Adoption of a Management System Approach to Geometric Design Process for Better and Safer Roads

By

Allan Kwan, P. Eng.
Former Executive Director, Technical Standards Branch, Alberta Transportation
Adjunct Professor, Department of Civil and Environmental Engineering, University of Alberta
Edmonton Alberta, Canada T6G 2W2
Tel: 1-780-405 4388, Fax: 1-780-492 0249
Email: allan@kwancollective.com

Ying Luo
Former Research Analyst, Department of Civil and Environmental Engineering, University of Alberta, 3-008 NREF
Edmonton, Alberta, Canada T6G 2W2
Tel: 1-780-492 1906, Fax: 1-780-492 0249
Email: yluo7@ualberta.ca

Robert Duckworth, P. Eng.
Director, Transportation Modelling and Analysis, Alberta Transportation
2nd floor, Twin Atria Building, 4999 - 98 Avenue
Edmonton, Alberta. Canada T6B 2X3
Phone: 1-780-415-1047, Fax: 1-780-427-0353
E-mail: robert.duckworth@gov.ab.ca

Bill Kenny, P. Eng.
Director, Design, Project Management and Training, Alberta Transportation
3rd floor, Twin Atria Building, 4999 - 98 Avenue
Edmonton, Alberta. Canada T6B 2X3
Tel: 1-780-415-1048, Fax: 1-780-422-2027
Email: bill.kenny@gov.ab.ca

Dr. T. Z. Qiu
Associate Professor, Department of Civil and Environmental Engineering, University of Alberta, 3-005 NREF
Edmonton, Alberta, Canada T6G 2W2
Tel: 1-780-492 1906, Fax: 1-780-492 0249
Email: zhijunqiu@ualberta.ca

Paper prepared for presentation at the Geometric Design – Lessons Learned: Linkage Between Design Standards and Road Safety Of the 2015 Conference of the Transportation Association of Canada Charlottetown, PEI
ABSTRACT
Transportation agencies are moving toward the development of enterprise-wide transportation infrastructure system (TIMS) or Transportation Asset Management System (TAMS). This is an opportune time to include geometric design and safety-based applications within the overall TIMS development. Alberta Transportation commenced the development of TIMS in 1996. As part of TIMS development, Network Expansion System Support (NESS) and Collision Information Application (CIA) were developed and implemented in 2007. NESS/CIA are geometric design and safety-based applications that are used for analysis in various phases of project development including capital planning, programming, planning, design, and rehabilitation phases. NESS/CIA performs highway network screening on roadway geometrics and roadway safety annually. Traditionally, geometric design and safety analysis are separate functions. Moreover, geometric design and safety applications are mainly considered at project level during the detailed design phase. The development of NESS/CIA applications enable geometry design and safety analysis to be assessed concurrently at various phases of project management. Over the past eight years, NESS/CIA demonstrated wide use applications in various phases of project development that would result in overall better and safer roads.
Contents

Introduction.................................................................................................................................................. 4
Background.................................................................................................................................................. 4
   Development of NESS And CIA Within TIMS ......................................................................................... 4
   NESS’ Functional Role in TIMS.............................................................................................................. 5
   Performance Measures and Performance Management ........................................................................... 6
   Geometric Design, Capacity and Safety Thresholds in NESS .............................................................. 7
   Highway Network Screening For Deficiencies and Work Activities....................................................... 8
NESS’ Output for Decision Support in Planning, Programming, Design and Safety Analysis 13
Geometric Design Decisions and Project Development Process ............................................................. 13
Case Studies ............................................................................................................................................... 15
   Geometric Improvement with Pavement Rehabilitation Project.......................................................... 15
   Intersection Safety Improvement Project Development .......................................................................... 16
   Multi-lane Project Development ........................................................................................................ 17
Review of Other Geometric Design and Safety Applications ................................................................. 18
Conclusions............................................................................................................................................... 19
Acknowledgement ............................................................................................................................ 21
References................................................................................................................................................ 21
INTRODUCTION

Geometric design of highways and streets is a complex process. In the design stage, designers typically use various geometric design guides and other documents to make design choices. However, geometric design activities and geometric design decisions may vary over time because many design choices are assessed throughout the project development stages through capital planning, preliminary engineering and programming prior to the detailed design stage. For better and safer roads, it is prudent to incorporate geometric design and safety analysis in the early stages of project development. With greater emphasis on safety, evidence-based and performance-based approaches, transportation agencies are seeking ways of incorporating geometric design and safety-based decisions in each phase of the project development. To accomplish this goal at the network level, an enterprise-wide management system that incorporates geometric design standards and safety information is required; the overall goal would be to plan, program and design better and safer roads.

