

# **Sustainability Metrics of Two Pavement Rating Systems Developed in Canada**

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# **Sustainability Metrics of Two Pavement Rating Systems Developed in Canada**

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## **ABSTRACT**

Sustainability is an increasingly important consideration in road building across North America. 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.

This paper describes the development and implementation of these two SRS and compares their analysis through two case studies, one dealing with a rigid pavement rehabilitation project and the other addresses a flexible pavement project.

## **INTRODUCTION**

There is growing demand around the world for public agencies to implement “green” and sustainable initiatives into public infrastructure projects. While agreeing with the principles of sustainability, many agencies struggle with how to implement these objectives in a systematic manner. 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 compares their analysis through two case studies, one dealing with a 20 year old rigid pavement rehabilitation project and the other addresses a flexible pavement rehabilitation project.

## **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 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 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

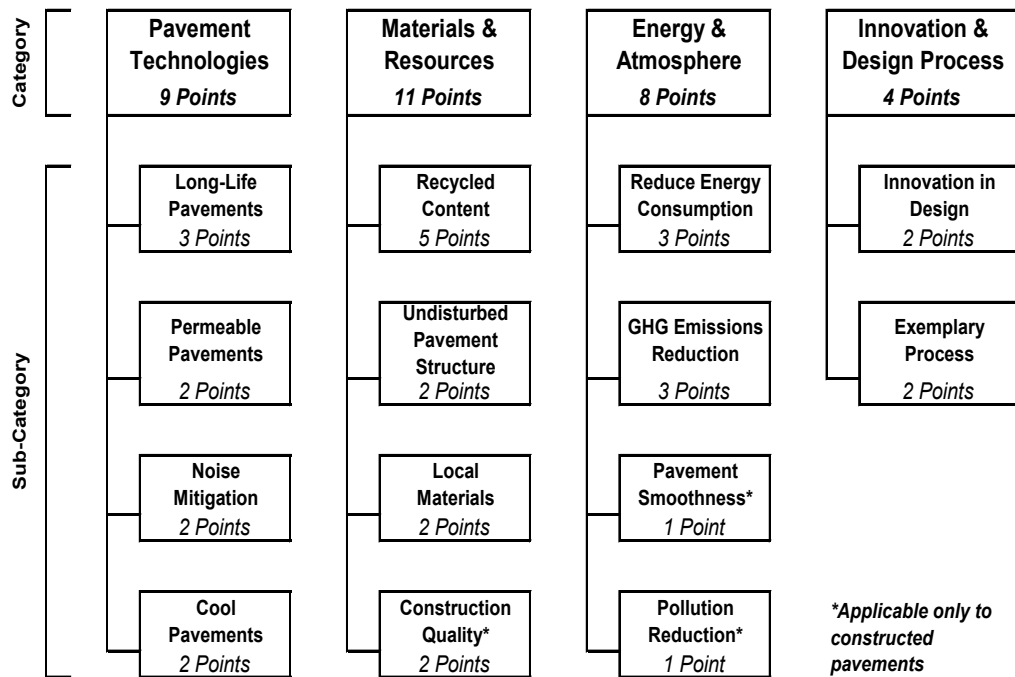
that are submitted for GreenPave evaluation. Results are maintained in a GreenPave database. GreenPave ratings are communicated to the regional offices on an individual project basis and on an annual basis with the preparation of a report summarizing regional progress.

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

**Table 1: MTO GreenPave Categories**

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

The four categories are further divided into sub-categories. Figure 1 shows the GreenPave points distribution at each sub-category. For a detailed explanation, 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. Two case studies are 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**

