Integration of Sustainability Rating Tools in Contemporary Pavement Management Systems

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ABSTRACT

There is growing demand around the world for public agencies to implement sustainable initiatives into public infrastructure projects. Sustainability principles need to be integrated seamlessly into all decision making processes, especially when it relates to public expenditures on vital infrastructure. While agreeing with the principles of sustainability, many agencies struggle with how to implement these objectives in a systematic manner. Pavement sustainability can be evaluated using several different methods or tools, including life cycle assessment, life cycle cost analysis, performance assessment, and sustainability rating systems (SRS). A SRS is basically a list of sustainability best practices with a related measure, usually a point score, which quantifies each best practice in a common unit. The challenge is to develop a System or Program that can identify the benefits and project impacts, compare options in a balanced manner and quantify the benefits.

To meet this challenge, both the Ontario Ministry of Transportation (MTO) and Golder Associates Ltd. (Golder) have developed user-friendly sustainability rating systems (SRS) to promote sustainable pavement technologies for the design, construction, rehabilitation, reconstruction, and preservation of roads. The MTO system is known as GreenPave and the Golder system as GoldSET.

This paper describes the development and implementation of these two SRS and assesses their sustainability measures through a case study of a highway using innovative pavement preservation/rehabilitation techniques. In addition, the paper discusses how these SRS tools can be incorporated into pavement management and asset management practices.

Word Count: 3262

INTRODUCTION

Sustainability is an increasingly important consideration in road building across North America. Given the public visibility of modern road networks and the vast quantities of non-renewable resources and energy they consume to maintain, this is not surprising. Pavement sustainability can be evaluated using several different methods or tools, including life cycle assessment, life cycle cost analysis, performance assessment, and sustainability rating systems (SRS). A SRS is basically a list of sustainability best practices with a related measure, usually a point score, which quantifies each best practice in a common unit.

In an effort to bring awareness of and promote "green" initiatives to designers, both the Ontario Ministry of Transportation (MTO) and Golder Associates created user-friendly SRS to promote sustainable pavement technologies for the design, construction, rehabilitation, reconstruction, and preservation of roads. The MTO system is known as GreenPave and the Golder system as GoldSET.

GREENPAVE OVERVIEW

The development of MTO's GreenPave began in 2008 [1]. At the time, there were a small number of sustainability rating systems available or under development. The concept of GreenPave was based on the LEED (Leadership in Energy and Environmental Design) certification program for buildings [2]. Other guides referenced in the development of GreenPave include the University of Washington's Greenroads system [3], and the New York State Department of Transportation GreenLites Project Design Certification Program [4]. The main difference between GreenPave and other systems is that its primary focus is on pavements rather than the entire roadway. GreenPave takes into consideration pavement structure, rehabilitation strategies, use of material, pavement performance, and type of vehicles and equipment used during construction.

GreenPave rating system development was a team-based effort that included an extensive literature review, research, civil engineering analysis and deliberation on how to quantify the rating and weighting for each category and sub-category. Most of the sub-category ratings are based on initial assessment. A few of the sub-category ratings are based on life-cycle assessment and include: long-life pavements, noise mitigation, cool pavements and pavement smoothness. GreenPave has been reviewed by internal and external stakeholders and is expected to be further enhanced and fine-tuned by the GreenPave engineering team during implementation.

GreenPave is a simplified rating system that evaluates the sustainability of pavements in new construction and rehabilitation projects in Ontario. It is a voluntary, self-evaluated rating system.

GreenPave provides guidance to designers to develop 'green' pavement design alternatives and encourages contractors to incorporate 'green' practices during construction. Since the GreenPave certification is voluntary, it is intended to recognize an agency, consultant or contractor that incorporates sustainability during pavement design and construction.

Strategies for achieving pavement sustainability include minimizing the use of raw materials, maximizing the use of recycled materials, and reducing energy consumption, air pollutants and greenhouse gas (GHG) emissions.

GreenPave points are awarded at the:

1. Design Stage to ensure environmental impacts are considered and to provide assistance to the designer(s) in evaluating the "greenness" of design alternatives.

