Making Context Sensitive Design an Everyday Part Of Geometric Design Practice

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Abstract

At the last TAC meeting in 2006 in Charlottetown, a full morning was devoted to a workshop on Context Sensitive Design (CSD) practices. Nearly 100 people participated in the workshop. Four presentations were made on different aspects of CSD by Messrs. John Robinson, Tim Neuman, Roy Biller and Leonard Ng. Each presentation was followed by informed comments and suggestions from the participants. The focus was on moving CSD into mainline practise.

This paper, presented by the Chair of the Workshop, is a synopsis of the main points raised in the workshop session. The overall message was one of acceptance of CSD and the need to advance the science by taking certain explicit initiatives and including the subject of CSD in the TAC Geometric Guide.

In his presentation, John Robinson stressed the need for designers to dwell on the possible and never to refrain from action because it's not "in the book." He appealed for:

- a greater use of heuristics and better understanding amongst practitioners about the derivation of design elements and parameters;
- increasing design flexibility by understanding speed management and for practitioners to know more about the way geometric elements limit speeds;
- more use of risk management for designers to recognize the risks inherent in their designs and how these can be evaluated.

Tim Neuman gave a good background on USA applications of CSD. He pointed out that CSD must equally address safety, mobility, scenic values, history and the environment. Key to successful development is:

- understanding the problem;
- communicating decisions; and
- showing technical leadership in making trade-offs.

He stressed the need for roads to convey traffic and asked, 'who advocates mobility?'

Roy Biller spoke on corridor applications of CSD and focused on designing to meet historical, social and political goals. He suggested treating sight distance separately from operating speeds. He also stressed the need for better articulation of values in the value engineering process.

Finally, Leonard Ng spoke about CSD in suburban communities. He stressed the design need for:

- respecting historical context;
- a better understanding of visual clues in the roadside environment so as to moderate driver expectations; and
- for creativity in deriving solutions to meet the objectives of both the community and the owner.

The paper expands on the issues raised during the workshop and relates them to Human Factors. It proposes a new chapter or supplement to the TAC Geometric Design Guidelines.

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1. Introduction

Context Sensitive Design (CSD) is an approach that has been used in the geometric design profession for the last ten years. It is an approach that the Geometric Design Standing Committee of the Transportation Association of Canada (TAC) would like to make part of everyday practice. CSD requires practitioners to use design guidelines in a flexible and innovative manner. In order to facilitate CSD, the Geometric Design Standing Committee scheduled a four-hour workshop on the subject at the 2006 conference in Charlottetown. This paper has been prepared by the Chair of the workshop and reviews CSD and its relationship to human factors. It summarizes the four presentations that were made at the workshop, and proposes that TAC supplement their Geometric Design Guidelines with either a chapter or addendum on CSD.

2. Context Sensitive Design

CSD and its complementary context sensitive solutions are understood by different practitioners in different ways. Urban planners think of CSD as the incorporation of ambient planning and landscaping features into road designs. Municipal engineers think of CSD as a way of incorporating a sense of community into a road design. Geometric designers think of CSD as designing roads to influence rather than to accommodate driver behaviour.

The CSD approach to highway design emphasizes interdisciplinary collaboration in order to develop transportation facilities that not only address issues of safety, capacity and mobility, but are also responsive to the constraints of the physical setting. This incorporates the user needs of communities and the preservation of aesthetic, cultural, historic and environmental resources. CSD attempts to influence driver behaviour using TAC geometric design procedures in a consistent yet flexible manner. This requires:

- always addressing safety and reliability;
- providing long-term mobility;
- protecting environmental and community interests;
- accommodating commercial interests along with recreational objectives;
- preserving aesthetic, visual, cultural and historic resources; and
- minimizing capital and maintenance costs of highway improvements.

CSD demands that the designer always be cognizant of influence that the design has on the behaviour of all road users: drivers, pedestrians, cyclists, transit users and transit operators. Design is targeted at explicit safety; in other words: safety that can be supported scientifically rather than anecdotally. Community values, the natural and landscaped environment and vehicular mobility are equally important considerations. CSD requires knowledge of the background of contemporary geometric design practices, traffic engineering and human factors. It also requires a clear understanding of community values and the socio-environmental context.

CSD entails the flexible use of design guidelines. Flexibility in design incorporates the Canadian concept of the “design domain” that provides for a ranges of design values to be used to facilitate designs in corridor and community environments.

Flexibility is not the random use of "guideline" design parameters which have been worked out using Newtonian physics. Instead, flexible use of guidelines implies a firm understanding of design elements and the knowledge and circumstance of when certain design values can be reduced because of prevailing contexts. Such adjustments usually necessitate some form of peer review. The reasons for reducing parameters must be documented in a professional manner.

