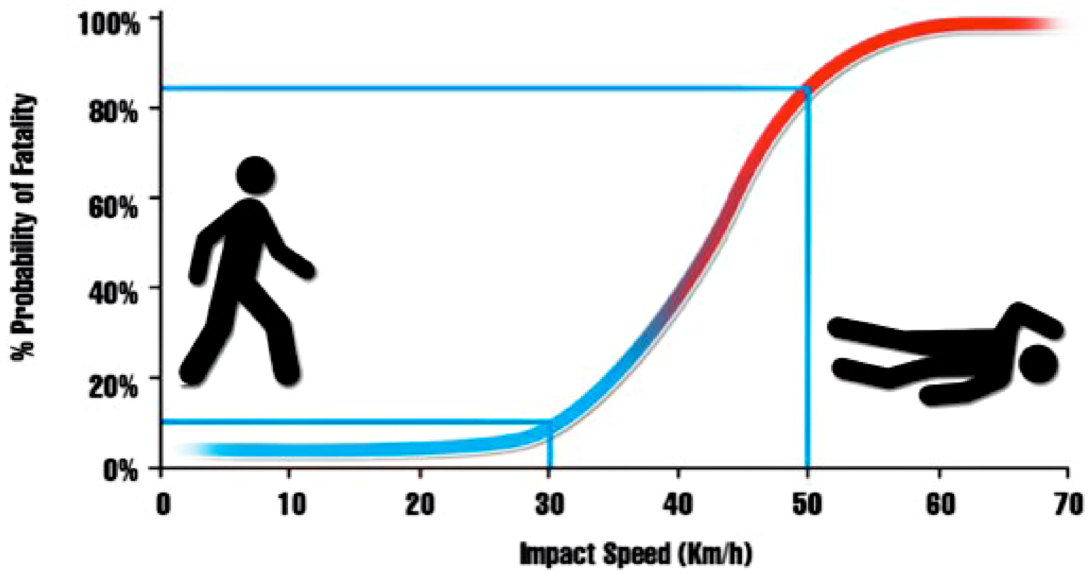


Exhibit 3: Probability of Pedestrian Fatality
City of Hamilton New Zealand

The TAC Design Guide provides very useful discussion on the application of design speed, its relationship to driver desired speed, as well the limitations of the design speed approach to design. The following limitations are particularly noteworthy:

- Design speed has no meaning for a tangent section of a horizontal roadway alignment
- Design speeds are not transparent to drivers and do not ensure consistency in achievable driver speeds or driver expectancy
- Drivers' desired speed is not typically influenced by a design speed, and is more typically governed by driver perceptions of the prevailing topographic conditions, traffic conditions, roadside conditions, roadside activity, access frequency, adjacent development/built form as well as the road width and number of lanes.

3.2 Target Speed

The practice of selecting a "target speed" as the basis for roadway design is quite prevalent in Europe and is promoted as a fundamental element of the "*context sensitive design*" approach. *Target speed* is the speed at which vehicles should operate on a street in light of the surrounding context. The target speed approach is aimed at developing a roadway design that influences driver behaviour and speed such that it aligns with the prevailing (or desired future) context. In some jurisdictions, the posted speed is set at the target speed. In these cases, it is important for the design of the roadway to encourage the desired operating speed to ensure that actual speeds align with the target speed. The context sensitive design approach in general and the target speed approach in particular is aimed at moderating vehicle operating speeds from levels that are typically achieved through the traditional design speed approach. Techniques for achieving speed moderation consistent with a target speed include:

- Narrower lane widths
- Removal of shoulders or other offsets
- Signal progression appropriate to the target speed
- Removal of superelevation
- Inclusion of on-street parking
- Provision of smaller corner radii
- Elimination of high speed right turn design
- Possible inclusion of street tree canopy

The use of the context sensitive design approach in general and target speed in particular is focused very specifically at rendering

3.3 Design Vehicle

The traditional design approach has been to select a specific "design vehicle" for a specific roadway classification. Typically designers have opted for larger design vehicles as a matter of course, sometimes often with little consideration for, or knowledge of the prevalence of the large design vehicle at a given location. In recent years, design guidelines have encouraged a more analytical and more nuanced approach to design vehicle specification, which considers the prevalence and frequency of larger design vehicles.