2. As-Constructed Stage to encourage “green” practices at the construction stage and to evaluate constructed pavements and contractor performance.

Information and data for the design phase of the evaluation are obtained from project-specific pavement design reports. The design-related GreenPave evaluation is supplemented with post-construction information to complete the construction stage evaluation. A single custodial office currently rates all pavement designs that are submitted for GreenPave evaluation. Results are maintained in a GreenPave database. GreenPave ratings are communicated to the regional offices on an individual project basis and on an annual basis with the preparation of a report summarizing regional progress.

The GreenPave rating system is divided into four categories as shown in Table 1 below.

Category	Goal	Points
Pavement Design Technologies	To optimize sustainable designs. These include long life pavements, permeable pavements, noise mitigating pavements, and pavements that minimize the heat island effect.	9
Materials & Resources	To optimize the use/reuse of recycled materials and to minimize material haul distances.	11
Energy & Atmosphere	To minimize energy consumption and GHG emissions.	8
Innovation & Design Process	To recognize innovation and exemplary efforts made to foster sustainable pavement designs.	4
	Maximum Total:	**32**

Table 1: MTO GreenPave Categories

The four categories are further divided into sub-categories. Figure 1 shows the GreenPave points distribution at each sub-category. For a detailed explanation of each of the sub-categories, refer to the GreenPave Reference Guide [5].

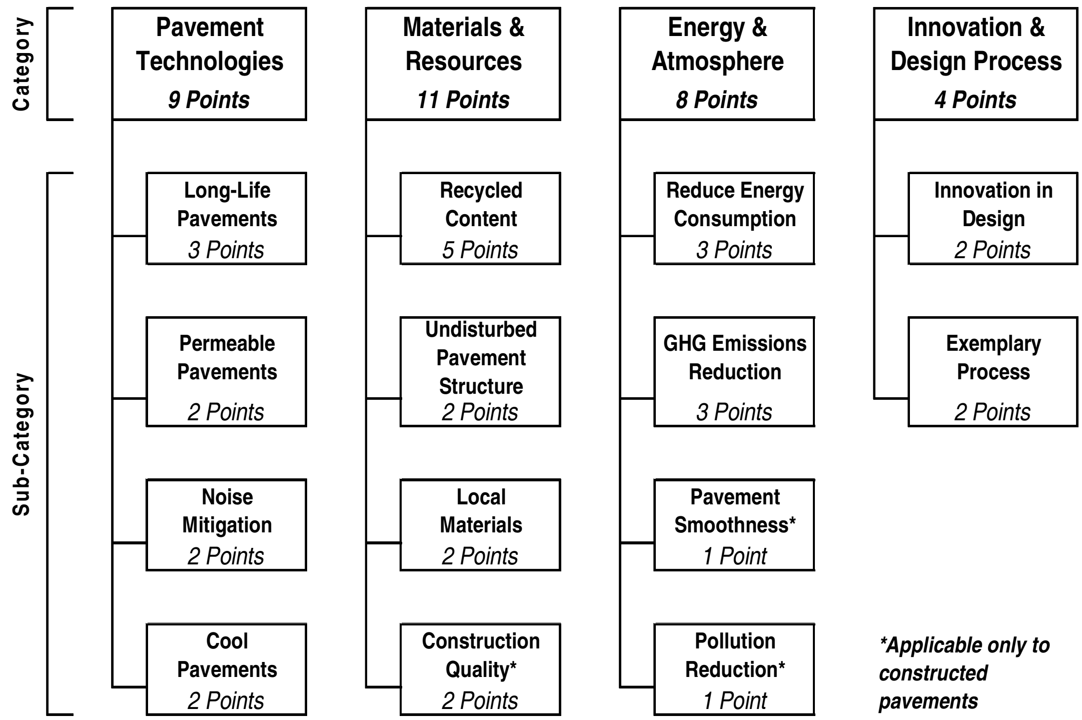

Figure 1: Overview of GreenPave Points Distribution

Because GreenPave combines points for both design and construction, initial assumptions are made during the design stage regarding construction processes. For example, the percentage of reclaimed asphalt pavement (RAP) being utilized cannot be verified until construction completion. The post-construction information is submitted by both the contract administrator and contractor. The GreenPave Reference Guide provides typical assumptions and detailed explanations on how to evaluate pavement design projects [5].

