Development of Decision Support System for Highway Capital Planning in Alberta, Canada

By

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Abstract

Highway infrastructures represent one of the largest public investments, and they are a very significant factor for the nation's advancement. Managing the resources to optimize the network performance and its level of service is one of the greatest challenges that face public agencies while having funding constraints.

Alberta Infrastructure and Transportation (AIT) owns the provincial highway network that is worth a total value of approximately $19.2 billon. This includes 30,000 km highway and over 3,800 bridges that need to be managed. AIT will be investing approximately $1.0 billion annually over the next ten years to enhance its network level. This requires conducting analysis on long-term and short-term periods, and investigates the impacts of various decisions while incorporating engineering principles and business logic to optimize funding expenditures.

To achieve this goal, AIT is currently developing a highway Capital Planning Decision Support System (NESS) that will assist solving this multi-objective dilemma in short-term and long-term horizons. NESS is an engineering analysis tool that uses geometric design standards safety and level of service criteria to identify highway deficiencies for planning and design of highway capital improvement. The system will have the capacity to assess the safety efficiency, analyze cost effectiveness of various treatment options while achieving the optimal use of resources. The proposed system will recommend alternative activities that will incorporate risk analysis. This will assist to accomplish the overall benefit to the entire highway transportation system.

The objective of this paper is to describe the Capital Planning Decision Support System concept and the proposed approach followed by Alberta Infrastructure and Transportation (AIT) to manage its highway network on a micro-level and subsequently a macro-level. This Decision Support System will incorporate expert knowledge, engineering principles, network physical conditions, geometric design, safety, level of service benchmarking, and funding aspects.

Background

Alberta has approximately 30,800 kilometers of roadway in the provincial highway network. Over 26,200 kilometers of these highways are paved, the rest are gravel roads.

There are 3,870 bridge structures on the provincial highway network, and about 8,800 bridges on the local road system. The combination of the previous components contributes the majority of the Alberta Transportation Infrastructure system. The total replacement value is estimated at over $19.2 billion. Alberta has 2.3 million licensed drivers and over 3.3 million registered vehicles. Traffic is growing on average at 3.5% per annum. Approximately 21% of Alberta's international exports, valued at $7.8 billion per year, are moved by road.

This infrastructure system, however, is not protected from deterioration due to usage, aging, climate, and geological conditions. Furthermore, because of inadequate funding or inappropriate support technologies, certain components of this infrastructure have been neglected and received only remedial treatments (OAG, 1994)

Alberta Infrastructure and Transportation is faced with demands for improved highways to support economic growth and increased traffic, as well as the need to preserve the condition of the existing highway network. The preservation includes maintaining, if not improving, the roadways utilization and the level of service (LOS), safety characteristics, and geometric technicalities.

Managers of infrastructure face a dilemma regarding when and how to maintain, repair, or renew their assets while working with continuously shrinking budgets. Fund allocation among competing yet deserving needs is a great challenge especially when it is based on incomplete data.

Done well, asset management will ensure best value for money and prevent unnecessary costs over the life of the asset. An asset management plan will help communities respond with limited dollars to meet higher public expectations and new regulations in innovative ways. Good asset management is implemented at the strategic, corporate and operational levels, building on sound principles including establishing asset value, life cycle management, long-term affordability, risk management and assessment, performance measurement, operational plans and integration of technical and financial plans.

The current practice of highway geometric design contains a vast amount of diverse information that is linked together in a variety of configurations. During the design process, engineers and designers bring together information such as the public needs, technical and engineering principles, safety aspects, and physical characteristics. Designers apply numerous techniques to minimize and manage the complexity of the design process and the component being designed. Typically, complexity results from a large number of components in an assembly, complex geometry or multiple functions within an individual part, or the combination of many different design disciplines within a single assembly (Tegel, 1997)

A properly designed roadway takes into consideration mobility and safety while addressing natural and human environmental aspects. To achieve such a balance, tradeoffs among these factors are needed and are routinely performed either explicitly or implicitly. Recently, an emphasis has been placed on the existing flexibility in design guidelines and the use of creative design in addressing the site-specific project needs has been encouraged. This philosophy was coined in the United States as context-sensitive design (CSD) and represents an approach in which a balance is sought between safety and mobility needs within the community interests. Both the Federal Highway Administration (FHWA) and the American Association of State Highway and transportation Officials (AASHTO) recognize the flexibility that exists in the current design guidelines, while acknowledging that the current focus on providing high levels of mobility may conflict with some interests of the community. Research and workshops have increased awareness of CSD issues within the highway community and encouraged a desire to improve and enhance established roadway design practices and address elements of community interest.

Flexibility and creativity in geometric design outlines and the engineering judgement allow lowering the standards below the benchmarks while examining the consequences. This issue usually requires taking some risks. The geometric design matter involves risk management to alert the designer to the need for evaluation and monitoring on an on-going basis and for creating a decision support system. AIT concerns about a "do nothing" approach can create potential liability for public safety. Ignoring risks does not make them go away. Identifying potential risks, doing something and then evaluating the results as part of a systematic program is proving to be a more defensible approach.
To mitigate and manage the risk in the design phase, the current and future conditions and demands of governing parameters should be identified. Screening the entire network and its components should be carried over; defining the current and future deficiencies should be conducted; and most suitable treatment alternative should be planned accordingly. Emphasis should be given to geometric elements, intersections, interchanges, and public safety.

This paper describes the Capital Planning Network Expansion Decision Support System (NESS) that under construction by Alberta Infrastructure and Transportation (AIT). The NESS is a major part of the TIMS project. TIMS stands for Transportation Infrastructure Management System. TIMS is the AIT software system for managing Alberta's highway assets. TIMS comprises an integrated data repository and several decision support applications that enable full life-long techno-economic analysis of the highway assets to ensure that investments in the assets yield maximum returns. In TIMS, the data migration and the Geographic Information System (GIS) are interrelated. A GIS backbone comprises a set of software that provides key functionality to broad range of users.

The NESS incorporates experts' knowledge, network physical conditions, safety principles, level of service bench marking, funding aspects. In addition, it illustrates the importance of considering risk management in geometric design and creating predictable risk in geometric design phase while meeting the benchmark standards under budget constraints.