The use of design values that differ from prevailing road engineering practice usually arises from different interpretations of design speeds. Most road design values have been calculated using designated vehicular speeds. This design speed may not comply with the preferred operating speed of a particular road. When the road design requires drivers to use slower operating speeds, other measures than the use of design manuals need to be employed.

These other measures usually involve making use of speed management. This approach is in its infancy. Its techniques involve the use of behaviour-predictive modelling and the incorporation of human factors. Such modelling requires site-specific experience and the ability to demonstrate that a new or reconstructed facility will experience fewer collisions. It is unlike the procedures that have been generally used in North American practice where the designers try to accommodate, rather than design for, specific driver behaviour.

Table 1 demonstrates the use of design domains in the flexible application of design values.

Table 1. Alignment Ranges of Design Dimensions for Anticipated Operating Speeds

Anticipated 85th Percentile Operating Speed **(km/h)**	**70 – 80**	**50 - 60**
Horizontal Curvature		
Minimum Curve Radii (m)	250 – 340	120 – 190
Curve Spirals (m)	50 – 80	40 – 60
Maximum Superelevation	6% - 8%	4% - 6%
Tangent Cross-Slope	2% - 3%	
Weaving Distance (m)	500 - 700	
Minimum Stopping Sight Distance (m)	120 – 150	77 – 90
Decision Sight Distance (m)	185 – 275	120 – 150
Lane Widening	Verify requirements for WB-20 design vehicle	
Vertical Curvature		
Maximum Grade	5%	6%
Sag K Factor	25 – 40	15 – 25
Crest K Factor	25 – 40	10 – 25
Vertical Clearance	5.0 – 5.3 M	

CSD recognizes that operating speeds may vary over the length of a highway corridor, depending on the community, physical or environmental context. CSD further takes the position that greater safety is afforded from design dimensions that consistently and closely conform to the design guidelines for the 85th percentile speed on any particular section of highway.

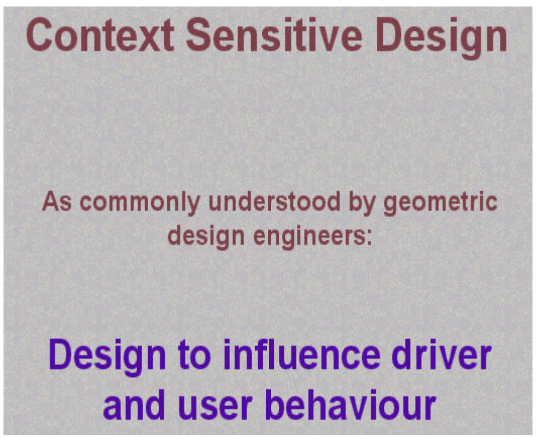
Common wisdom has supposed that greater safety is derived by exceeding the dimensions of the design guidelines for particular design speeds. Current research has shown that narrower, rather than wider, cross-section dimensions and limiting curve radii give the driver a clearer perspective of the path and the speed of travel.

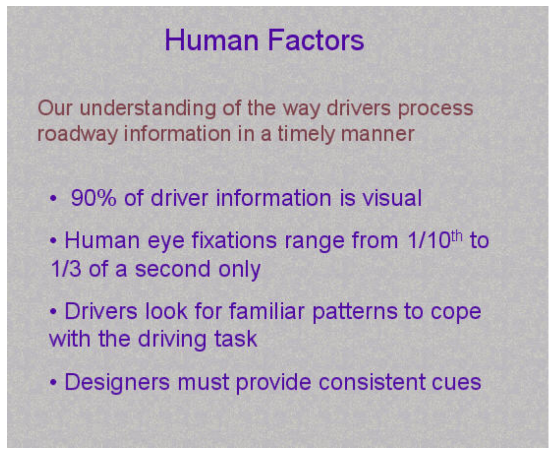
CSD acknowledges the need to provide for clear and visible cues for transitions between two sections of contextual operating speed. This can be achieved by using a number of visual techniques. In urban conditions, roads are usually curbed with sidewalks and driveways, while in inter-urban conditions, roads are usually provided with open shoulders and wide verges. Transition treatments include facilities like gates, portals, textured paving and transitional geometrics. These treatments require familiarity in applying such techniques as well as observational research to determine their impacts on human behaviour.

In concentrating the designer’s attention on user behaviour and contextual cues, CSD provides an approach to flexible designs that meet the goals of the public in the communities they serve. By using design domains and consistently applying geometric dimensions and visual clues, safe, acceptable facilities can be provided. A summary of familiar layouts which the driver looks for as clues include:

- portals, gateways or entrances that signify a change of conditions, from slow to fast or from fast to slow;
- the width of lanes and the perceived dangers of the roadside which require appropriate speed choices;
- the sharpness of curves that signify the driver’s ability to operate at certain speeds; and
- peripheral objects such as trees, driveways, signage, parked vehicles which indicate the likelihood of an unexpected occurrence.