A GreenPave Rating Worksheet (available in Microsoft Excel format) was created to assist the evaluator in assessing the GreenPave projects. The evaluator assigns points for each sub-category in accordance with the GreenPave Reference Guide. A case study is presented in a subsequent section of this paper to demonstrate the GreenPave rating system.

The "greenness" of a project is based on the total number of points scored. Specific objectives within the subcategories must be met in order to achieve the maximum points available. Certification levels for GreenPave projects are bronze (9 to <12 points), silver (12 to <15 points), gold (15+ points), and trillium (future development stages), as shown in Figure 2 below. Obtaining these levels is an official acknowledgement by GreenPave that a project has achieved the number of points.

Figure 2: GreenPave Certification Levels

Additional points can be achieved during the construction phase if the Contractor chooses, for example, to incorporate more recycled materials in pavement layers, to use diesel retrofit or alternative fuel for the construction vehicles, and/or to use local materials to reduce hauling distances.

GOLDSET OVERVIEW

Inspired by ISO 26000 on Corporate Social Responsibility and international best practices on environmental stewardship and social responsibility, Golder Associates developed GoldSET, a cost effective way of optimizing project planning and design. Based on a rigorous multicriteria analysis (MCA) approach, GoldSET is a web-based engineering tool that provides a simple, systematic process to evaluate project alternatives. This is achieved by using qualitative and quantitative indicators from economic, social and environmental dimensions. Results are summarized in a diagram that clearly illustrates the strengths and weaknesses of each option. As such, the GoldSET tool supports the integration of triple-bottom-line considerations within projects, and fosters proactive engagement with stakeholders. GoldSET can be used to evaluate pavement design options using the three basic pillars of sustainability; social, environment, financial or people, planet, profit.

The GoldSET tool was originally developed to apply sustainability principles to the environmental clean-up of contaminated sites in 2007. Based on the success of this application, Golder adapted GoldSET to evaluate road rehabilitation/construction pavement design options [6, 7]. GoldSET for Pavements is a decision-support tool that incorporates sustainability principles into the design, construction and operational phases of road projects. The sustainability framework compares different project alternatives relative to the environmental, social, and economic dimensions.

The GoldSET process can be applied at different levels of detail, designated as Tier 1 to 3 as illustrated on Figure 3 below. Progressing to Tier 3 requires extensive stakeholder consultation.