Need for Decision-Making tools

Many agencies in North America are beginning to recognize the importance of knowing the current and future states of their infrastructure. This is on the municipalities and provincial/states levels.
Many organizations have recognized the scope of the problems facing today's asset managers (Melvin, 1992). Managers face practical questions related to infrastructure maintenance and rehabilitation. Some of these questions are: how much annual maintenance is required; how can the remaining service life of a component be calculated; how can an asset manager make a logical, cost-effective and objective decision with so many unknowns?

Large selection of computerized maintenance management systems that are database applications have been developed to meet the data handling needs to asset managers. However, their capacity with respect to life cycle economics, service life prediction and risk analysis is considerably limited.
In their paper, Vanier et al described the development of an innovative decision-making tool for assisting engineers and managers make choices between long-term alternatives related to maintenance, repair and capital renewal of mixed infrastructure assets (Vanier, 1998).

Lemer identified the potential problems of integrating asset management data for decision-making. The problems include the lack of complete data regarding facilities, and the integration with GIS. Lemer stressed the need for proper data collection, performance modeling, decision analysis, and management reporting (Lemer, 1998)
GIS are becoming extremely popular to manage infrastructure information. In a geographical information system, the data about a particular asset are directly related to their physical location on a map of a region. The location of a specific component can be viewed in the context of other components. Satellite images data can also be included in GIS system.

Ammar et at introduced a methodology for evaluating capital management performance that employed a fuzzy-rule based system. The main purpose for using fuzzy-rule was to adjust the sensitivity of small measurement errors. The data to support this fuzzy-rule system was collected from 35 large American cities. The fuzzy-rule system was developed for city capital management (Ammar, 2001).

Stephen J. Wooldridge investigated budgeting and alternative financing as factors that affect decision making perspectives. It is suggested that accounting and budgeting data are the most tangible of decision factors considered by decision makers. As such, this data plays a critical role in how decision makers address the key components of the capital allocation process. These key components include condition assessment, planning, financing, and acquisition. The authors introduced case studies of infrastructure development and recent applications of a decision-support system that assists engineers and planners with the analysis and comparison of infrastructure production strategies provide the basis for characterizing the effects of accounting and budgeting on capital allocation. (Wooldridge, 2001)

The National Research Council of Canada and the City of Montreal have recognized the need for decision-making tools in the area of municipal infrastructure planning. They initiated a project for "Municipal Infrastructure Investment Planning" (MIIP). The objectives of the projects are to locate tools and techniques to assist municipal infrastructure investment planning; develop a prototype tools and techniques for asset managers to better manage their municipal infrastructure; and to cooperate with software vendors to develop useful and reliable system (Lacasse, 1996)

Problem Statement

Roadway geometric design follows engineering guidelines that takes into account roadway safety, service life, capacity and level of service. In general, each geometric design element has its limiting design domain range relative to the desired level of performance and agency policies. For any given roadway segment, each geometric design element could be assessed against established benchmark values. However, geometric design element that does not meet its associated benchmark value is not necessary unsafe. Conversely, roadway segment with very high geometric design features and values might not offer a safe road. Judgment and experience play a significant role in the final assessment. It is a trade off between cost and safety to minimize risks (TAC, 1999)

In highway capital planning process, it is a challenge to identify and prioritize capital improvement projects without the support of infrastructure management system tool similar to pavement and bridge. From a risk management perspective, early identification of geometric deficiencies and safety concerns in short and long terms enable timely engineering assessment to determine scope and costs of capital improvements to optimize performance and safety. Improvements follow guidelines that focus on the most safety cost-effectiveness and encourage the use of low-cost opportunities. These opportunities carry risk resulted from some deviation from the benchmark values due to budget constraints.

Within a roadway agency, a capital plan usually includes traditional programs such as pavement rehabilitation, roadway capital improvement, new capital projects and other ancillary activities. With declining rate of increase in annual budgets in comparison to increasing needs for various programs, decision makers must be presented with a strong business case to decide what to incorporate in the capital plan. Performance, cost and safety are key factors in these decisions.

Objective

The NESS system screens the entire Alberta's highway network to identify all deficiencies in the network. The deficiencies will be due to insufficiency in geometric and/or collision/safety records. The existing technical conditions for the roadway segments and their components are compared to benchmark thresholds. Likewise, the safety records and collision rates for these components are compared to collision rates benchmarks. The NESS produces three levels of work activities for current year and up to 50 of future years. Level 1 activity includes reporting all missing data; level 2 activity

assigns work activities such as Planning Study, Geometric and Safety assessment; and level 3 provides a list of feasible strategies such as grade widening, new construction, passing / climbing lane, horizontal curve reconstruction, and intersection improvement to segments below the benchmark levels.
NESS provides cost analysis for the recommended level 2 and level 3 activities. The cost will be provided for the current assessment year, and forecasted for future 50 years.

Methodology

The entire network is divided into segments. Each segment is combined of several components, for example, intersections, horizontal and vertical curves. Each component has parameters that are generally used for the analysis purposes. The NESS uses these specific parameters that describe the roadway to perform the analysis. These parameters are needed for each road segment for the assessment purposes. These parameters are:

- Level of Service (LOS)
- Traffic volume (AADT)
- Collision records
- Roadway information
    - Service classification
    - Divided – Undivided
    - Posted Speed
    - Passing Zones
    - Number of Lanes
    - Surface Type

The NESS screens the entire provincial highway network to determine its segments' conditions. The conditions are found by comparing the components (defined by their parameters) to benchmarks. Two benchmarks are used for the geometric analysis purposes: the Rehabilitation, Resurfacing, Restoration, and Reconstruction (3R/4R) and the New Construction benchmarks (Alberta, 1999). In addition, a collision rate benchmarks were developed to compare the components' collision records to the collision benchmarks.
The NESS accesses the Alberta Transportation Data Repository (TDR) to obtain all needed information for the screening and comparison processes. The network is broken down to several modules that are evaluated separately. After the analysis is completed, the results of these modules are amalgamated to obtain the network condition rating. These modules are: tangent roads expressed in the Width, the Horizontal Curves, Vertical Curves, and Intersections.
For each of these modules, several parameters are identified to better describe the module and to enable the NESS evaluate each road segment. NESS then compares the road segments' parameters to the benchmarks values. Examples for these parameters are: Service Classification, Posted Speed, Traffic Utilization (AADT), and Number of Lanes. When the benchmark value is not met, a Delta value is generated. Delta is defined as the difference between the existing and benchmarks value for the component of interest.