If designers can embrace the need for consistency and provide these features in their layouts, the resulting roads will exhibit consistent speeds and this usually results in fewer crashes.





3. Using Human Factors to Understand Driver Behaviour

One of the key requirements of CSD is an understanding of how human factors influence design behaviour. The ability of drivers to process roadway information in a timely manner is essential to safe driving conditions.

The goal of human factors in traffic safety is to use knowledge of driver abilities and limitations to optimize the design of highways and traffic control devices. Another goal is to minimize errors which cause crashes. More specifically, human factors provide information on the ability of the road user (driver, cyclist or pedestrian) to undertake the following.

- Search a rapidly changing roadway and roadside environment.
- Process the roadway and roadside information. This involves road geometry, the movement of other traffic, the presence of cyclists and pedestrians, and the information of traffic control devices. The information enables users to make accurate and timely assessments of appropriate lane position, speed, headway and direction.
- Carry out required manoeuvres in a safe and timely manner. This involves negotiating curves, changing lanes and making emergency stops.

In assessing road user behaviour, human factors also consider the impact on performance of age, inexperience, impairment, familiarity with conditions, fatigue and other stress factors.

It has been estimated that 90% of the information used by drivers is visual. While the visual field of the human eye is large, only a small portion requires accurate vision. The central area covers a cone of 2-4° which is an area about the size of a quarter held at arm's length. The quality of vision falls off rapidly from the central area.

A driver searches the road ahead in a series of fixations, looking at successive objects of interest. While driving, fixations on lane position and peripheral objects take less than one third of a second. Longer fixations of up to two seconds are used for estimating sufficient gap distance, the effect of cross traffic and for reading signs. At 80 km/h, a driver moves two metres during the shorter fixations and 45 m or more during a longer fixation. This demonstrates that a driver is limited in the number of fixations that can be made and the number of objects that can be identified.

The driver's field of vision is determined by the demands of the driving task. Studies show that most driver fixations are concentrated in an area which extends approximately 10 degrees horizontally and six degrees vertically. When closely following another vehicle, a driver's fixations become even more concentrated, with focus mainly on the vehicle ahead. When approaching a traffic light or preparing to make a left turn, a driver has high visual workload and must check oncoming traffic, sometimes in two or three lanes. Each glance takes time, which means that two seconds or more can elapse between glances at any given area. Fast-moving vehicles, cyclists or pedestrians can "appear out of nowhere." (Bahar and Smiley, 2000)

On tangent sections, drivers can maintain path and lane position by looking ahead and using peripheral vision to maintain lane position. On curves, a driver's visual workload can double. The driver must look ahead and to the left and right to determine the road path and speed. Sign information should appear on tangents because the driver's visual workload makes signs incidental on curves.

Not only are drivers limited in how many places they can look, they are also limited in how much information they can take in from the road environment. In any one second, drivers are presented with thousands of pieces of information. A driver can only be consciously aware of a small proportion and must select these judiciously in order to drive safely.

The higher the speed, the simpler the road design must be for the average driver to cope. At highway speeds, a driver's information processing capabilities are severely challenged. For this reason, freeways have the simplest and most consistent design with no pedestrians, cyclists or at-grade intersections.

Drivers are also limited in their ability to pay continuous attention. When drivers have some degree of experience, driving becomes an automated task. When there is little traffic and visual tasks are not demanding, a driver can maintain control of the vehicle while thinking or doing other things. Under such conditions, drivers are particularly vulnerable to error and errors do occur in situations where road design is unusual or traffic control devices are placed in unexpected locations.

CSD recognises that designing roads in a consistent manner with recognizable cues is critical, because, as demonstrated above, drivers are limited in what information they can process.

In applying design values in a flexible manner, designers must understand that drivers cope by looking for familiar patterns of road geometry, roadside features and signage. Drivers respond rapidly to operational cues for higher or lower speeds. Speed and traffic conditions only allow a driver the time to look for information in familiar places and to respond in familiar ways. High rates of crashes occur in locations where drivers encounter unexpected conditions like left exits or unfamiliar objects. When designs correspond to expectations, drivers react quicker and more accurately.

4. Incorporating Context Sensitive Design into Everyday Practice: Summary of Presentations Made at the Charlottetown Workshop

In order to bring attention to the need to incorporate CSD as an everyday designer task, TAC held a workshop in Charlottetown at the 2006 conference. Four practising designers made presentations on different aspects and experiences with CSD.

- **John Robinson**, one of the principal authors of the current TAC Design Guide, spoke on design flexibility in Canadian conditions. He highlighted the need for designers to understand the heuristics of design considerations and to dwell on possible solutions that might not be "in the book."
- **Tim Neuman**, one of the leading practitioners and researchers of geometric design in the United States, spoke about achieving practical context sensitive solutions and illustrated them with USA applications.
- **Roy Biller**, a principal with a leading Western Canadian design firm spoke about the application of CSD on road corridors with the need to meet historical, social and political goals.
- **Leonard Ng**, a transportation manager with York Region, one of Canada's largest municipalities, spoke about CSD in suburban communities, where the majority of Canadians live and travel.