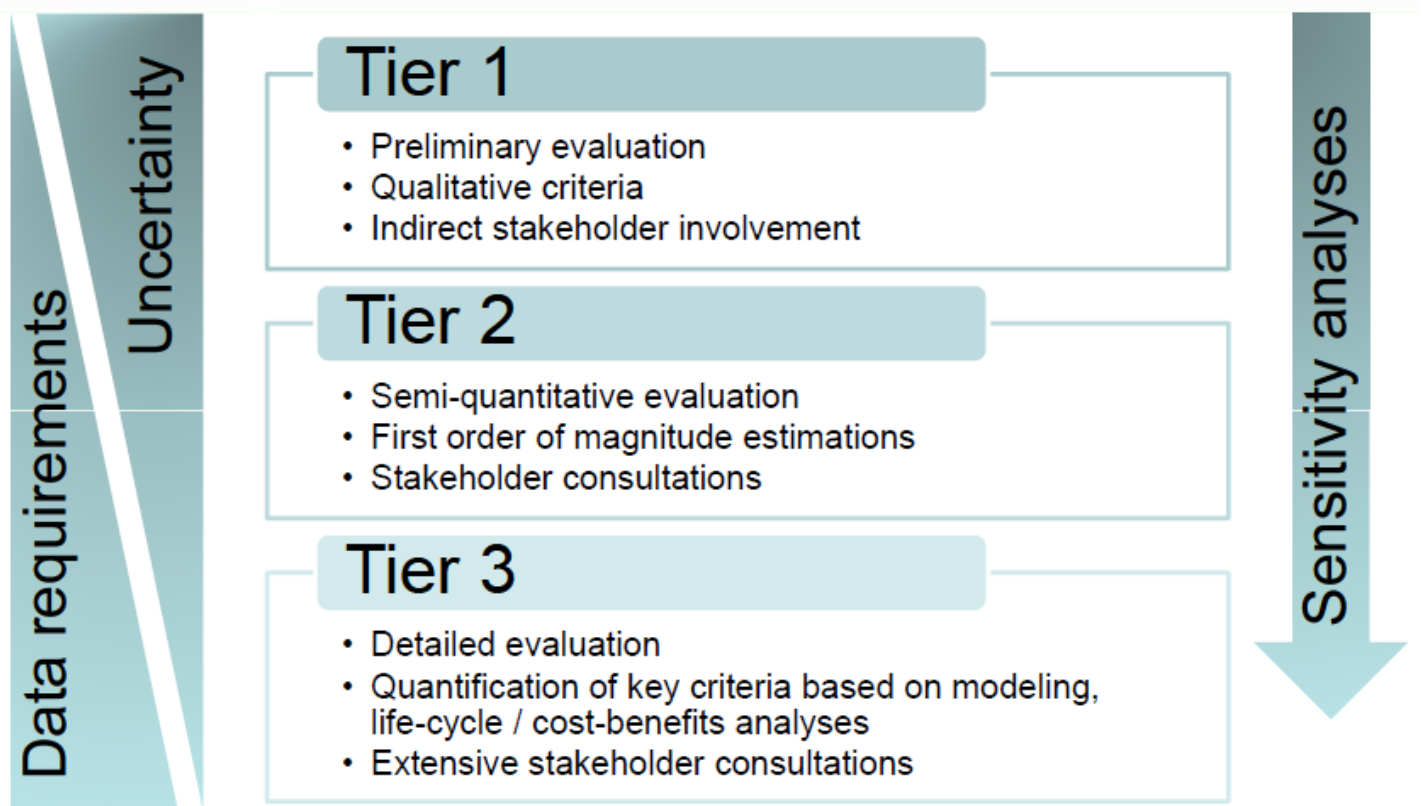
Additional points can be achieved during the construction phase if the Contractor chooses to incorporate more recycled materials in pavement layers, uses diesel retrofit or alternative fuel for the construction vehicles, and uses local materials to reduce hauling distances.

### **GOLDSET OVERVIEW**

To meet the challenge of developing a system that can identify the benefits and project impacts, compare options in a balanced manner and quantify the benefits, Golder developed an option analysis tool known as GoldSET which can be used to evaluate pavement design options using the three pillars of sustainability; people, planet, profit.

The development of the GoldSET tool to apply sustainability principles was first applied to the environmental clean-up of contaminated sites in 2007. Based on the success of this application, Golder has adapted the GoldSET tool 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 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 the figure below. Progressing to Tier 3 requires extensive stakeholder consultation.



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 will be 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 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 the figure below. These would 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

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.