The NESS system evaluates the current conditions of the segments as well as the future ones. These conditions are resulted from comparing the physical geometric conditions of

the segments to the established geometric design guides. In addition, the segments collision records are compared to collision benchmarks. NESS records the deviation from the benchmark values and marks a component with a minus (-) sign (negative Delta) when the component attributes measurement is below the benchmark value. Likewise, NESS marks a component with a plus (+) sign (positive Delta) when the component attribute measurement is above the benchmark value. Based on the conditions, feasible maintenance alternative lists are produced. The NESS uses the combination of the deficiencies within each segment to propose the alternative that would cure all.
NESS uses anticipated growth factors to predict the sufficiency of future utilization of the highway network segments and components. Based on the future deficiency and associated costs, NESS produces a capital budgeting for current and futures years up to 50 years.

Level of Service
The desirable level of service (LOS) that is expected on roadway segments depends on the service classification of the roadway. For major provincial highways, those classified as 1A or 1B, are expected to maintain a better level of service than collector highways that have a service classification of 2 or 3. Utilization of provincial highways is defined by the percentage of the network that is equal to or better than a targeted LOS. The targeted LOS for provincial highway is C. If a highway exceeds this targeted level, it is being considered as good condition.

Traffic Volume (AADT)
Traffic utilization is represented by Average Annual Daily Traffic (ADDT). This provides a representation of the traffic volume. AADT is the total number of vehicles to cross a point on a highway (in both directions) during a calendar year divided by the number of days in that year. Traffic utilization is provided for each roadway. AADT is one of the most important attributes used among most expert systems because many of the benchmark calculations are based on traffic utilization. The Transportation Data Repository (TDR) will provide the current AADT of the network segments. NESS predicts the AADT for all segments based on their growth rates. The prediction is conducted up to 50 years. NESS maps the predicted information to the network.

Collision Records
The Alberta Highway Collision Analysis System (AHCAS) is an application that provides the Transportation and Civil Engineering (T&CE) Division of Alberta Infrastructure and Transportation (AIT) with statistical tools to analyze collisions. Each year AHCAS obtains a new year of highway and collision data from the Alberta Collision Information System (ACIS) in the Transportation Safety Services Division. AHCAS uses statistical analysis software to manipulate the large volumes of data, perform statistical analyses on type, severity, frequency and rate of collisions at a particular location.
On an annual basis, the Technical Standards Branch produces the "Collision Data Analysis Reports" based on collision record for the previous five years. The reports include statistics at the provincial level collision rate.

Data stewards from Technical Standards Branch are responsible for the annual data table updates and maintenances. These update include loading the next year's highway and collision data, defining all highway changes that have occurred in the past year, and then synchronizing the data of all previous years with the current highway layout.

To develop a collision benchmark for the horizontal curves, for example, the data described above was used to conclude the analysis.

There was high variability in collision rate records on horizontal curves. The project team decided to develop a curve that best represent collision rates for all horizontal curves with various radiuses. The standard deviation was added to the best fit curves The standard deviation curve is assumed the benchmark. When the collision rates of a curve that has a specific radius is greater than the best fit plus the standard deviation value, the curve is considered of a high risk nature and does not satisfy the benchmark threshold. Figure 1 illustrates the developed collision rates benchmark for horizontal curves.

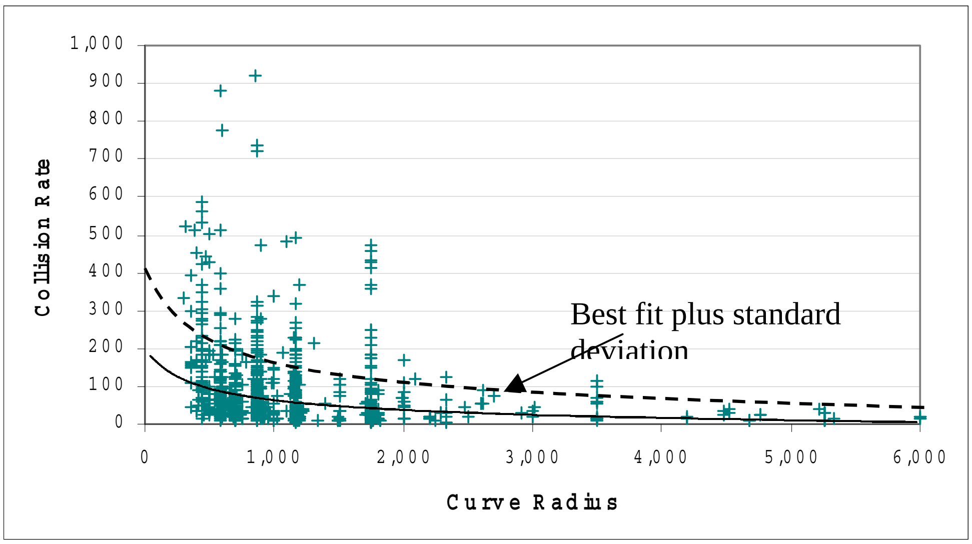

Figure 1. Developed benchmark for horizontal curves collision rates

Service Classification

The Highway Service Classification System was developed in 1997 to categories Alberta's major highway network. The Highway classification describes the functional purpose of the road and allows the planner/designer to understand the purpose of the road and provide different design standard required for the road (e.g. use of interchange, design speed). It has also been used to identify acceptable parameters for key geometric elements of the highway system. The service classification system is based on the US Federal Highway Administration (FHWA) guidelines. The current three road classifications are as follows:

- Class 1A - Major Arterials intended to serve all major cities and accommodate provincial and international travel demands.
- Class 1B - Minor Arterials intended to address primarily provincial or inter-regional travel demands.
- Class 2 - Collectors intended to address intra-regional travel demands.

- Class 3 - Local Roads - Any roadway that is not classified as either Class 1 or 2. Approach Roads and License of Occupation Roads would also be included under this class as they usually represent a temporary roadway or special case related to funding.

These classifications are used to define different road usage allowing NESS to apply different benchmarks based upon usage.