Many transportation agencies are adopting enterprise-wide transportation infrastructure management systems (TIMS) to support achieving organization objectives in accessibility, mobility, reliability, safety and quality of service. In general, TIMS enable organizations to:

- improve infrastructure reliability and accessibility;
- plan and determine best life-cycle investment strategies to minimize missed opportunity costs;
- increase efficiency and transparency in decision-making through enterprise-wide road and bridge inventory and their roadway geometric and safety conditions;
- manage road and bridge projects more collaboratively, and;
- improve the organization’s ability to perform risk management.

BACKGROUND

Development of NESS And CIA Within TIMS

In 1995, Alberta Transportation decided to outsource all highway maintenance and engineering services to the private sectors; staff complements were reduced from over 3200 to 780 staff. It was determined that remaining staff would focus on developing standards and policies and managing outcomes while the private sector would performing design, construct and maintenance services. Alberta Transportation was to be viewed as a knowledgeable owner so that it could maintain a balance between public interests and private initiatives. As a result, it was decided that an enterprise-wide Transportation Infrastructure Management System (TIMS) was needed to enable staff to plan and manage Alberta’s highways and bridges. Moreover, existing legacy pavement and bridge management systems required major upgrading and integration in order to share data and information within and outside of Alberta Transportation; these functions would be rolled into the TIMS system as well.

Alberta Transportation commenced the development of TIMS in 1996. One of its modules, the Network Expansion Support System (NESS) was a geometric design-based decision support tool within TIMS. During the NESS concept definition phase, it was determined that safety information...
was needed as well to fulfill the safety aspect of Alberta Transportation’s mission of providing a safe and efficient transportation network for movement of goods and people. Consequently, another module, the Collision Information Analysis (CIA), a safety-based information support tool, was being developed concurrently with NESS. Both were implemented in 2007. NESS is capable of producing various analytical reports for uses in planning, programming, design, rehabilitation and safety projects. Overall, the application of NESS/CIA in an integrated manner has enabled Alberta Transportation to plan, program and design better and safer roads to meet performance measures and performance management objectives.

NESS’ Functional Role in TIMS

Alberta has nearly 31,000 km of provincial highways and over 3,800 bridges (3, 4). TIMS is a web-based knowledge system to manage highway assets and capital improvement investments. The overall objective is to deliver the maximum lifetime socio-economic value for investments by measures of safety, economics, environmental sustainability and innovativeness. As shown Figure 1, it has different applications, among which, NESS/CIA assists staff and engineering consultants to identify deficient highway segments based on capacity, geometric design standards, safety and performance measures.

![Figure 1, TIMS Applications](image-url)
Performance Measures and Performance Management

In the early 2000s, the Alberta Government aimed to develop a long term capital plan for all government owned infrastructure in Alberta. Performance measures were to be used to determine capital investment requirements for various government departments. Common corporate infrastructure performance measures were developed that would be applicable to both vertical infrastructures (hospital, school, senior housing) and horizontal infrastructures (roads and bridges). They were (1) physical condition, (2) utilization and (3) functional adequacy. For Alberta Transportation, (1) IRI (pavement smoothness), (2) level of service and (3) 3R/4R roadway width, speed reduction and road ban were chosen for physical condition, utilization and functional adequacy respectively. Level of service, 3R/4R roadway width and speed reduction were related to geometric design and safety. Annually, Alberta Transportation would report overall highway network performance in accordance to these performance measures as shown in Figure 2. Utilization was dropped subsequently from annual reporting but it was still being used at the programming level.