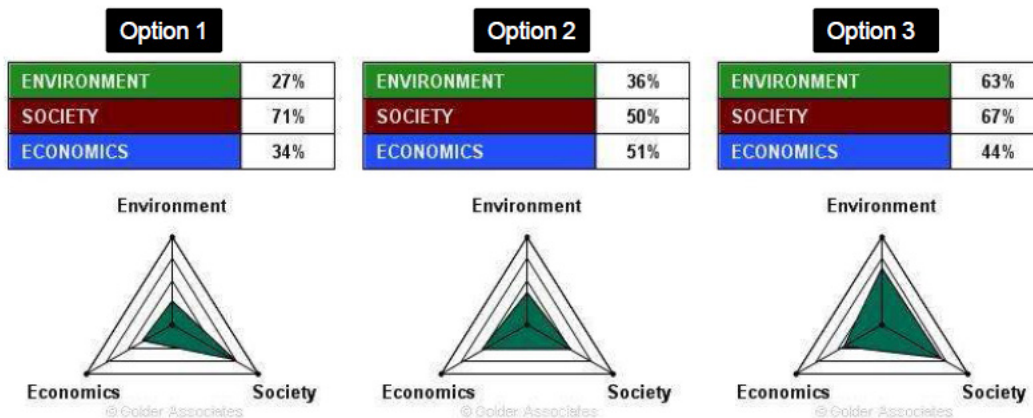
### GoldSET Methodology



As shown in the illustration, 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.



The scoring for each alternative will be plotted using a triangular ‘spider-web’ diagram. This is illustrated in the figure 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.



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 I

To demonstrate how GreenPave and GoldSET methodologies are carried out, two case studies are provided. The first case study provides assessment for a highway with 20+ years of documented performance using numerous concrete pavement preservation and rehabilitation techniques.

Highway 126 in Southwestern Ontario (now known as Highbury Avenue in the City of London) is a four-lane divided arterial with 22,000 AADT and 9.6% commercial traffic in year 2000. The existing pavement, originally constructed in 1963, consisted of 230 mm mesh reinforced Portland Cement Concrete (PCC) pavement with dowelled joints at a spacing of 21.3 m. The rehabilitation of the northbound lanes, which had experienced premature severe mid-slab cracking and joint spalling deterioration, consisted of using the latest concrete pavement rehabilitation (CPR) techniques, material specifications and construction methods, which included full depth repair, partial depth repair, diamond grinding and joint sealant replacement.

### GreenPave Assessment

Post-construction GreenPave evaluations were submitted from the contract administrator and quality assurance officer. Their assessments indicated that the construction quality on Hwy 126 exceeded requirements of the contract. In addition, the following sustainability benefits were achieved through the rehabilitation process:

CPR and diamond grinding - NBL

- Noise mitigation resulting from the re-textured pavement surface;
- Use of existing concrete pavement rather than removal and replacement;
- Reduced GHG generation and energy consumption associated with CPR techniques; and
- Innovative 1989 trial of sustainable rehabilitation strategies.

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.

**Table 2: GreenPave Assessment Summary**

Maximum Point	GreenPave Category		Option 1
<b>9</b>	<b>Pavement Technologies</b>		<b>6.0</b>
3	<b>Credit PT - 1</b>	Long-Life Pavement	3.0
2	<b>Credit PT - 2</b>	Permeable Pavements	0.0
2	<b>Credit PT - 3</b>	Noise Mitigation	1.0
2	<b>Credit PT - 4</b>	Cool Pavements	2.0
<b>11</b>	<b>Materials &amp; Resources</b>		<b>8.0</b>
5	<b>Credit MR - 1</b>	Recycled Content	2.0
2	<b>Credit MR - 2</b>	Undisturbed Pavement Structure	2.0
2	<b>Credit MR - 3</b>	Local Materials	2.0
2	<b>Credit MR - 4</b>	Construction Quality	2.0
<b>8</b>	<b>Energy &amp; Atmosphere</b>		<b>3.0</b>
3	<b>Credit EA - 1</b>	Reduce Energy Consumption	1.0
3	<b>Credit EA - 2</b>	GHG Emission Reduction	1.0
1	<b>Credit EA - 3</b>	Pavement Smoothness	1.0
1	<b>Credit EA - 4</b>	Pollution Reduction	
<b>4</b>	<b>Innovation &amp; Design Process</b>		<b>1.0</b>
2	<b>Credit I - 1</b>	Innovation in Design	
2	<b>Credit I - 2</b>	Exemplary Process	1.0
<b>32</b>	<b>Total GreenPave Score:</b>		<b>18.0</b>
	<b>Green Pave Rating:</b>		<b>GOLD</b>

The CPR and diamond grinding rehabilitation treatments were awarded a GreenPave Gold certification. A significant amount of construction material was hauled within 100 km of the job site that reduced the transportation distances and associated energy consumption generation of GHG emissions. The NBL rehabilitation strategy utilized the existing pavement structure, thereby reducing energy consumption, GHG generation, and new material consumption. Credits were also given to innovations in design at the time of construction and superior quality during construction.