Posted Speed

It is the guiding speed for designing roadways that ties the various roadway elements together. Roadway design philosophies were the reliance on the physical roadway design to “enforce” operating speeds and the development of a “consistent” or “self-explaining” appearance for each road category. These self explaining, self-enforcing roads are designed for specific purposes or functions. Safety is addressed in an efficient way, by implementing an aesthetic approach to explain the road function and enforce speeds.

This function retrieves the posted speed for the segment. Posted speed limits are usually set to approximate the 85th percentile speed of traffic as determined by measuring the speeds of a sizeable sample of vehicles. The 85th percentile speed is usually within the 15-km/h-speed range used by most drivers.

Number of Lanes

Roads are made up of roadways which in turn contain one or more lanes. A roadway is designated as left and right (“L1” and “R1”) where the highway is divided and central (“C”) when undivided. Lanes describe the movement of a single line of vehicles. Typically the network is made up of two lane highways with one lane for each direction of flow; a four lane highway with two lanes of for each direction of flow; and six lane highways with three lanes for each direction of flow. The width measurement and benchmark will vary for divided and undivided highways and encompass all lanes in one direction of flow for divided highways; and all lanes, regardless of flow, for undivided highways. Consequently the number of lanes is a key when establishing the benchmark width value.

Benchmarking

Benchmarking is a structured approach for identifying the best practices from industry and government, and comparing and adapting them to the organization's operations.

The NESS approach uses the 3R/4R and the New Construction Geometric Design Guides benchmarks to measure the deviation of the roadway’s parameters of interest from their points of reference. The benchmarks for the geometric analysis purpose were developed by the Alberta Infrastructure and Transportation in the Geometric Design Guides. Collision and safety benchmarks were developed by analyzing the collision records for five years, 1998 to 2002.

New Construction

New construction is defined as construction of a new road including relocating of an existing route on a new alignment or reconstruction of an existing route on approximately the old alignment where the old pavement structure is removed and replaced. In general, the primarily objective is to increase the traffic-carrying capacity of the highway system. New construction design standards are continuously updated. In most cases, the standards in effect at the time a roadway was constructed are generally used to assess the adequacy of the road.

When decisions to utilize lower standards (less than recommended design standards) are deemed necessary, the designer shall document the details and rationale for the specific decision of any design exceptions so that AIT can maintain a record for future reference. Often, the best defence in this situation is to demonstrate that the safety cost-effectiveness of further upgrading the geometric feature does not meet any reasonable criteria.

3R / 4R design guidelines

As Alberta's roadway infrastructure has matured, the focus of construction programming has shifted from system expansion to extending the service life of their existing roadway infrastructure and enhancing highway safety on a network basis. These projects involve resurfacing, restoration and rehabilitation (3R) of existing paved road. In some cases, these 3R projects involve a component of reconstruction (4R) of existing paved roads, which generally takes place in conjunction with 3R projects. Pavements are designed with 20 years life and it would be logical to review the geometric design standards on existing paved roads at that time. It provides an opportunity for AIT to review safety and traffic conditions. A network screening and collisions analyses should reveal any hazardous conditions of the highway network. If geometric improvements are required it is generally most cost-effective to construct at the time of rehabilitation. Geometric deficiency of existing highway can be routinely corrected on pavement rehabilitation projects

Modules

NESS performs the analysis by breaking down the network into modules. The results of the modules are integrated at the end of the calculation phase to produce the output. The output is the main decision support tool for the decision makers. The modules that undergo analysis are described below.

Width Module

Roadway width is a measurement of the road finished (paved) top width cross section. It is measured from the outside edge of the shoulder to the outside edge of the opposite shoulder.

This process identifies the width measurement of the highway network and then compares this information to 3R/4R and new construction benchmarks. The process then compares the width with the benchmarks and establishes if the network segment:

a) meets or exceeds the benchmark i.e. is in acceptable condition
b) does not meet the benchmarks. The difference is meters between the segment width and the benchmark width (called the delta)

The process also considers the safety of the highway segments using the segment width and predefined collision rate benchmarks for highway with the same width and traffic utilization. The collision rate is measured as number of collisions per 100 million vehicle kilometres. The difference in collision rate is measured for non –animal collisions.

Since traffic utilization changes overtime and the road network deteriorates over time due to the growth rates and future demands, the process will assess the width for the existing network and for future current year and up to year 50.

Horizontal Curve Module

Collisions are more likely to occur on horizontal curves than on straight segments of roadway because of increased demands placed on the driver and the vehicle and because of friction between tires and pavements. The safety effect of an individual curve is influenced not only by the curve's geometric characteristics, but also by the geometry of adjacent highway segments. The hazard is particularly intense when the curve is unexpected, such as when it follows a long straight approach or when it is hidden from view by a hill crest.

This module assesses the technical (geometric) and safety sufficiency of the network horizontal curves. Since the traffic utilization value (AADT) changes over time the module will perform the assessment for the current and future 50 years. NESS is evaluates four factors for assessment of horizontal curves: curve radii, safety, operating speed reduction and superelevation deficiency.

Curve radii

The key indicator of condition for a curve is its safe speed. The tighter the curve radius the more likely traffic has to slow down to safely navigate the curve. Accordingly curve radius for the roadway's posted speed is assessed within the horizontal sufficiency assessment of NESS. The existing curve radius is compared to the new construction standard and radius delta is recorded. If the new construction standard is not met, then the curve radius is compared to the 3R/4R guidelines. This radius delta is also recorded for further analysis. The delta is a positive or negative value measured in meters. A negative delta value is below the benchmark indicating an unsatisfactory radius i.e. the curve may be causing traffic to reduce speed.

Safety

The function considers the safety of the highway horizontal curve using the collision rate at the curve and predefined collision rate benchmarks for horizontal curves. The difference in collision rate between the benchmark and the curve's fatal collision rate is recorded. The collision data includes whether the collision involved fatalities. This data is used to determine the rate of collisions involving fatalities. Since the number of collisions rate is a measure of the number of collisions per 100 million vehicle kilometres the predicted changing traffic utilization in the future will alter the predicted collision rate.

Alberta Collision data indicate that there is a strong link between curve radii and collisions. AIT has developed a safety prediction curve based on these data. As curve radius decreases, this curve predicts that the number of collisions at the curve increases as shown in Figure 1. Depending on traffic volumes, collision reduction potential and construction costs, curve flattening may cost-effectively improve safety and reduce vehicle operating costs. Where an existing curve does not meet the safety benchmark threshold values, it is recommended that a detailed geometric assessment be undertaken and also creates the delta values for analysis.