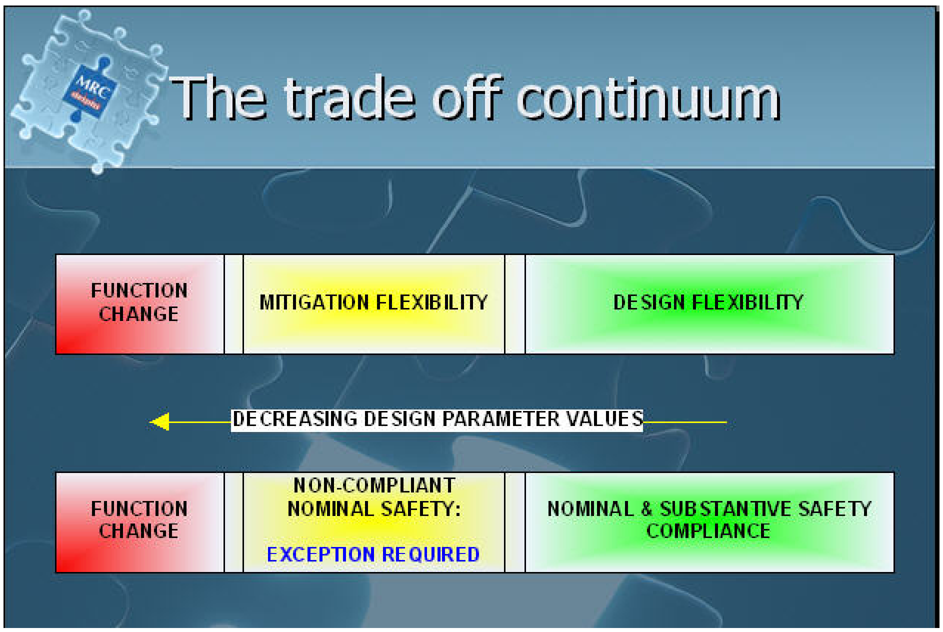
4.1 John Robinson's Presentation on CSD Issues in the Canadian Design Context

John Robinson, spoke about CSD in terms of the multiplicity of trade-offs that the average designer has to make. These trade-offs include:

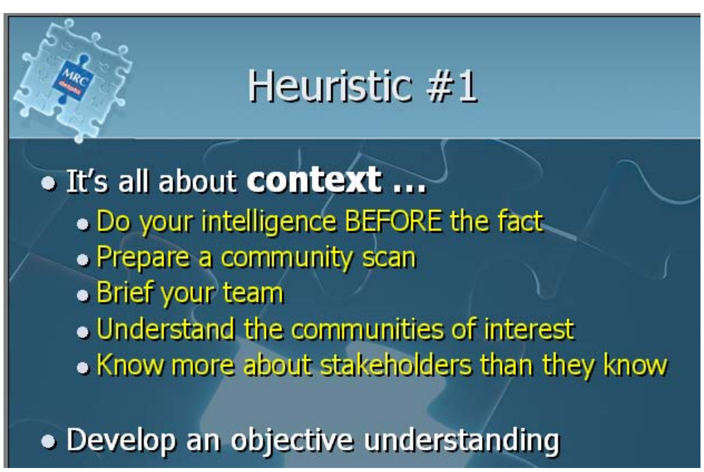
- Mobility
- Environmental impacts
- Capital costs
- Safety
- Aesthetics
- Maintenance costs
- Vehicle operating costs
- ---and many others---

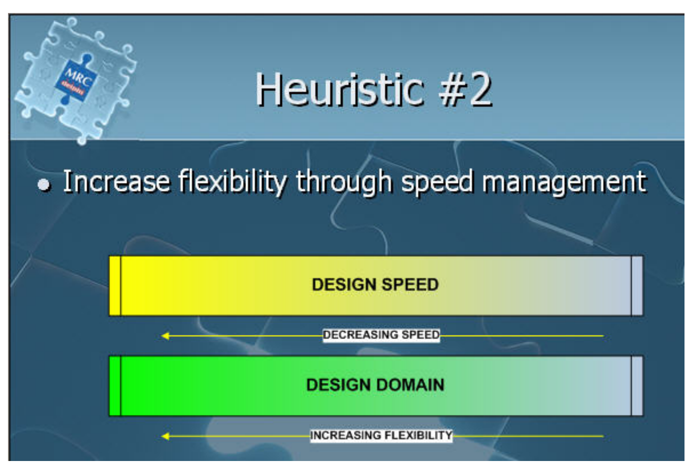
He summarized the concept of the design domain, which is a uniquely Canadian approach to flexibility in geometric design. Highway design requires a multiplicity of trade-offs. The more complex and creative the design, the greater will be the design domain. CSD assumes flexibility and a thorough understanding of design engineering.