<table>
<thead>
<tr>
<th>Core Businesses/Goals/Measure(s)</th>
<th>Prior years' Results</th>
<th>Target</th>
<th>Actual 2010-11</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal 1:</strong> Alberta's provincial highway network connects communities and supports social and economic growth.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Measure 1.a:</strong> Physical Condition of Provincial Highways,*</td>
<td>Good: 59.0% 58.6% 58.1%</td>
<td>58.0% 58.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fair: 25.9% 26.3% 26.8%</td>
<td>26.0% 26.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor: 15.1% 15.1% 15.1%</td>
<td>16.0% 14.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Measure 1.b:</strong> Functional Adequacy of Highways: Percentage of provincial highways that meet current engineering standards.</td>
<td>81.1% 82.2% 83.9%</td>
<td>80.0% 84.2%</td>
<td></td>
</tr>
<tr>
<td><strong>Measure 1.c:</strong> Construction Progress on the North-South Trade Corridor: Percentage of four-laning open to travel.</td>
<td>90.4% 90.4% 91.1%</td>
<td>92.0% 92.2%</td>
<td></td>
</tr>
<tr>
<td><strong>Measure 1.d:</strong> Ring roads in Edmonton and Calgary: Percentage of ring roads open to travel.</td>
<td>36.4% 38.0% 58.5%</td>
<td>56.0% 58.5%</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2, Highway Performance Measures in Alberta Transportation’s Annual Report (15)*

For utilization, Level of Service (LOS) of each highway segments would be rated based on HCM’s Capacity Manual methodology for rural highways. For example, Alberta Transportation aimed to have its highway network level operating at LOS C or better. Highway segments operating below LOS C would be candidates for assessment for capital improvement. Geometric improvements such as provision of passing lanes, access management, grade widening to 3R/4R or new construction standards and four-laning would contribute to LOS improvement.

For functional adequacy, 3R/4R width was chosen for safety and speed reduction zones was selected for speed management. Figure 3 illustrates the relationship amongst road width, traffic volumes and roadway safety. Through cost-benefit analysis, Alberta Transportation established 3R/4R traffic volumes that would require road widening or four laning. Speed reduction zones were identified that were due to poor horizontal and vertical geometric design such as sharp horizontal curves with inadequate superelevation, inadequate sight distances, poor access management and congested intersections. Accordingly, geometric improvements to these segments could restore its original functional adequacy to a posted speed of 100 km/hr on rural highways.
Performance management is related to activities that maintain highway integrity relative to highway safety and compliance with Highway Geometric Design Guide and other technical requirements. These activities may not have a short-term impact on overall highway network performance measures as corporate performance measures are high-level indicators at the network level. For example, Alberta Transportation undertakes geometric assessment and improvement of all highway pavement rehabilitation projects in the three-year pavement rehabilitation program. As such, removal of redundant accesses according to access management design guidelines and intersection improvements based on future traffic volumes and future safety performance will not have immediate impact on overall highway network performance measures.

With the use of geometric design and safety based metrics and performance measures during the early stage of project development, it will bring smarter decision-making for better and safer roads. These measures also provide quantitative evidence and transparency for safety and/or operation improvements within the current highway network; it assists highway agencies’ performance management process in a forward-looking way.

**Geometric Design, Capacity and Safety Thresholds in NESS**

NESS is capable of identifying and reporting highway segments’ and intersections’ deficiencies in terms of geometric design, capacity and safety thresholds. Geometric design thresholds on vertical and horizontal alignments and intersections are based on Alberta Transportation’s Highway Geometric Design Guide. Capacity thresholds in terms of new construction and 3R/4R guidelines are shown in Figure 4a and Figure 4b. As shown, capacity thresholds were further categorized in accordance to Alberta Transportation’s service classification of Level 1 (National Highways), Level 2 (Intra Provincial), Level 3 (Intra-Regional) and Level 4 (Collectors (local)).
For safety thresholds, provincial non-animal collision rates for road widths and intersections were calculated in CIA for usage on each highway segment, intersection and other highway geometric features. Based on these safety thresholds in CIA, NESS would identify highway segments, intersections, horizontal and vertical curves with ‘negative delta’ values to alert the users on safety deficiencies.

**Highway Network Screening For Deficiencies and Work Activities**

NESS performs network screening annually after updating of data on traffic projection, collisions and newly constructed highway segments and intersections. Geometric design elements are all considered, such as design speed, lane width, horizontal alignment, vertical alignment, grade, superelevation etc. After network screening, it identifies the segments deficiencies and provides
recommended ‘work activities’ such as planning study and safety assessment, intersection and roadway improvements relative to the established geometric design and safety thresholds.