In the *"context sensitive"* and *"complete streets"* design approaches, selection of a design vehicle or multiple design vehicles is very much a deliberate and well thought out process that fully considers the trade-offs between the use of different design vehicles. In particular, the prevalence and frequency of large design vehicle is considered relative to the impact they may have on such elements as intersection size, corner radii as well as pedestrian crossing convenience, ease and distance.

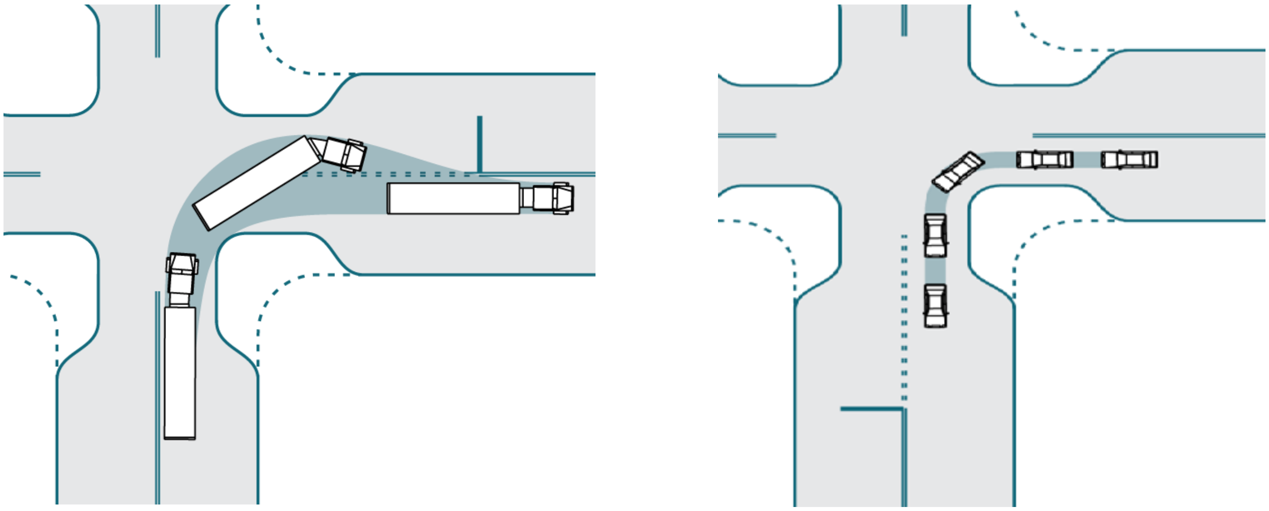


Exhibit 4 – Design Vehicle Choice and Trade-offs
Slower Turning Speeds and Enhanced Pedestrian Safety and Comfort
Source: NACTO Web Site

3.4 Traffic Volumes, Capacity and Level of Service

Traditional roadway design practice has always considered current and projected future traffic volumes, capacity and level of service (LOS) as a significant determinant of roadway design. These parameters are crucial to the process of sizing any road to accommodate expected vehicular traffic.

The process of determining roadway lane requirements based on projection of volume and specification of a level of service has changed somewhat over the years. More sophisticated traffic projection models are now in use that enables more precise estimation of future traffic volumes. Likewise, current traffic analysis tools for signalized and unsignalized intersections, roundabouts and freeways allow for robust analysis of alternatives and selection of recommended designs.

As North American cities have grown and traffic levels with them, the practice of expanding roadway infrastructure in response to growth and a desired quality of traffic operation has been somewhat tempered by high costs, environmental impacts, community impacts and an increased concern over quality of life and livability. Whereas cities have historically aimed to achieve longer term LOS of C to D, they are now accepting with LOS D to E. Cities are being forced to consider multi-modal approaches that focus on moving people rather than vehicles. This has fostered greater attention on the design of facilities that better accommodate transit, bicycle travel and pedestrian circulation for shorter trips.

The roadway design community has responded to these challenges somewhat unevenly. The adoption of multi-modal analysis and design techniques has been somewhat tenuous except in the largest urban centres, where it has become the norm.