**GoldSET Assessment**

A GoldSET evaluation was also carried out on the NBL CPR and diamond grinding rehabilitation strategy. The indicators specific to the needs and conditions of the project were identified and were used to carry out a comparison of options on the basis of Environmental, Social, and Economic considerations.

The indicators selected for the evaluation of the new pavement design options are presented in Table 3.

**Table 3: Selected Indicators**

<b>Environmental</b>	<b>Social</b>	<b>Economic</b>
Greenhouse Gas Emissions <sup>1</sup>	Heat Island Effect	Life Cycle Cost (LCC) <sup>1</sup>
Non-Renewable Natural Resources <sup>1</sup>	Direct Local Employment	Reliability (Maintenance and Repair)
Water Usage <sup>1</sup>	Opportunities for Local Business Generation	Technological Uncertainty
Energy Consumption <sup>1</sup>	Motor Vehicle Disruption and Accident Potential <sup>1</sup>	
Heat Island Effect <sup>1</sup>	Vehicle Movements <sup>1</sup>	
	Friction and Permeability Emissions <sup>1</sup>	
	Ride Quality	
	Construction Noise	
	Tire Pavement Noise	
	Aesthetics	

Note: <sup>1</sup> Quantitative estimation during the evaluation process.

## Weighting of Indicators

The weights for each of the indicators listed in Table 3 were assigned based on assumed indicator expectations and past project experience.

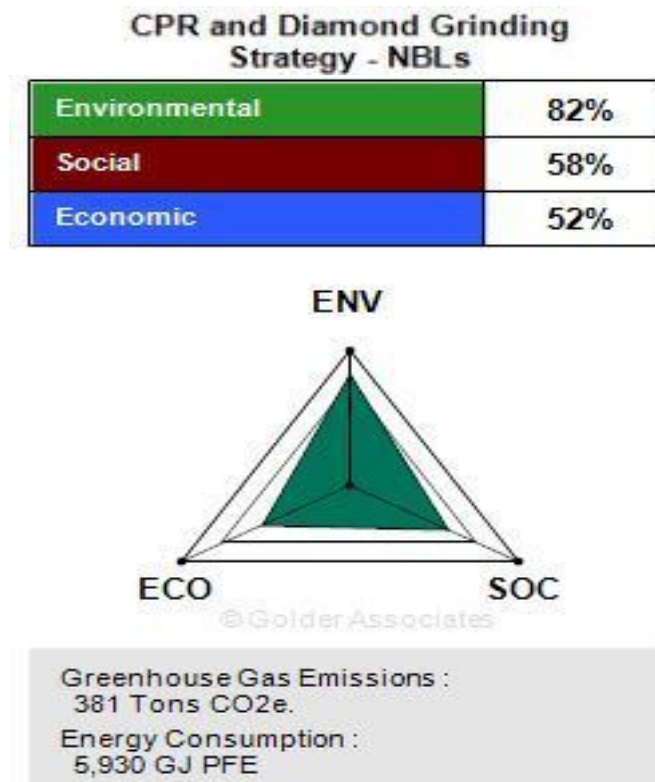
## Scoring of Indicators & Ranking of Options

The indicators listed in Table 3 were used to assess the relative advantages and disadvantages of the CPR and diamond grinding rehabilitation treatments with respect to 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 3 were normalized between 0 and 100 automatically by GoldSET using a regressive relationship. A regressive relationship is used to reflect the fact that these indicators are to be minimized in order to optimize performance. For example, water usage, GHG emissions, and costs (etc.) are generally expected to be minimized in order to reduce their negative impacts on the performance of a project. A score of 100 maximizes performance (i.e., minimizes emissions, waste generation, costs, etc.) while a score of 0 minimizes performance (i.e., maximizes emissions, waste generation, costs, etc.). Intermediate scores reflect intermediate performance.

## Interpretation & Decision Making

The results obtained from the evaluation are presented on Figure 3.



**Figure 3: Results of the Evaluation.**

Figure 3 indicates that that Environmental, Economic and Social benefits are maximized and performance goals are achieved with the CPR and diamond grinding rehabilitation strategy.

The CPR and diamond grinding rehabilitation strategy did not generate a large amount of construction waste, the construction waste that was generated was hauled within 100 km of the job site, and because the strategy focused on maintaining the existing pavement structure benefits from all three dimensions were able to be recognized.