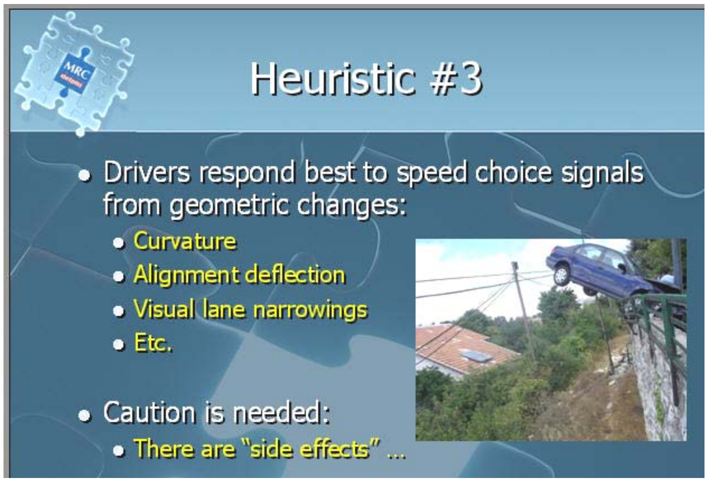
He focused his presentation on nominal and substantive safety and said that nominal (or anecdotal) safety can meet criteria while being substantively unsafe. Safety is not the only factor governing the flexible use of design parameters. He described a trade-off continuum between compliant substantive safety, non-compliant nominal safety and the functional changes that may occur in a typical road design.

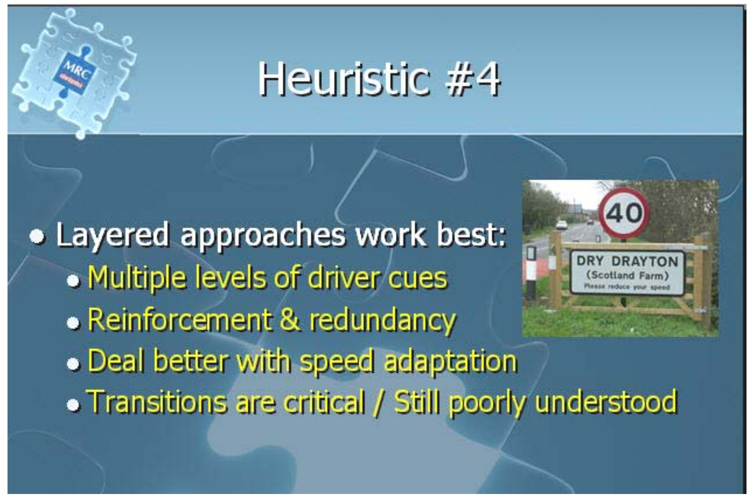


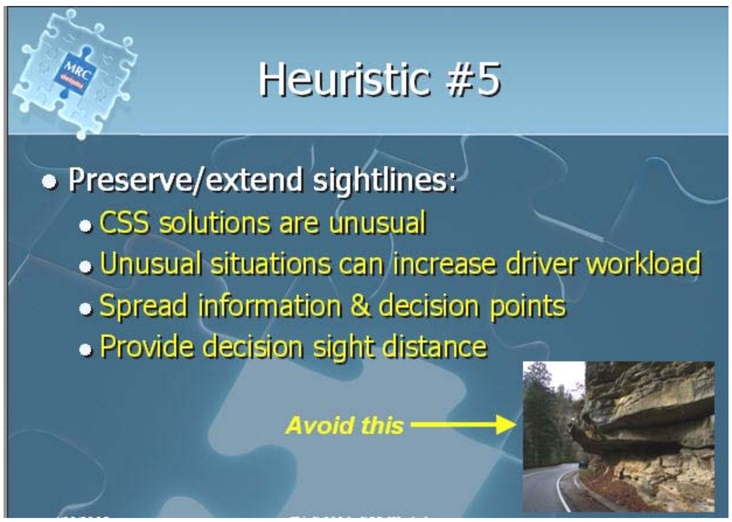
In order to illustrate the trade-off continuum, John Robinson introduced the following six heuristics as a means of searching for answers in the right places.











John Robinson made particular reference to speed management and risk management. He encouraged a better understanding of the benefits of speed management. This will enhance use of the road by alternative modes and aesthetic considerations while reducing:

- The need for clear zones;
- Requirements for barriers;
- Radii of horizontal and vertical curvature;
- Cross-section domains; and
- Environmental impacts.