To illustrate, some NESS reports on Highway 754 in Alberta are shown in the following figures:

**Figure 5a.** Highway 754 – NESS Roadway Summary Report

**Figure 5b.** Highway 754 – NESS Width Safety Report (partial)
Figure 5c, Highway 754 – NESS Intersection Report

Figure 5d, Highway 754 – NESS Intersection Report (partial)
Figure 5e, Highway 754 – NESS Horizontal Report (partial)

Figure 5f, Highway 754 – NESS Vertical Report (partial)

Figure 5g, Highway 754 – NESS Posted Speed Report
NESS produces Work Activity Summary as illustrated in the above table. There are three levels of work activities in NESS. Level 1 is data collection. Level 2 is engineering studies or safety assessment. Level 3 is remedial measures such as installation of speed advisory sign,
superelevation improvement, horizontal and vertical alignment reconstruction, grade widening, intersection improvement and passing lanes.

NESS generates a high level report on geometric design and safety recommendations. In general, these reports are further used as reference for engineering studies or for programming of capital improvement projects.

**NESS’ Output for Decision Support in Planning, Programming, Design and Safety Analysis**

After performing network screening and processing, information on geometric design and safety analysis and associated work activities are stored in Transportation Infrastructure Management System (TIMS) Inventory.

As shown previously, users could generate various types of NESS reports on roadway geometric conditions with associated safety analysis. Customize reporting could be generated for planning, programming, design and safety analysis.

NESS outputs are used for different aspects:

- Infrastructure planning engineers use information from NESS to identify and prioritize highway sections that require geometric and safety improvements.
- NESS reports form the basis as terms of reference for preliminary engineering and detailed design for each project.
- NESS information can assist to analyze impacts from changes in standards and policies.
- Safety engineers use NESS information for development of various Traffic Safety Plan programs such as catch-up shoulder rumble strips program and black spot program.
- Geometric designers use NESS for scoping of 3R/4R geometric and safety improvements for incorporation into pavement rehabilitation projects.
- Safety engineers use NESS reports to conduct in-service road safety review.
- Planning and geometric design engineers use NESS reports with geometric design and safety information to assist in highway corridor planning and access management studies.
- As shown in Figure 2, the performance measures are listed on the annual report; it shows the department’s effort in highway performance management.
- The output is used for capital funding requests to Treasury Board, Government of Alberta’s statutory Cabinet committee.

**Geometric Design Decisions and Project Development Process**

Geometric design and safety decisions are interdependent and they should be considered in all phases of the project development process with intended outcomes or target performance. Geometric design and safety decisions will evolve throughout the project development process. In this regard, geometric and safety engineers should be undertaken geometric and safety analysis and provide appropriate input to influence final outcomes and performance related to safety, mobility, accessibility and quality of service in all stages of the development process.
Figure 6 shows the highway capital planning and project development processes. Through this ten year cycle, projects are being identified for planning, preliminary engineering, survey and design, right-of-way acquisition, environmental assessment and finally construction programming. Traditionally, geometric design has limited roles in capital planning and programming of highway projects. System planning or long range planning may consider the role of geometric design at a rudimentary level in terms of geometric design relative to service classification. As projects advance to the preliminary engineering and planning study phases, geometric design and safety would be given stronger consideration. The application of NESS and CIA in Alberta enable geometric design decisions and safety are taking into strong consideration in the capital planning stage that ultimately will result in better and safer roads.

*Figure 6, Highway Capital Plan and Project Development Process*
CASE STUDIES

Three case studies are shown in this section to demonstrate the earlier application of geometric and safety considerations for project development. The case studies illustrate the functionality of NESS in terms of: (1) incorporating 3R/4R geometric and safety improvement to pavement rehabilitation projects; (2) developing geometric and safety improvement projects to eliminate safety inadequacy; and (3) developing geometric improvement projects to meet capacity requirements.