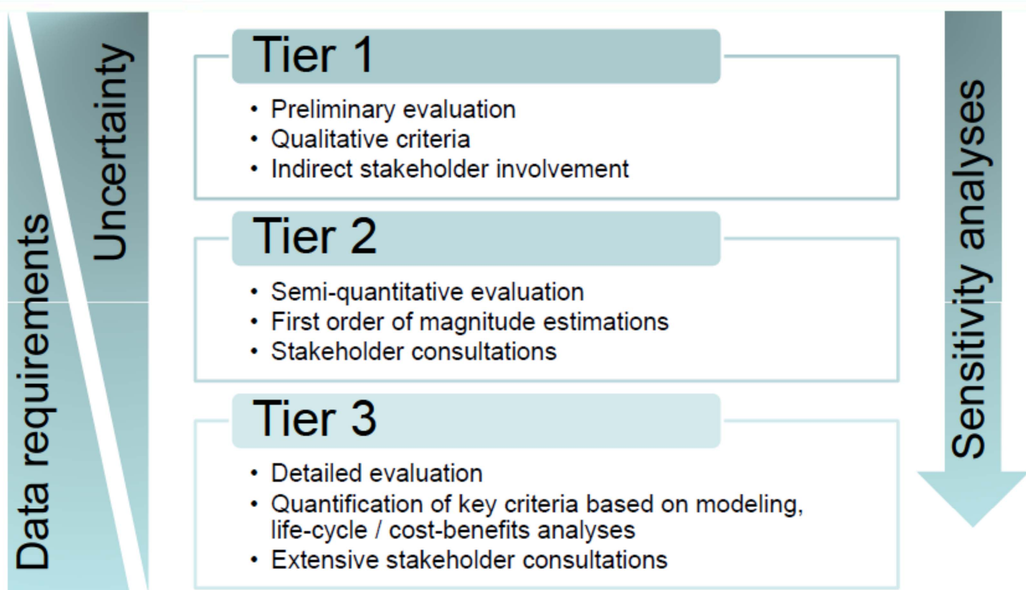

Figure 3: GoldSET Levels of Detail

The steps to successfully implementing a GoldSET evaluation can be broadly described as follows:

- Define project, including critical pavement performance considerations.
- Identify appropriate materials and technologies and prepare alternative designs. Consider best practices, Region policies and requirements for safety and durability.
- Select an appropriate set of sustainability indicators under the Environmental, Economic and Social categories. The indicators are based on the GoldSET Pavement module.
- Weigh each decision criterion (or indicator) by factoring in the relevance to the Region and the level of anticipated concerns of its external stakeholders.
- Score each alternative by quantifying them under each indicator.
- Produce graphic output showing the sustainability score of each alternative.
- Prepare a summary report ranking the pavement solution options from a sustainability perspective.

An example list of the sustainability indicators that can be used is provided in Figure 4. These can be modified based on the actual specifics of the Project and the critical factors.

Environmental Dimension	
Natural Resources	Non-Renewable Natural Resources
	Water Usage
	Energy Consumption
Water	Water Quality
Ambient Air Quality	Heat Island Effect
Climate Change	Greenhouse Gas Emissions

Economic Dimension	
Cost	Construction Cost
	Life Cycle Cost
Impact on Local Business/Commerce	Impacts during Construction
	Impacts from Maintenance Interventions

Social Dimension	
Economic Benefits to Community	Local Employment & Job Creation
Public and Employee Health & Safety	Motor Vehicle Accident Potential
	Inhalation
	Heat Exposure
	Hazardous Materials
Community Wellbeing	Ride Quality
	Traffic Disruption
	Aesthetics

Figure 4: GoldSET Sustainability Indicators

The GoldSET tool allows for an unbiased appraisal of alternative strategies on the basis of sustainability principles and identifies optimal solutions. This sustainability analysis results in a 'triple bottom line' assessment. The technical merits of alternative technologies are also incorporated. The benefits of this approach are that it allows sustainability to be easily incorporated into the decision-making process.

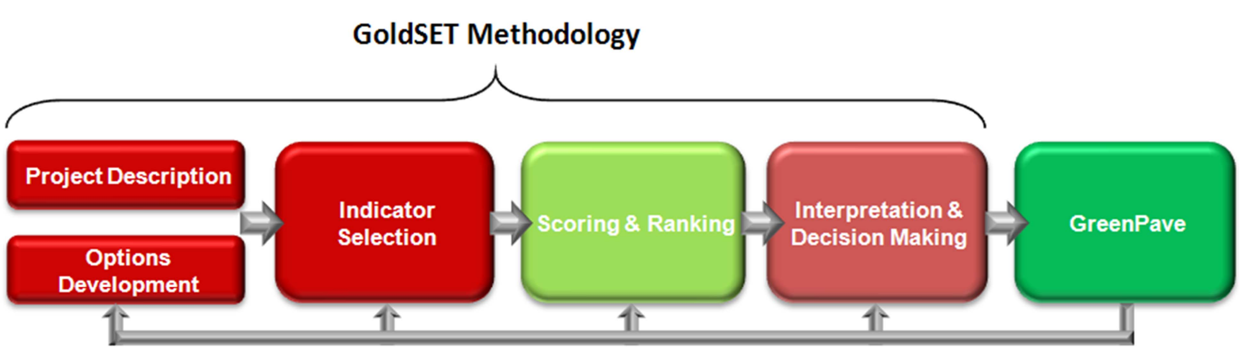

Figure 5: GoldSET Approach

As shown in Figure 5, the iterative nature of the GoldSET approach allows the model to be updated with new information and feedback at any time during the process, so as to foster innovative thinking throughout the design cycle. GoldSET does not make decisions, but it provides the relevant sustainability metrics in a succinct format, to allow informed decisions to be made and communicated to stakeholders.