The environmental aspect recognized the benefits of reduced GHG emissions and energy consumption from hauling waste construction materials long distances was reduced as all materials were hauled within 100 km of the project site.

The diamond grinding strategy was fast and efficient, leading to less disruption to the travelling public and businesses, recognized by the social aspect. Improved pavement frictional properties, and reduced GHG emissions and construction noise also maximized societal benefits related to this strategy.

The initial construction and LCC of this strategy, coupled with the reliability of the strategy in terms of maintenance and effectiveness, maximized the benefits related to the economic dimension. Considering the area of the triangle on Figure 3, the CPR and diamond grinding rehabilitation strategy achieves an effective balance between the environmental, social and economic sustainability principles.

## **CASE STUDY II**

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 QEW 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 was rated as fair to poor with a 2010 pavement condition rating (PCR) value of 68. The recommended 12-year pavement rehabilitation strategy:

- Mill 50 mm asphalt
- Pave 40 mm of Superpave 12.5FC2 over 50 mm of Superpave 19.0

The rehabilitation strategy selected comprised of the following:

- Surface course - 40mm Superpave 12.5 FC2:
  - Applied Warm Mix Asphalt (WMA) technology
  - 15% Reclaimed Asphalt Pavement (RAP) utilized
  - 15% aggregate by mass was transported within 100 km

- Binder course - 50 mm Superpave 19.0:
  - Applied WMA technology
  - 20% RAP utilized
  - 100% aggregate by mass was transported 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 requirements of the contract. In addition, following innovations were incorporated in the construction process

- RAP generated from milling was used entirely within the project limits
- Some paving in echelon was carried out
- Thermal imaging was performed to verify WMA temperature

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 4.

**Table 4: MTO GreenPave Assessment Summary**

Maximum Point	GreenPave Category	Option 1
<b>9</b>	<b>Pavement Technologies</b>	<b>5.0</b>
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
<b>11</b>	<b>Materials &amp; Resources</b>	<b>6.6</b>
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 Quality	2.0
<b>8</b>	<b>Energy &amp; Atmosphere</b>	<b>6.1</b>
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	
<b>4</b>	<b>Innovation &amp; Design Process</b>	<b>3.0</b>
2	Credit I - 1 Innovation in Design	2.0
2	Credit I - 2 Exemplary Process	1.0
<b>32</b>	<b>Total GreenPave Score:</b>	<b>20.7</b>
	<b>Green Pave Rating:</b>	<b>GOLD</b>

Bronze 9-12 points Silver 12-15 points Gold ≥20 points

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 local material was hauled within 100 km from the job site that reduced the transportation distances and associated pollutions. Applying WMA technology reduced the asphalt mix production temperature, thereby reducing energy consumption and GHG emissions. Credits were also given to innovations in design and superior quality during construction.

### GoldSET Assessment

A GoldSET evaluation was also carried out on this flexible section of Highway 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 5.

**Table 5: Selected Indicators**

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

Note: <sup>1</sup> Quantitative estimation during the evaluation process.

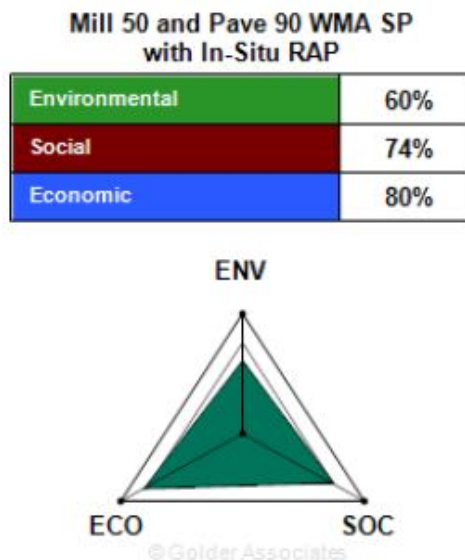
### Weighting and Scoring of Indicators & Ranking of Options

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 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 & Decision Making

The results obtained from the evaluation are presented on Figure 4.



**Figure 4: Results of the Evaluation.**

Figure 4 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 4, WMA technology with the use of in-situ RAP, achieves an effective balance between the environmental, social and economic sustainability principles.

## 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 a wide variety of sustainability best practices.

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



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