Geometric Improvement with Pavement Rehabilitation Project

Prior to NESS implementation, Alberta Transportation geometric designers and engineering consultants performed 3R/4R geometric and safety assessment of future pavement rehabilitation projects. The purpose of 3R/4R improvements is to extend the service life of existing paved highways and enhance highway safety on a network basis. Geometric assessment was a labour intensive and tedious process as most roadway geometric and safety data were not readily available. In 2007, geometric and safety assessment of planned pavement rehabilitation projects were automated through NESS. Suggested 3R/4R safety improvements generated by NESS would be assessed for inclusion in corresponding pavement rehabilitation projects scheduled in future years. Figure 7 shows the general work flow of including geometric improvement projects to the pavement rehabilitation project.

[Diagram of work flow for Pavement Rehabilitation Scoping]

As shown in Figure 8, a snapshot of work activities summary for Highway 36:26, NESS suggests grade widening, vertical curve reconstruction and turning lanes at two intersections be included with this pavement rehabilitation project. Further engineering studies were also suggested for other segments of Highway 36:26.
### Work Activity Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>LFLS</th>
<th>Length</th>
<th>int #</th>
<th>Location</th>
<th>Direction</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>3626</td>
<td>0.276</td>
<td>56-330</td>
<td>0.031</td>
<td>1 km N of Hwy 05 - 5 km S of Hwy 05</td>
<td>Grade Widening</td>
</tr>
<tr>
<td>2022</td>
<td>3626</td>
<td>0.302</td>
<td>56-034</td>
<td>0.094</td>
<td>7 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Grade Widening</td>
</tr>
<tr>
<td>2013</td>
<td>3626</td>
<td>0.325</td>
<td>56-181</td>
<td>0.085</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Vertical Curve Reconstruction</td>
</tr>
<tr>
<td>2013</td>
<td>3626</td>
<td>0.339</td>
<td>56-051</td>
<td>0.186</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Vertical Curve Reconstruction</td>
</tr>
<tr>
<td>2013</td>
<td>3626</td>
<td>0.339</td>
<td>56-051</td>
<td>0.070</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Vertical Curve Reconstruction</td>
</tr>
<tr>
<td>2013</td>
<td>3626</td>
<td>0.339</td>
<td>56-051</td>
<td>0.112</td>
<td>5 km S of Hwy 05 - 5 km S of Hwy 05</td>
<td>Vertical Curve Reconstruction</td>
</tr>
<tr>
<td>2023</td>
<td>3626</td>
<td>0.385</td>
<td>56-200</td>
<td>0.012</td>
<td>2 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Construct Front Turn lane</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.413</td>
<td>56-230</td>
<td>0.244</td>
<td>Highway 30-35 And 2 Avenue</td>
<td>Construct Right Turn Lane</td>
</tr>
<tr>
<td>2019</td>
<td>3626</td>
<td>0.413</td>
<td>56-230</td>
<td>0.244</td>
<td>Highway 30-35 And Var A Wash School Access</td>
<td>Install Signal</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.081</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Geometric Study - Vertical Curve</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.070</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Geometric Study - Vertical Curve</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.125</td>
<td>Hwy 05 - Hwy 05</td>
<td>Geometric Study - Vertical Curve</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.037</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Planning Study (Grade Widening)</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.070</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Planning Study (Grade Widening)</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.068</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Safety Assessment</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.150</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2015</td>
<td>3626</td>
<td>0.431</td>
<td>56-250</td>
<td>0.090</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.464</td>
<td>56-280</td>
<td>0.264</td>
<td>1.5 km N of Hwy 05 - 1.5 km N of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.464</td>
<td>56-280</td>
<td>0.510</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.464</td>
<td>56-280</td>
<td>0.427</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.464</td>
<td>56-280</td>
<td>0.273</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2020</td>
<td>3626</td>
<td>0.464</td>
<td>56-280</td>
<td>0.246</td>
<td>1 km S of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2021</td>
<td>3626</td>
<td>0.470</td>
<td>56-305</td>
<td>0.212</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2021</td>
<td>3626</td>
<td>0.470</td>
<td>56-305</td>
<td>0.186</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2021</td>
<td>3626</td>
<td>0.470</td>
<td>56-305</td>
<td>0.200</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
<tr>
<td>2021</td>
<td>3626</td>
<td>0.470</td>
<td>56-305</td>
<td>0.202</td>
<td>1 km N of Hwy 05 - 1 km S of Hwy 05</td>
<td>Speed Study (vertical curve)</td>
</tr>
</tbody>
</table>

**Figure 8, Work Activity Summary for Highway 36:26**

### Intersection Safety Improvement Project Development

The NESS intersection report (Figure 9) provides information on highway intersections. NESS gives a detailed report for the location description, intersection details, safety performance, turning lane analysis, traffic signal analysis, illumination analysis and summary of work activities.