The scoring for each alternative is plotted using a triangular 'spider-web' diagram. This is illustrated in Figure 6 below. The best approach from a sustainability standpoint is based on the biggest, most balanced triangle. The plots allow the highest performance in each dimension to be readily identified and the extent of balanced performance achieved between all dimensions.

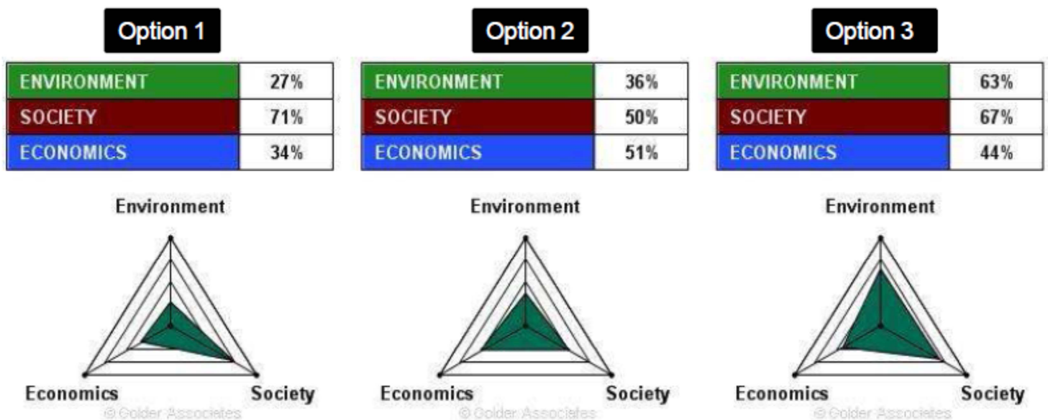

Figure 6: Graphical Representation of Scored Alternatives

GoldSET also facilitates communication by presenting the results in a graphical representation that clearly illustrates the strengths and weaknesses of each option with respect to sustainability indicators.

CASE STUDY

To demonstrate how GreenPave and GoldSET assessments are carried out on a flexible pavement rehabilitation project, the following case study is presented. The project is located on a section of the Queen Elizabeth Way (QEW) freeway near Niagara Falls, Ontario. The mainline pavement structure is comprised of:

- 40 mm Dense Friction Course
- 220 mm of Heavy Duty Binder Course
- 100 mm of Open Graded Drainage Layer (OGDL)
- 300 mm of Granular A

The pavement condition was rated as fair to poor with a 2010 pavement condition rating (PCR) value of 68 (out of a maximum of 100). The recommended pavement rehabilitation strategy to achieve a safe and serviceable pavement for a minimum period of 12 years was as follows:

- Mill and remove 50 mm of existing asphalt
- Pave with 40 mm of Superpave 12.5FC2 surface course over 50 mm of Superpave 19.0 binder course asphalt

The rehabilitation strategy was further refined by incorporating the following sustainable enhancements:

- Surface course - 40mm Superpave 12.5 FC2:
    - Applied Warm Mix Asphalt (WMA) technology with significant energy reductions compared to conventional hot mix asphalt
    - 15% Reclaimed Asphalt Pavement (RAP) incorporated into the mix
    - 15% aggregate by mass was transported from within 100 km of the project site

- Binder course - 50 mm Superpave 19.0:
    - Applied WMA technology
    - 20% RAP utilized
    - 100% aggregate by mass was transported from within 100 km

Post-construction GreenPave evaluations were submitted from the contract administrator and quality assurance officer. Their assessments indicated that the construction quality exceeded the requirements of the contract. In addition, the following innovations were incorporated in the construction process

- RAP generated from milling was used entirely within the project limits and thus none of it needed to be disposed of off site

- Some paving in echelon was carried out which improves the quality of joints and reduces future maintenance requirements

- Thermal imaging was performed to verify WMA temperature. This facilitated achieving good compaction of the asphalt mixes and improves pavement durability.