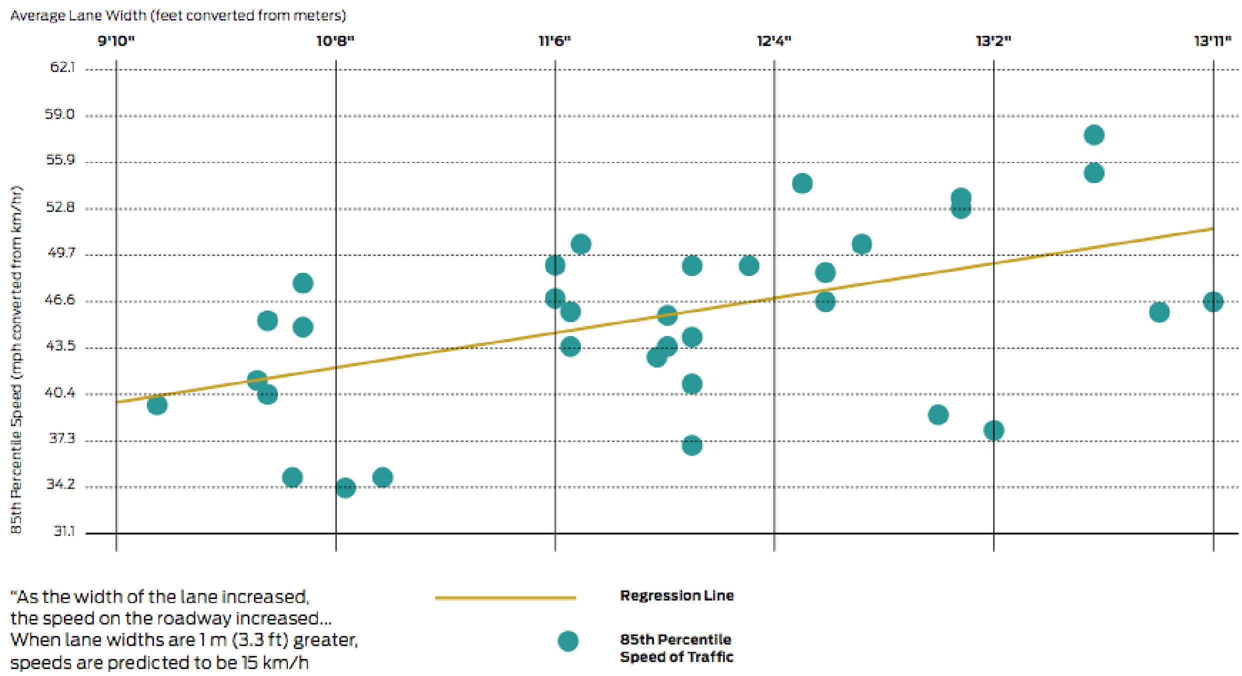
3.5 Number of Travel Lanes and Lane Widths

AASHTO indicates that the prevalent practice is to use of travel lane widths in the 2.7-3.6m range with 3.6m being the recommended width for higher speed facilities.

The number of lanes and the dimensions of these lanes is a significant elements of roadway design which affects the operation and safety of vehicular and non-vehicular users. The number of through and turning lanes is typically determined on the basis of operational performance for a forecast travel horizon, some 25 to 30 years into the future. In some jurisdictions, broader transportation policies may intervene and may limit the extent to which LOS driven roadway expansion is pursued.

With respect to lane width, there has been an evolution in the selection of lane widths used in urban areas. The roadway design community has traditionally favoured lane widths that were at the higher end of the suggested spectrum; the rationale being that wider lanes offer a greater degree of comfort, added safety, higher capacity and some buffer for driver error corrections. The current TAC Guide recommends basic lane widths as high as 3.7 for all road classes, although lower widths are presented for application on minor arterial, collector and local streets. In practice, there is an evolutionary movement towards more widespread use of 3.5 m lanes in some Canadian municipalities. This is in part a response to a growing body of empirical evidence that points to limited safety benefits of lane widths in excess of 3.3 m. In addition, there is evidence to suggest that wider lane widths can induce faster driving (Exhibit 4) and lower vehicle separation.