In referring to risk management, which he called the dark side of highway design, he presented a series of steps for recognizing risks, evaluating risks and choosing appropriate design measures to balance risk. Risk management requires monitoring of the completed facility and documentation of the designer's intent. We have to recognize that all design carries a risk. We must learn better how to evaluate risk and to adjust our designs while still maintaining flexibility. Monitoring performance on newly-designed highways and highway corridors is essential but seldom undertaken. By monitoring, we learn from our mistakes and how respond to risks.

CSD can influence driver behaviour by introducing a layered approach to their designs.

- Providing driver cues
- Reinforcing the cues
- Providing clear transitions between domains
- Provide for speed adaptation

John Robinson concluded by appealing to designers always to dwell on the possible, to be flexible in their designs, to respond to society's demands, to gather contextual information collaboratively and to be explicit in the execution of designs while recognizing the need for safety.

4.2 Tim Neuman's Presentation on Achieving Practical Context Sensitive Solutions

Tim Neuman spoke about his experiences with CSD and some of the solutions that are being commonly used in the USA.

He introduced the technical report that he had helped author, *NCHRP Report 480 - A Guide to Best Practices for Context Sensitive Solutions*. This guide addresses the current needs for roads to be assets to communities and to be compatible with natural and built environments.

He went on to say that the key to successful design development is the ability to address equally the need for safety, mobility, scenic values, history and the environment. He said that the keys to successful design development are:

- An appreciation of the problem;
- An ability to communicate decisions;
- The showing of technical leadership; and
- An ability to apply trade-offs.

In CSD, technical creativity involves

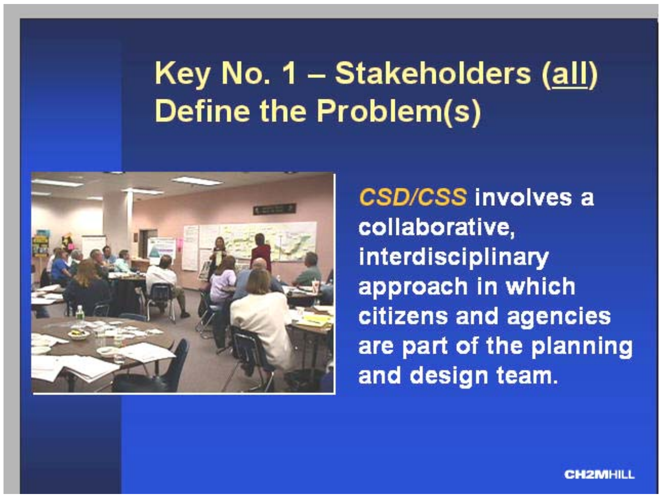
- Equating low speeds and high quality;
- Exercising choice;
- Providing designs to meet community needs; and
- To be able to apply not only that which is required but also to answer why we are providing a certain design.

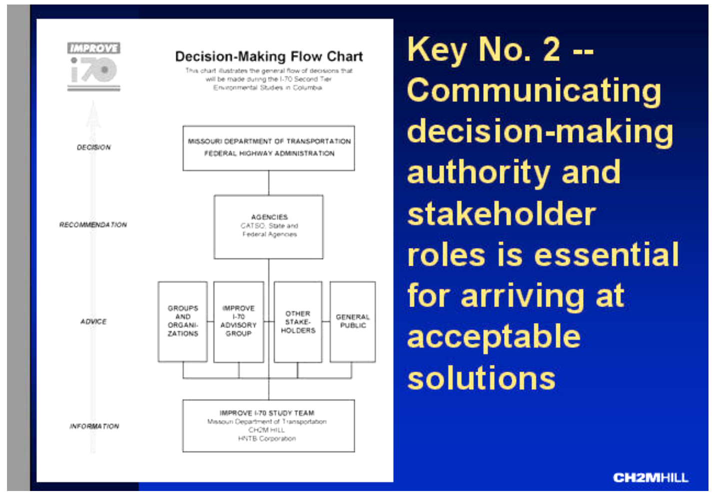
Fundamental to a road project is the need to ask questions about its need and purpose. CSD addresses equally the requirements for safety, mobility and the preservation of scenic, aesthetic, historic, environmental and other community values. This requires collaboration and an inter-disciplinary approach in which communities become a part of the design team. He said that the keys to successful development of practical solutions involve:

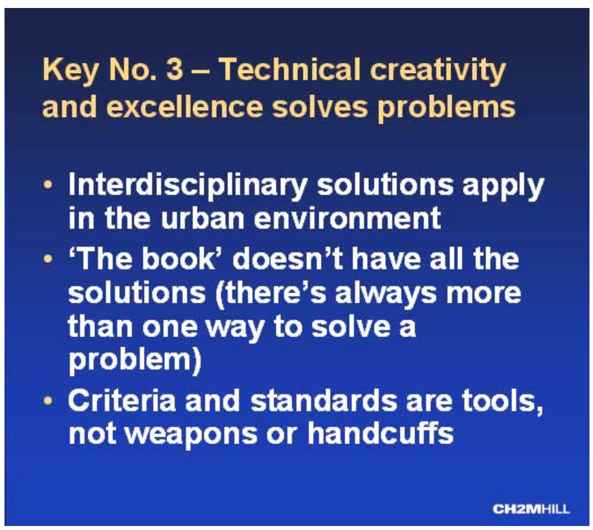
- agreement among stakeholders;
- communication between decision makers and communities;

- technical leadership especially in advocating mobility; and
- the ability to provide trade-offs between engineering and community needs.