The report includes reported collisions within the intersection area during the latest five years. Fatal, injury and property damage only (PDO) has their associated collision cost, which is used for calculate the total collision cost at the intersection. The benchmark is determined using the average collision cost per intersection having similar entering volumes. Turning lane warrant is conducted as per geometric design guidelines in Chapter D of the Highway Geometric Design Guide.

Based on the aforementioned studies, the work activities for an intersection are summarized (see Figure 10).
Figure 9, Intersection Report that Identifies Safety Deficiencies

Multi-lane Project Development

The NESS multilane report shows road segments that require more driving lanes to accommodate future traffic demand and address safety performance. The Weighted Annual Average Daily Traffic (WAADT) is the latest traffic data in the TIMS data repository. Using the growth rate for Multi-lane Project Development.
the road segment, traffic volume in year 20 is projected. The level of service is computed for road segments at year 0 and year 20. The year in which the 4-lane, 6-lane or 8-lane work activity is triggered, as shown in the work summary (see Figure 11).

Figure 11 Multi-lane Project Development for Future 20 Years

Review of Other Geometric Design and Safety Applications

Highway network expansion and rehabilitation is one of the key components in transportation asset management. From a geometric design and safety perspective, there were several policy initiatives to achieve optimum return on investments. In 1997, FHWA developed the national guidance document *Flexibility in Highway Design* (5). The “flexibility” means that design will not only meet the minimum requirements of geometric design standard, but also will achieve an optimum solution that balances conflicting interests from all stakeholders. In 1999, FHWA began the research on Context-Sensitive Design (CSD), now called Context-Sensitive Solutions (CSS) (6). The philosophy of CSD is to incorporate community impacts beyond the basic transportation considerations. CSD concept seeks a collaborative project development process that understands the design decisions’ impacts and trade-offs for all the stakeholders. Recently, Transportation Research Board released a National Cooperative Highway Research Program (NCHRP) publication on Performance-Based Analysis of Geometric Design of Highways & Streets. This publication describes the proposed performance-based analysis framework for geometric design. The framework includes (1) the project initiation phase, which determines intended outcomes within the project context; and (2) the concept development, which analyzes the influence of discrete design decisions of a geometric element to generate a set of potential solutions for further evaluation; and (3) the evaluation and selection phase, which performs performance measure process and financial feasibility evaluation. The best alternatives are selected according to the whole process. Six case studies were demonstrated to showcase this analysis process (7, 8).
The concept of using performance measures for geometric design is widely accepted in various agencies. Several state DOTs started to implement Practical Design policy, which was consistent with CSS principle. They identified target objectives for design alternatives. Missouri Department of Transportation (MoDOT) started to implement Practical Design policy from 2005. The related projects addressed insufficiency, corridor needs, and cost reduction (9). MoDOT suggested that Practical Design can apply to all projects, while it was most effective at the scoping level (10). Kentucky adopted the Practical Design procedure in 2007. They considered project investment to achieve optimal safety, mobility and utility return. The Practical Design was applied from planning through operations and maintenance (11). Idaho adopted CSS approach in 2005 and started their Practical Solutions in 2007. They considered safety benefits as the most important goal, and they also reported cost savings (10). Oregon incorporated Practical Design into their project delivery-cycle from 2009 (12). They considered system optimization from safety, corridor context, and public support perspective and found most cost efficiency design alternatives. Utah also adopted Practical Design concept from 2011, they set objectives and optimized the transportation system as a whole (10).