Operating speed reduction
The speed reduction on a horizontal curve relative to the preceding curve or tangent clearly has the strongest and most sensitive relationship to collision frequency. Research has indicated that the speed reduction on a horizontal curve is a better predictor of collision frequency than the radius of that curve. NESS is calculating the safe speed of the existing curve and compares it with the posted speed of the highway tangent segment adjacent to the curve. The calculated speed delta is also used for further analysis.
Safe speed is the speed that curves can be safely driven around. NESS calculates the safe speed of the existing curve and compares it with the posted speed of the highway tangent segment adjacent to the curve. The curves safe speed is a function of the curve radius, superelevation, and side friction factor. The delta value between the curves calculated safe speed and the posted speed is recorded; this is simply the difference between the highway safe speed and the posted speed recorded as a negative value. The calculated speed delta is also used for further analysis.

Superelevation deficiency
Horizontal curves on highways are usually superelevated for safety and passenger comfort. Superelevation is tilting of the roadway surface to partially counterbalance the centrifugal forces on vehicles on horizontal curves. The further the horizontal curve superelevation is from the benchmark the more likely traffic has to slow down to safely navigate the curve. Accordingly superelevation is assessed within the horizontal sufficiency assessment within NESS. Alberta Design Guide specifies superelevation requirements based on radius and design speed. NESS measures the actual superelevation against the optimal superelevation as recommended by the Guide. On a curve where there is superelevation deficiency, improving superelevation as part of pavement rehabilitation project is a relatively inexpensive way of increasing design speed and it can also significantly reduce curve collisions.

Intersection Module
This module will identify and assess all the highway network intersections for capacity, illumination, signalization and safety. This is achieved by comparing the highway network intersections to benchmark value as identified in Alberta Design Guide. The process establishes if the intersection:

c) meets the benchmarks i.e. is in acceptable condition
d) the difference between the individual intersection information and each benchmark (called the delta)

Currently, intersection capacity deficiency delta is based on the need for Type IV or V treatment at those at-grade intersections where a turning movement summary is available. The two legs of the major road are analyzed to see if left turn lanes, right turn lanes, and channelization are warranted. The left and right turn warrants for Type IV and V intersections are as indicated in the Alberta Highway Design Guide. Channelization is warranted where both a right turn lane is warranted and the AADT on the main road is greater than 4000 vehicle/day.
AIT has developed criteria for identifying intersections that warrant careful evaluation and checklists of improvements to be considered. Table 1 illustrates the analysis. The criteria are encompassing collision frequencies and rates, night / day collision ratio,

traffic volumes and type of existing traffic control. Improvements are organized on the basis of three primary design objectives:

1. Reduction of potential vehicle conflicts (e.g., traffic signals, left / right turning lanes and channelization).
2. Improvement of driver decision-making (e.g., lighting and lane markings)
3. Improvement of the braking capability of vehicles in the intersection (e.g., warning signs to reduce approach speed)

NESS identifies all the intersections where no turning movement data exists. An exception "report" is generated to flag which segments are missing turning movement data. This is provided to the turning movement data custodian for resolution.

	Intersection Colllision	Night/Day Collision Rate > 1.5	Left Turn Warrant	Right Turn Warrant
Major AADT>= 1,800 Minor AADT >= 900 Right Turn AADT >=360	N/A	N/A	(+)	(-)
Major AADT > 1,800 and 100 <=Minor AADT 200<= Major AADT<=1,800 and Minor AADT >=1,800	(+)	N/A	(-)	(+)
	(+)	N/A	(-)	(-)
Major AADT => 6,000 Minor AADT => 6,000 Angle Collision > 5 Part 2 (Figure B 2-6) >= 80 Part 3 (Figure B 2-6) >=20	N/A	N/A	N/A	N/A
All AADT		(-)		
Follow Interchange Flowchart	(-)	N/A	(-)	(-)
All AADT AADT (Major) x AADT (Minor)	(-)	N/A		

Table 1. Intersection Analysis Module

Vertical Curve Module

A vertical curve is a change in gradient along a longitudinal profile. This module assesses the technical (geometric) and safety sufficiency of the network vertical curves.

The crest and sag curves form the complete vertical curve. A vertical curve is measured as a "K" factor that is a coefficient for defining the rate of gradient change..The existing k values of vertical curves are compared to the new construction standards and 3R/4R guidelines to determine the vertical curve delta. Desirable crest / sag curve k values for various design speeds for new construction and 3R/4R guidelines are indicated in Alberta Design Guide. Reconstructing crest and sag curves to improve sight distances can improve safety and to a lesser extent reduce travel time costs. However, the cost-effectiveness of these types of improvements is very dependant on the extent and potential severity of the hazards within the sight restricted area. Vertical crest curve reconstruction should be evaluated if any one of the following conditions exists:

1. There is a safety problems, or
2. There is a hazard in close proximity to the crest, or

NESS retrieves the segments of horizontal curve and intersection (on or near the vertical curve) with safety non animal delta value. This is used as a proxy to determine the safety of the vertical curve. This has already been created by NESS within the Horizontal Curves and Intersections modules. The vertical curve is considered to be near an intersection / a horizontal curve when the end of the crest curve does not satisfy the stopping distance required for the assigned design speed. NESS considers the traffic utilization and only considers these curves where the AADT is greater than 3,000.This value is recorded as the “vertical safety delta”. Since the safety delta values are recorded for the segment by assessment year the delta value will be retrieved for current and future 50 years.

Where a vertical curve has a below benchmark (unsatisfactory) crest curve and is considered to be high risk as it has a high traffic utilization and is on or near an intersection / a horizontal curve the process continues the analysis and assesses the safety collision rate of the curve. NESS identifies these high risk vertical crest curves.

Life Cycle Analysis

Life Cycle Cost (LCC) analysis is introduced within NESS to analyze the cost of treatment options over a spectrum of 50 years. The objective of performing the analysis is to select the most cost-effective approach. It provides a systematic process for evaluating and quantifying the cost impacts of alternate courses of action. It is a process to determine the sum of all the costs associated with the proposed work activities such as: Passing lane, Grade Widening and 4-lanning, and using a discounted rate to calculate the present worth. Figure 2 illustrates the approach followed that uses the growth factors and the expected life of alternative work activities to develop the best value for capital planning.