GreenPave Assessment

Applying the GreenPave rating scheme shown in Table 1 and Figure 1, the GreenPave assessment summary for this project is presented in the GreenPave Rating Worksheet below, Table 2.

Maximum Point	GreenPave Category		Option 1
9	Pavement Technologies		5.0
3	Credit PT - 1	Long-Life Pavement	2.0
2	Credit PT - 2	Permeable Pavements	0.0
2	Credit PT - 3	Noise Mitigation	1.0
2	Credit PT - 4	Cool Pavements	2.0
11	Materials & Resources		6.6
5	Credit MR - 1	Recycled Content	1.6
2	Credit MR - 2	Undisturbed Pavement Structure	2.0
2	Credit MR - 3	Local Materials	1.0
2	Credit MR - 4	Construction Quaility	2.0
8	Energy & Atmosphere		6.1
3	Credit EA - 1	Reduce Energy Consumption	2.6
3	Credit EA - 2	GHG Emission Reduction	2.6
1	Credit EA - 3	Pavement Smoothness	1.0
1	Credit EA - 4	Pollution Reduction	
4	Innovation & Design Process		3.0
2	Credit I - 1	Innovation in Design	2.0
2	Credit I - 2	Exemplary Process	1.0
32		Total GreenPave Score:	20.7
		Green Pave Rating:	GOLD

Table 2: GreenPave Assessment Summary

The project was awarded a GreenPave Gold certification. It utilized recycled materials (RAP) in the mix, thereby reducing new material consumption. A significant amount of the granular material was sourced locally within 100 km from the job site. This reduced the transportation distances and thus minimized the social impacts of heavily loaded gravel trucks in residential areas and also reduced greenhouse gas (GHG) emissions and dust pollution.

Applying WMA technology reduced the asphalt mix production temperature, thereby reducing energy consumption and GHG emissions. Credits were also given for innovations in design and superior quality during construction.

GoldSET Assessment

A GoldSET evaluation was also carried out of the rehabilitation strategy of this section of the QEW. The indicators specific to the needs and conditions of this project and used to carry out a comparison of options on the basis of Environmental, Social, and Economic considerations are presented in Table 3.

Environmental	Social	Economic
Greenhouse Gas Emissions[1]	Direct Local Employment	Life Cycle Cost (LCC) [1]
Non-Renewable Natural Resources [1]	Motor Vehicle Disruption and Accident Potential[1]	Reliability (Maintenance and Repair)
Water Usage[1]	Vehicle Movements[1]	Technological Uncertainty
Energy Consumption[1]	Friction and Permeability	
	Emissions[1]	
	Ride Quality	

Note: [1.]Quantitative estimation during the evaluation process.

Table 3: Selected Indicators

Weighting and Scoring of Indicators and Ranking of Options

The weights for each of the indicators listed in Table 5 were assigned based on assumed indicator expectations and past project experience.

The indicators listed in Table 5 were used to assess the relative advantages and disadvantages of utilizing WMA technology with respect to the Environmental, Social, and Economic dimensions. For the qualitative indicators, a score of 100 maximizes performance while a score of 0 minimizes performance. Intermediate scores were also assigned during the evaluation. Similarly, the quantitative indicators listed in Table 5 were normalized between 0 and 100 automatically by GoldSET using a regressive relationship.

Interpretation and Decision Making

The results obtained from the evaluation are presented on Figure 7.