He illustrated the keys to successful development in the following figures.







Tim Neuman emphasised that a commitment to CSD does not mean relinquishing ownership of the project. Decisions remain with the owner's agency and meaningful public involvement is a process of information gathering for both owners and the public who will use the facility. Professional challenges include:

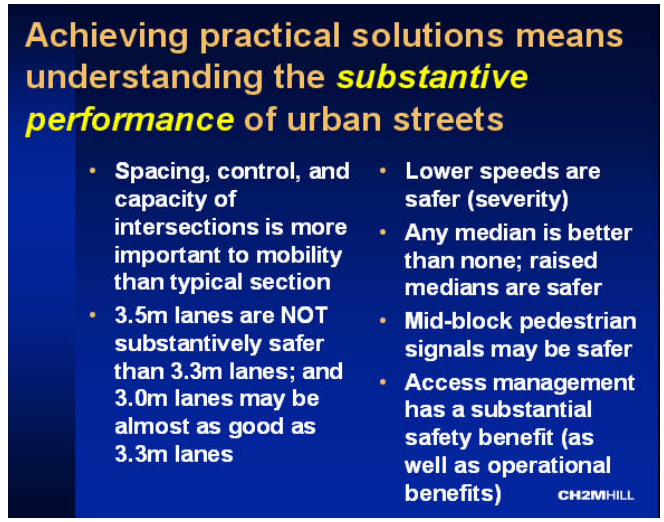
- equating low speed with mobility;
- sometimes narrower or fewer lanes are better;
- mobility can be achieved by means other than the use of typical sections;
- understanding that design is a series of choices;
- thinking of pedestrians in the context of mobility;
- getting beyond the model that "standards are safe"; and
- using meaningful safety information as part of the design process.

Tim Neuman illustrated solutions to these challenges with the following examples.

Tim Neuman reported on recurring issues at AASHTO with "best solutions" for the design of urban arterials, as illustrated in the slide above:

- the safety of having trees planted in the roadside environment;
- accommodation of pedestrians;
- definitions of design speed and operating speed;
- intersection safety and automated enforcement.

He concluded his presentation with the following two exhibits.



4.3 Roy Biller's Presentation on Context Sensitive Design

Roy Biller, a consulting engineer in Western Canada specializing in geometric design, addressed CSD in road corridors. He emphasised the need for designers to understand the historical, social and political contexts of corridors and to design highways that satisfy their location and character. Aesthetics is only one feature of good design. A driver should be able to recognize a road by the corridor through which it passes. He illustrated this with two examples.

- The Sea-to-Sky Highway in British Columbia which will be the main access to the snow events of the 2010 Olympics. The corridor is well-defined by the mountainous character and the steepness of the terrain. The highway, which is currently being upgraded through this corridor, responds to the need for roadside views, scenic pull-offs and slower driving conditions. The use of 2+1 roads is a first in Canada and is intended to satisfy the demands of capacity and mobility while providing safe driving conditions in areas where it is difficult to build wide roads.
- The 23rd Ave corridor in Edmonton, which is a suburban corridor, through what could be a ubiquitous urban landscape across flat terrain. 23rd Ave, which crosses Edmonton from east to west, maintains a consistency of design in terms of roadside berms and plantings, curvilinear alignment, bicycle and pedestrian accommodation and consistent treatments of driveways and intersections.

As part of Roy Biller's presentation, he presented the following examples from the above two corridors.


The Sea to Sky Highway
•Pacific Ranges
•Mountain Range Vistas
•Broad Glaciated Valleys
•Southern Fjiordland
•Dramatic Ocean Vistas
•Immediate and Rugged Terrain
•Interspersed Urban Sections
•Lions Bay – Hillside Village
•Britannia Beach – Shallow Slopes from Shoreline
•Squamish
LEGEND
WHISTLER
SQUAMISH


Concerns Influencing Context
– Contrasting Environments
Urban Areas
Natural Areas
– Costal Regions
– Lowland Areas
– Highland Valleys
– Political Goals
Olympic Access
Local Concerns
Long Term Implications
– Restoration Costs
– O & M Costs
PORTEAU COVE PROVINCIAL PARK


23 Avenue
3 Kilometre Transition from High Speed Rural to Congested Urban

4.4 Leonard Ng's Presentation on CSD in Suburban Communities

Leonard Ng spoke from the perspective of a manager of the roads and streets for the York Region in Ontario. He described CSD in one of Canada's largest suburban municipalities. A suburban municipality could be described as urban sprawl, characterized by shopping plazas, single family dwellings and high-speed arterials. York has taken the initiative of highlighting the heritage and environmental character of the region. Roads have been designed to enhance wetlands and to enhance flora and fauna.