Wider travel lanes are correlated with higher vehicle speeds.



"As the width of the lane increased, the speed on the roadway increased... When lane widths are 1 m (3.3 ft) greater, speeds are predicted to be 15 km/h (9.4 mph) faster."

Chart source: Fitzpatrick, Kay, Paul Carlson, Marcus Brewer, and Mark Wooldridge. 2000. "Design Factors That Affect Driver Speed on Suburban Streets." *Transportation Research Record* 1751: 18–25.

Exhibit 5 – Relationship between Speed and lane Width

Source: NACTO Web Site

While mainstream practitioners are more open to the use of lower lane widths in the 3.5 metre range, advocates of "complete streets" and "context sensitive" design are promoting even more aggressive reductions to 3.0 to 3.3m. This push towards more compact designs is related to a desire to achieve slower vehicular operating speed and a more favourable (safety, comfort, noise) environment for the adjoining uses and the more vulnerable users who interact with the roadways.

3.6 Pedestrians and Cyclists

There is high interest and growing public demand for much better accommodation of pedestrians and cyclist in the urban transportation setting. Over the last two decades significant progress has been made in recognizing the needs of vulnerable users on foot or bicycle. It is common to have sidewalks on both sides of roadways and not uncommon to have wider shared-use paths along main arteries. Most intersections have curb-drops at the corners and selective intersections include mechanisms for the visually impaired.

The accommodation of cyclist is in an evolutionary state; cities are doing more in terms of wider curb lanes, exclusive bike lanes, sharrows, bike boxes and bicycle signals. There is a fair bit of public discourse and at times tension regarding how cyclist are accommodated; this is especially the case where vehicular mobility is perceived to have been compromised or diminished.

4.0 CONCLUSIONS

4.1 The Roadway Design World is Changing

While the conventional approaches to road design are firmly in place, this paper has provided some insights into how practices and attitudes have already and are continuing to change. The degree of acceptance of new approaches varies widely by locale and by agency.

There is an emerging strong interest in more multi-modal solutions to urban transportation challenges and willingness in some quarters to explore new approaches, or to import well tested ideas from abroad.

The emerging philosophy of “context sensitive” design is redefining the problems and changing the rules about how to solve urban transportation problems. The strength of this approach is that it relies on a wide range of inputs that include multiple professional disciplines as well as public and political engagement.

4.2 Challenges and the Need for Further Work

4.2.1 Research and Validation

The design of urban roadways is a highly complex process that has been made even more so by increased expectations by the public and elected officials. There is a need for extensive research and validation of new approaches to ensure that the initially perceived benefits are in fact yielding positive results in the longer term.

4.2.2 Openness to New Approaches

The roadway design community needs to continue to be open to new approaches to solving urban transportation problems in an environment that has become more complex and more resource constrained.

There is a need to continue to improve the knowledge and awareness of human factors as they relate to roadway design. This needed level of awareness and experience is not an obvious area of training or knowledge transfer in the roadway design community at the present time.

Greater cooperation and collaboration amongst design professionals is essential if we are to arrive at a consensus on how to resolve transportation problems in a manner to addresses wider but relevant issues.

4.2.3 Learning from Overseas Experiences.

While there is a tendency to only look at North American knowledge and experiences, we should continue to be open to successes from abroad. Not too long ago, roundabouts as an intersection type were pretty scarce in North America, despite being widely used in other parts of the world as both a traffic control and traffic calming tool. A number of jurisdictions now require that the roundabout intersection type be a part of the alternatives development and evaluation process.

In a similar vein, the words “traffic calming” were viewed d with scepticism and suspicion some years ago. Now, there are multiple guides at both the national and local levels that provide guidance to practitioners on ways to reduce travel speeds and shortcutting traffic to the betterment of community livability.

4.2.4 Multi-modal Design Proficiency and Better Design Integration

While we have made strides in multi-modal approaches, it remains an area where we need to learn more in the areas of transit, pedestrian and bicycle accommodations. All too often the design skills related to alternative modes reside in separate departments or sections of the same department; design professionals need to become more proficient in these areas so that the designs that emerge are more integrated and the people that are involved in the design are involved in and understanding of the interrelationships and trade-offs between different design elements.

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