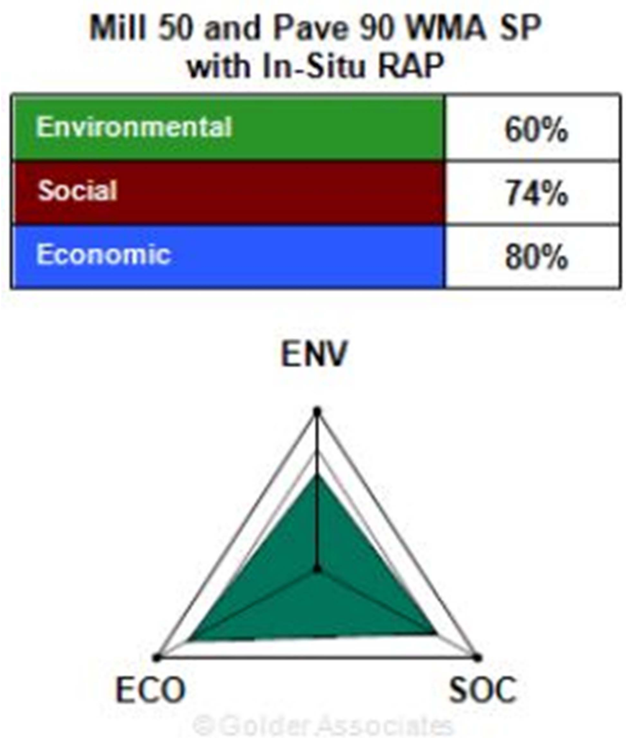

Figure 7: Results of the Evaluation.

Figure 7 indicates that that Environmental, Economic and Social benefits are maximized and performance goals are achieved with the use of WMA technology, reuse of the existing milled asphalt as RAP in both the binder and surface course mixes and use of local raw materials.

The processing and re-use of the existing milled asphalt surface as RAP in both the surface and binder course asphalt, reduced costly hauling and disposal fees of the milled asphalt, and also helped to reduce GHG emission output. Further, the construction waste that was generated was hauled within 100 km of the job site. These factors contributed to benefits from all three dimensions being recognized.

Considering the area of the triangle on Figure 7, WMA technology with the use of in-situ RAP, achieves an effective balance between the environmental, social and economic sustainability principles.

INTEGRATION OF SRS INTO PMS AND AMS

Public agencies responsible for the construction and preservation of road networks across North America are dealing with major shortfalls in budgets while road conditions continue to deteriorate. Superimposed on this dilemma is the increasing pressure from government leaders and the public to be more sustainable and to do more with less. The daily challenge with constrained engineering and financial resources is to balance:

- Best value for money
- Being more sustainable, which requires the ability to quantify sustainable benefits and to integrate these benefits into life cycle costing analysis
- Staying abreast of the latest road construction/preservation technologies and bringing innovation into practice
- Delivering longer lasting pavement treatments, i.e. increased durability and longevity

Sustainability principles need to be integrated seamlessly into all engineering decision making processes and management systems, especially when it relates to public expenditures on vital infrastructure.

Sustainability rating systems can be readily incorporated into modern pavement management and asset management systems through the development of a simple Excel-based decision support tool for provincial, state and municipal road agencies. This tool will streamline the selection process for pavement construction and preservation options, ensuring that all viable sustainability opportunities are considered. The sustainability profiles in graphical form can be provided seamlessly alongside the life cycle cost data. This will raise awareness of sustainability and demonstrate that being more sustainable does not need to cost more money.

CONCLUSIONS

Pavement sustainability can be evaluated using several different methods or tools, including performance assessment, life cycle cost analysis, life cycle assessment, and pavement sustainability rating systems (SRS).

SRS are essentially a list of sustainability best practices with an associated common measure. SRS are a good example of how to quantify and acknowledge a wide variety of sustainability best practices.

The GreenPave and GoldSET Sustainability Rating Systems have been well received and are endorsed as viable sustainability assessment tools for pavements. Ultimately, the goal of GreenPave and GoldSET is to enhance the sustainability of transportation infrastructure through designing, selecting, communicating and promoting the most economical and environmental-friendly pavement treatment alternatives.

A simple decision-support tool for provincial, state, and municipal road agencies is proposed for incorporation in pavement management and asset management systems that will allow agencies to identify appropriate sustainable pavement solutions and provide related life cycle costs and sustainability ratings.

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