Speed management techniques characterize many of York's arterials. Each community center or shopping center within the Region has defined entry points. Arterial boulevards provide some curvilinear alignments and are naturally landscaped. Bus shelters contain heritage themes which have been reflected in road signs and at community gateways. Leonard Ng illustrated York as an example of how road design has been used to characterize a community and to provide transportation facilities for all road users.

As part of his presentation, he presented the following examples of CSD in suburban areas.

A newly constructed arterial 20 years ago

Man-made Wetland, 2003 Construction

Yonge St, Newmarket

Elgin Mills Rd, Richmond Hill

A bus stop with heritage theme

Walkability on St. John's St, Aurora

Public Praise for a new Road Project

5. Future Direction of CSD in Canada

Over 100 people attended the CSD workshop in Charlottetown and there was considerable discussion between presenters and participants on the direction that the design profession in Canada could be taking with CSD. Points made during discussion included the following.

- The need to make road design part of the community and not only a conduit for vehicles.
- The need to involve communication experts with public involvement and an understanding of community context and evolving expectations.
- The question of safety; what is "safe" if we are flexible with our design guidelines?
- The question of speed management, how it can be applied and whether innovative design really does slow traffic speeds.
- The question of human factors, which are poorly understood by design engineers.
- Mitigating risk and a need for practitioners to better understand the dynamics of new infrastructure.
- The need to ensure that designers continue to provide mobility and that roads are not an exercise in creative landscape architecture.

Workshop participants strongly supported ongoing discussion and education with CSD and the need to update the TAC Geometric Design Guidelines to include a chapter or supplement on the topic of CSD. Such an addition to the TAC Guidelines could include some of the following topics.

Figure 1. Suggested Table of Contents

Suggested Table of Contents for a TAC Geometric Guidelines Chapter or Supplement on Context Sensitive Design

1. **Introduction and Description of the Topic**
1.1 Introduction to Context Sensitive Design
1.2 Typical Project Design Objectives
1.3 Documenting Design Decisions
1.4 Design Hour Traffic Forecasts and Road Lane Requirements
1.5 Adjacent Land Uses
1.6 Design Vehicles
1.7 Transit Accommodation
1.8 Operations Management and Maintenance Considerations

2. **Highway Speed and Classification**
2.1 Definitions of Speed
2.2 Discussion on Highway Functional Classifications
2.3 Design Flexibility

3. **Road Corridor Theme and Aesthetics**

4. **Incorporating of Human Factors**
4.1 Definition of Human Factors
4.2 Basics of Driver Visual Search and Information Processing
4.3 Importance of Expectancy in Highway Design

5. **Discussion on Applicable Alignment Elements**
5.1 Alignment Parameters
5.2 Design Consistency
5.3 Anticipated 85th Percentile Operating Speed
5.4 Ranges of Curve Radii
5.5 Spiral Lengths
5.6 Superelevation
5.7 Stopping and Decision Sight Distances
5.8 Guide Sign Placement Relative to Decision Points
5.9 Lane Widths
5.10 Vertical Alignment
5.11 Lane Balance and Weaving

6. **Applicable Cross-Section Elements**
6.1 The Road Message
6.2 Cross-Sections for Different Road Segments
6.3 Traffic Lanes
6.4 Bicycle Facilities
6.5 Pedestrian Facilities
6.6 Medians and Median Barriers
6.7 The Use of Highly Visible Pavement Markings and Rumble Strips
6.8 Shoulders, Edge Treatments and Clear Zones
6.9 Transit Accommodation

7. **Speed Reducing Countermeasures**
7.1 Driver Speed Selection on Tangents
7.2 Countermeasures to Reduce Speed on Tangents
7.3 Speed Selection on Curves
7.4 Countermeasures to Reduce Speed on Curves

8. **Intersections and Interchanges**
8.1 Designing for All Road Users
8.2 Intersection Design Principles
8.3 CSD and At-Grade Intersections
8.4 Roundabout Design
8.5 CSD and Interchanges

9. **Verifying Explicit Safety**
9.1 Collision Modelling
9.2 Consistency Modelling
9.3 Intersection Safety Review
9.4 Safety Audits

10. **CSD with Guide Signing, ITS and Lighting**
10.1 Guide Signing
10.2 Lighting
10.3 Intelligent Transportation Systems

11. **Bridge and Structural Design and Aesthetics**

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