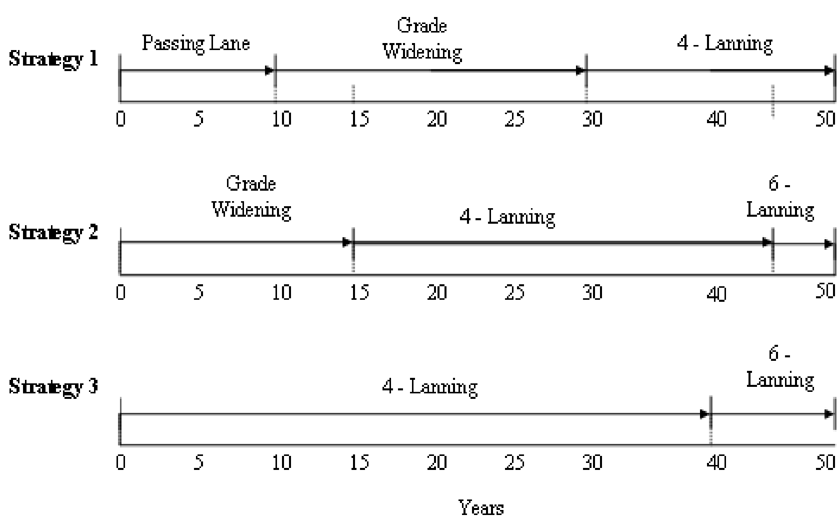

Figure 2. Illustration for life cycle analysis.

Outputs

The NESS output will assist the decision maker to select the proper projects and locations for the entire highway network. NESS reports segments deficiencies from both the technical and the safety aspects. According to the combinations of deficiencies for each segment, NESS proposes a work activity alternative that might be the most appropriate for these combinations. The output is based on the components that do not meet the benchmark standards due to technical and safety issues.

Three outputs levels are obtained from NESS: Level 1 Work Activity, Level 2 Work Activity, and Level 3 Work Activity.

The system provides functionality to assess the overall condition of the highway network. The process considers network condition indicators that meet target criteria (benchmarks) for functional adequacy, utilization and safety. The condition could be evaluated for current and future years as described before.

This process analyzes the target criteria condition for each highway segment using delta created within NESS. For example, by “Assess Width” and “Assess Horizontal Curve”. These delta values represent a comparison of the condition such as width with the relevant benchmark to provide a positive or negative value called the delta value. It should be noted that a condition such as width does not meet the benchmark when the delta value is negative i.e. the roadway width is too narrow.

Since the NESS system predicts future utilization of the network the process will assess thee condition of the network for the current year (year 0) and future years up to year 50. The specific assessment years are year 0, 5,10,15,20,25,30,40 and 50. One of the NESS outputs in the overall evaluation for the network conditions. The network is rated based on combining the segment condition into a single assessment value such as “Good, Fair or Poor”. This is calculated for each segment and is then combined to provide the condition of the entire network or specific geographic regional area of the network. Figure 3 illustrates the decision tree to calculate the network condition rating.

Level 2 and Level 3 work activities are produced in deficiency tables, maps and charts to demonstrate the roadway conditions. In addition, NESS produces output reports that recommend the various construction work activities.

NESS allows the user to run analysis for a specific highway, or a specific climatic region. This gives the supports the decision makers of different regions of the province to decide what need to be done to enhance the network in their area. The NESS can produce the output for the entire province, or can break the output down per region. Alberta is divided into four regions, these regions are:

The network is divided into these four regions based upon Alberta Transport organizational responsibilities. These are four regions are:

- North
- North Central
- Central
- South

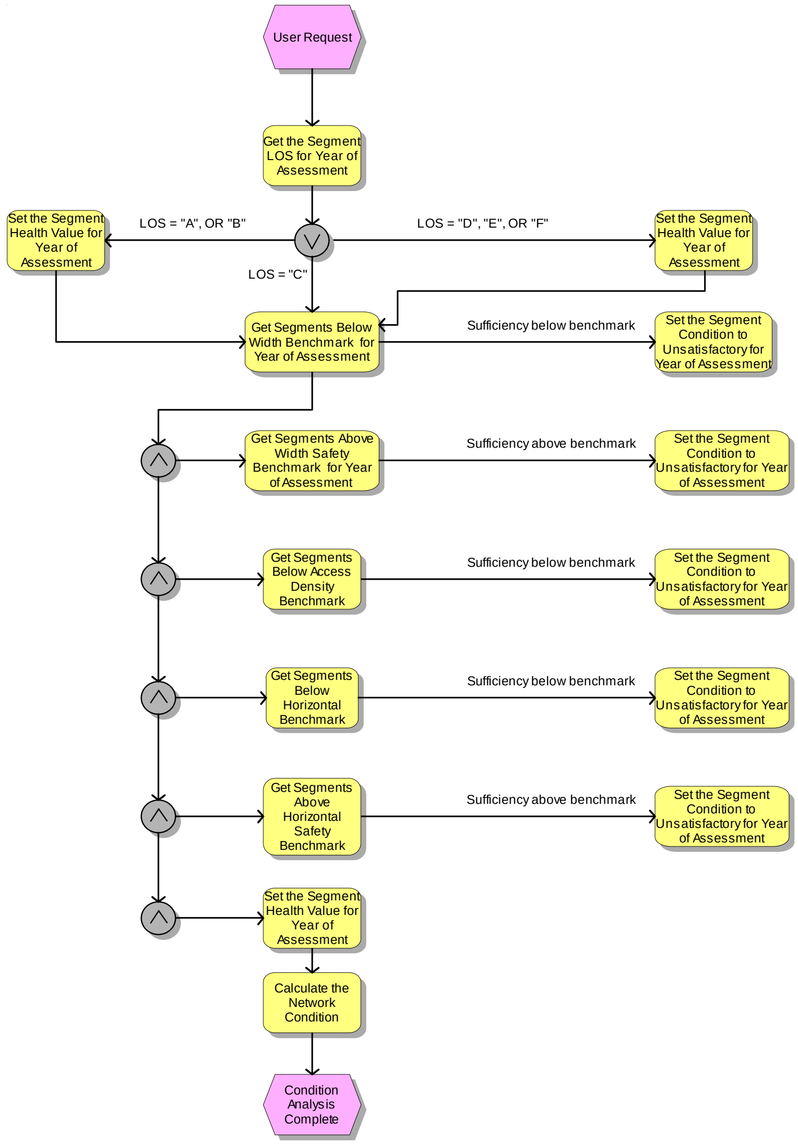

Figure 3. Highway Network Condition Rating Decision Tree

Level 1 Work activity

The NESS scans the TDR to evaluate the entire network. When NESS finds missing information or data gaps, it generates an exception report including description of the missing information to alert the Transportation Agency initiate investigation of how to incorporate the missing information in the TDR for further analysis.