Safety Analyst (SA) is a system-wide safety analysis tool that applies Practical Design concept. It screens the roadway network to find the sites that potentially require safety improvements. It diagnoses the problems, assists selection of countermeasures, and prioritizes improvement projects based on benefit-cost analysis. Currently, 11 State DOTs, and Ontario in Canada are using SA for their capital improvement projects. FHWA also developed another web-based tool named Infrastructure Voluntary Evaluation Sustainability Tool (INVEST). This tool helps highway agencies evaluate highway projects from sustainability perspective, which includes three key principles: economic, social and environmental. In terms of life-cycle analysis, highway projects are evaluated through three stages: System Planning (SP), Project Development (PD) and Operations and Maintenance (OM). Six State DOT evaluated their projects with INVEST for sustainability (13).

For overall effectiveness, safety, level of service and capacity should be considered concurrently throughout the project development process. The analytical tools aforementioned only consider one perspective: safety or sustainability whereas NESS is capable of identifying and reporting highway segments’ and intersections’ deficiencies relative to geometric, capacity and safety thresholds. Its network screening incorporates the desired outcomes in performance measures and performance management. Within NESS, geometric design elements are considered, such as design speed, lane width, radius, superelevation, crest and sag curve, grade, intersection and access. Safety information for each geometric design element is analysed and evaluated relative to pre-determined thresholds. It determines both current and future technical requirements in the project development process, ahead of programming and construction activities.

CONCLUSIONS

NESS/CIA is a geometric design and safety-based decision support tool within Alberta’s Transportation Infrastructure Management System (TIMS). Annually, the provincial highway network is analyzed to assess for sufficiency in capacity, geometric design and safety. NESS can determine network deficiencies based on capacity, geometric design and safety thresholds. By knowing when and where these future network needs are, geometric and safety improvements can be assembled effectively and efficiently for capital planning, preliminary engineering and
programming prior to the detailed design stage. Ultimately, incorporation of geometric design and safety based decisions in all phases of project development process will lead to better and safer roads. Based on Alberta Transportation’s experience, it is possible to develop an enterprise-wide transportation infrastructure management system that incorporates geometric design and safety-based applications.

The case studies shown in this paper demonstrate NESS’ capability of addressing different transportation issues. Case Study One shows how it incorporates geometric improvements to pavement rehabilitation project. Case Study Two shows that NESS is able to conduct detailed intersection geometric analysis to address possible future safety inadequacy. Case Study Three shows the development of multi-lane projects to meet future capacity requirements.

The aforementioned NCHRP 15-34 project: Performance-Based Analysis of Geometric Design of Highways and Streets defines a process that geometric design and safety decisions and other considerations be assessed in more details at the preliminary engineering stage. It is worthwhile to note this process is only applicable at the project level, not at network nor programming level. It is anticipate that Performance-Based Analysis System of Geometric Design would be the next phase of development to enable geometric design consideration be included in earlier phases of project development. NESS has been using the ‘system’ or network approach for over eight years. It performs an integrated analysis to identify desired outcomes and suggests cost-effective geometric design and safety work activities based on performance management metrics and performance measures. Geometric design standards for various geometric parameters and other related technical guidelines for traffic and safety analysis are included in the applications. In conjunction with roadway inventory and their conditions, NESS performs network screening and transfer the processed roadway information back into TIMS data/information repository for usage by users.

NESS is becoming an important tool to achieve Alberta Transportation’s organizational excellence. To a large extent, the readily available roadway geometric and safety information and proposed work activities have successfully reduce costs and time in planning, programming and engineering analysis. It has gained around 300 users in total, both internal and external to the department. With NESS’ outcome-driven principle, more and more professionals are using NESS to analyze geometric and safety deficiencies within their planning and design projects, or to assess the health of the network.

Therefore, NESS has several unique features that made the analysis tool gains its user in a sustainable way:

1). NESS is within an enterprise-wide infrastructure management system such that data and information from traffic management, pavement management and bridge management are available for application.
2). NESS uses a sound performance-based analysis framework that includes geometric design and safety analysis at network, programming and project levels and.
3). NESS’s web-based service enhances accessibility and reliability.
ACKNOWLEDGEMENT

The authors would like to thank Transportation Modelling and Analysis with Alberta Transportation for providing NESS report user guide. The authors would also like to thank Touraj Nasseri, TIMS Program Director, TIMS Office, Alberta Transportation, for the time he spent on internal discussion and providing suggestions. The contents of this paper reflect the reviews of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of Alberta Transportation. This paper does not constitute a standard, specification, or regulation.

REFERENCES