Level 2 Work Activity

According the combination of the deficiencies within the segment, NESS recommends a study and assessment to the proposed segments with deficient combinations. Examples for this level are: Planning study, Safety Assessment, and Geometric Assessment.

Level 3 Work Activity

This level of work activity proposes an appropriate construction activity for the segments with deficient combinations. An example of the work activities level 3 is the determination of building passing/climbing lanes. This is based on warrants as described in the AIT Highway Geometric Design Guide.

It should be noted that NESS takes the Socio-economic factors into account while considering Level 3 work activities. Socio-economic projects benefit the entire society and the decision for their improvements may not be supported by purely technical analysis. The North-South trade corridor is an example to such projects.

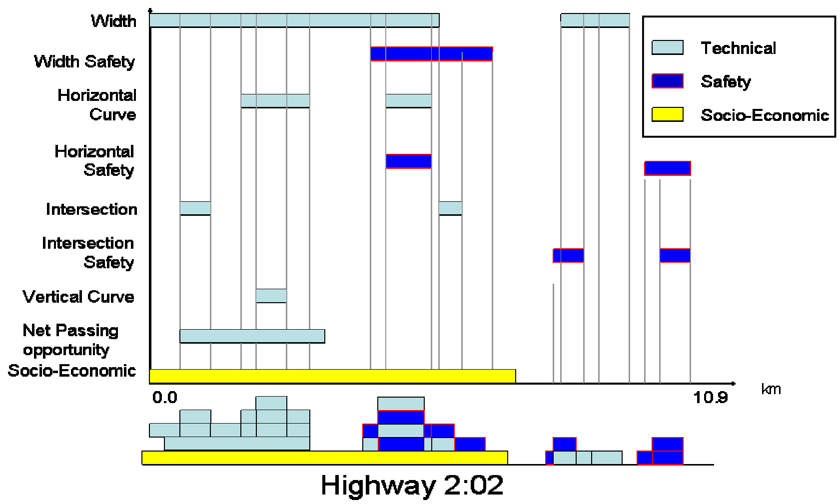

Figure 4. Technical and Safety analysis output

Figure 4 describes the NESS output approach for all segments below the benchmark levels per highway and control section. The figure shows all deficient segments due to technical and safety benchmarks. Based on the combinations of the segments below the benchmarks, the user can easily detect which part of the road needs enhancements. Figure 5 illustrates suggested Level 3 work activities for segments of roads below the benchmark values. Figure 5 illustrates a graphical integration for the proposed output labeled by the Level of Service (LOS) values. The road is defined to be in a good condition when its LOS is “A” or “B”. A fair condition exists when the LOS is “C”. The road segment is defined in a poor condition when its LOS is “D” and below.

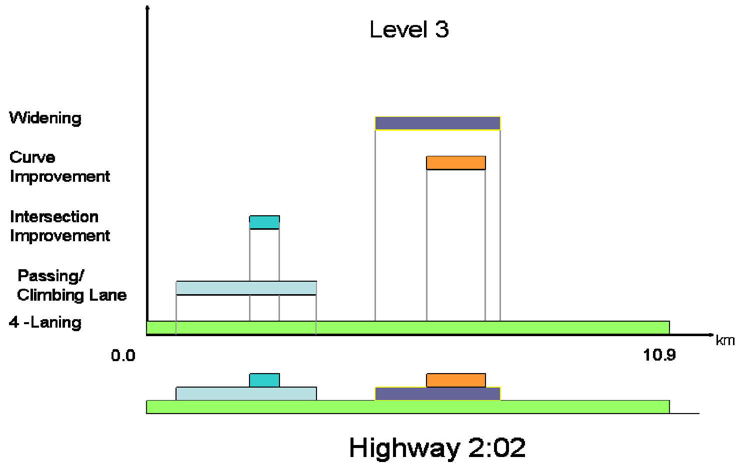

Figure 5. Proposed Level 3 construction work activities.

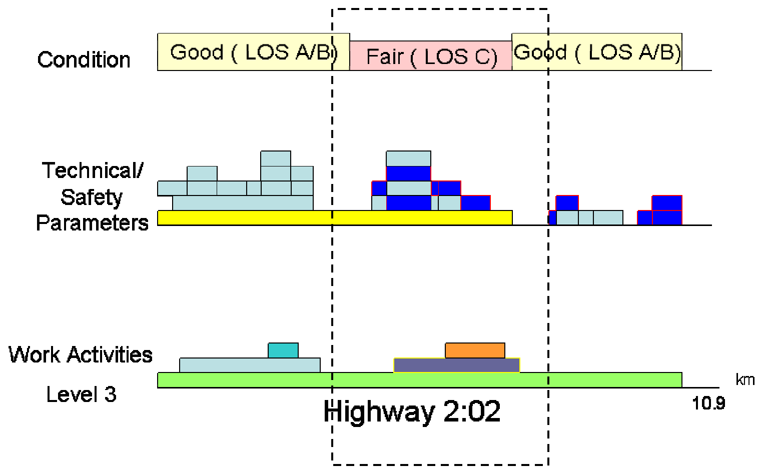

Figure 6. A graphical illustration of the NESS output.

Figure 6 suggests that the mid section of the highway shown is a good candidate for potential geometric improvement in 2010.

The entire network condition rating is resulted after evaluating all deltas of all modules. Table 2 illustrates the logic behind the network condition rating. The rating is done for current and future years. Based on the LOS and the components conditions, the rating is classified as: Good, Fair, and Poor.

Rating	LOS	HWY CS	Width 3R/4R	Width safety	Horiz Curve 3R/4R	Horiz Curve Safety	Intersec 3R/4R	Intersec Safety	Vert Curve 3R/4R	Passing Lane	Climbing Lane
Good	A, B	2:60	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(+)	(+)
		3:08	(-)	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)
		3:10	(+)	(-)	(-)	(+)	(-)	(+)	(+)	(+)	(+)
Fair	C	10:16	(+)	(+)	(-)	(+)	(+)	(+)	(+)	(+)	(-)
		11:12	(-)	(-)	(+)	(-)	(+)	(+)	(-)	(+)	(+)
		13:09	(-)	(+)	(+)	(+)	(-)	(-)	(-)	(+)	(+)
		83:12	(+)	(-)	(-)	(-)	(+)	(+)	(+)	(-)	(-)
Poor	D, E, F	15:04	(-)	(+)	(-)	(+)	(-)	(+)	(+)	(-)	(+)
		64:04	(-)	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(-)
		728:02	(-)	(-)	(+)	(+)	(-)	(+)	(-)	(-)	(-)
		567:04	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
		54:08	(-)	(-)	(-)	(-)	(+)	(-)	(-)	(-)	(-)

Table 2. Highway Network Condition Rating

NESS produces a higher level output for the user. As shown in Figure 7. NESS produces maps showing an area of interest while all deficient components are located on the highway within the map boundaries. The user has the luxury to zoom-in and zoom-out to get more specific information about the deficient components. These components are shown as red dots in Figure 7.

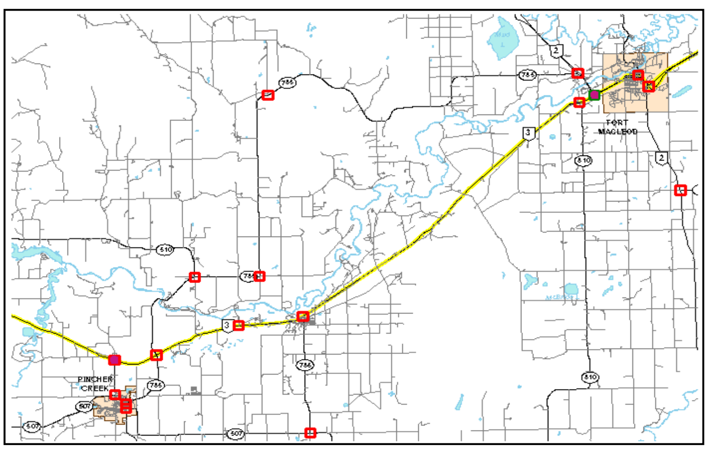

Figure 7. A map illustration showing deficient locations on highways.

Table 2 illustrates the level 2 and level 3 decision matrix. Based on the combinations of the deficiencies, the most suitable activity is recommended. A preliminary life cycle costing analysis is included in this NESS phase. However, the plan is to have an overall life cycle analysis conducted while integrating the NESS output with other decision support systems output (pavement and bridges systems) in rationalization and optimization analysis. A rationalization analyses will be conducted during this integration.

Note that the (+) sign is given when the measurement is satisfying or exceeds the benchmark value. The (-) is found when the measurement is below the benchmark values, therefore it is considered a deficiency.

Width 3R/4R	Width safety	Horiz Curve 3R/4R	Horiz Curve Safety	Access Density	Access Safety	Intersection 3R/4R	Intersection Safety	Super elevation 3R/4R	Vert Curve 3R/4R	Vert Curve Safety	Net Passing Opport	Climbing Lane	Work Activity 2	Work Activity 3
(+)	(+)	(+)	(+)	(+)	(+)	(+)/(-)	(+)	(-)	(-)	(-)	(-)	(-)	Geometric/Safety Assessment	Climbing/ Passing Lane/ Intersection Improvement/ "e"
(+)	(-)	(+)	(+)/(-)	(+)/(-)	(-)	(+)/(-)	(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	Safety Assessment	Rumble Strips/ Intersection Improvement/ Access Management Control
(-)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	Planning Study/ OR/ Geometric Assessment	Grade Widening
(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	Planning Study	Grade Widening/ Reconstruction
(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	(+)/(-)	Planning Study/Safety Assessment	Reconstruction

Table 2. Work Activities Decision Matrix.

Summary and Conclusions

NESS uses a simplified approach to break down the complex highway network into simple defined segments. These segments, including their components such as horizontal and vertical curves for example, are evaluated on an individual basis to determine the ones that do not meet the benchmark values. Benchmark values used are: geometric and safety benchmarks. In addition, NESS assists in capital planning and programming to optimize network performance, capital costs and safety.

NESS is a decision support system that uses the available network historical data in the Alberta Infrastructure and Transportation data repository (TDR) to perform the assessment. NESS uses the Design Guides geometric benchmarks that were developed by AIT. It includes the use of 3R/4R and new construction guidelines to determine the level of risk based on deviation from benchmark values. These benchmarks were developed using experts' opinion, past AIT's practices, and engineering principles. The AIT developed safety and collision benchmarks for all NESS components. All benchmarks adopted the risk assessment and mitigation algorithms to account for a safer network under budget constraints.

NESS compares the highway components and parameters within a segment to the benchmark thresholds. When the parameter meets the threshold, the segment is considered in a satisfactory condition. When the parameter does not meet the threshold value, the segment is considered unsatisfactory. NESS adopts a systematic approach to proactively identify geometric and safety deficiency in short and long terms at project or network levels.

All components that are defined as unsatisfactory are grouped within a roadway segment. NESS suggests a combination of work activities to treat the unsatisfactory segments.

Accordingly, expert algorithms are incorporated for the determination of appropriate engineering and construction work activities. The NESS includes the development of a strategy builder that calculates least life cycle cost options for capital program optimization due to budget constraints.
A graphical interface assists the decision makers to select the segment that has the most unsatisfactory components. The most appropriate work activity is selected as well as the expected cost.
NESS is currently in the system design phase. Release 1 is expected to be completed for release in early 2006. NESS uses different growth factors within the province to predict the utilization of the highway network in current and future conditions. The predicted future work activities and the associated needed funds are therefore produced. In future, it is anticipated that NESS will be integrated with pavement and bridge components to optimize life cycle work strategy for appropriate roadway segments.

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