LONG TERM SUSTAINABILITY OF ROAD NETWORKS REQUIRES MORE THAN BEING GREEN

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ABSTRACT: Pavement management success has always depended on a stable and comprehensive framework, institutional commitment, good technologies and life cycle approach. Increasingly, long term sustainability has become essential to successful application. While this includes “green roads” it also requires continuity in the adequacy of resources, institutional effectiveness, new ideas and innovation, proper data and analysis, technology improvements and retention and renewal/knowledge management. These requirements are discussed in the paper and suggestions are provided on specific technical, social and economic and institutional/leadership improvements toward realizing long term sustainability.

KEY WORDS: Sustainability, pavements, management, life cycle

1. INTRODUCTION

The evolution and legacy of pavement management in many countries represents a unique success story. Essential to this success, and to future long term sustainability of the process and the applications, is a stable and comprehensive pavement management framework, an understanding of the technical, economic and institutional needs of agencies and users, use of available technologies and best practices, incorporation of a life-cycle approach and an environment which fosters innovation [1].

Among the many issues facing the future is achievement of long term sustainability. Currently this is addressed largely by designing and building “green roads”. While substantial advances have been made in green roads systems and practices, the concept of sustainability should be extended. It should include continuity of a stable life cycle management framework, the provision of adequate resources for preservation and investment, generation of new ideas and innovation, institutional efficiency and effectiveness, thoroughness in data and information/analysis, technology improvements and retention and renewal/knowledge management.

The focus of the paper is on this extension of the sustainability concept as well as discussion of the underlying factors. As well, the paper provides suggestions on the technical, social and economic, environmental and leadership needed to achieve the extended concept.
2. LIFE CYCLE MANAGEMENT FRAMEWORK AND METHODOLOGIES

A core element and indeed foundation in sustainability of road asset or infrastructure management systems is a life cycle management framework, as indicated in Figure 1. Life cycle management is also a key part of public-private-partnerships (often termed “P3’s”) for long term, performance based contracts (PBC’s) in the roads sector. (see http://www.worldbank.org/transport/roads/resourcguide/index.html). Canadian, Australian and other international initiatives in the area have been described in [2].

Road asset management systems have evolved over the past few decades to the extent that many countries now have at least reasonably well developed component systems in place. They include pavement management systems (PMS), bridge management systems (BMS), maintenance management systems (MMS), and others. While component systems should function within an asset management umbrella (see Fig. 1), coordination and integration is not an easy task.

Examination of actual best practice internationally reveals that a comprehensive road asset management system functions at three distinct but interrelated levels, all of which should exist within the agency’s corporate business plan:

- **Strategic level** where the business plan’s mission statement, level of service and safety targets and policy objectives plus various economic, social, political, environmental and public or stakeholder group input factors are taken into account, where long range financial forecasts and investment needs are carried out, and cost estimates are prepared to meet the defined targets. Current and future expected asset values should be included.

- **Network or system wide level** where alternative programs of asset preservation and network expansion are considered, performance estimates are made and life cycle cost analysis (LCCA) are used to determine an optimal program for given budget(s) or funding levels.

- **Project level** where detailed LCCA and other relevant inputs are used to identify and implement the most economically effective alternative for a project/link/site specific area.

The Figure 1 framework identifies the key elements at each level, within boxes, and various applied factors, models, constraints, forecasts, and time horizons listed at the right of the boxes. An integration platform is also shown, which is a mechanism for tying the asset types, condition, and other factors together. Location would be a requisite, but asset value, level of service provided and risk exposure are also desirable.

A Business Plan is shown in Figure 1 as Road Authorities operate within some sort of plan, which may be formally articulated (e.g., a mission statement followed by, for example, a 20-year vision of broad goals related to safety, environmental stewardship, mobility and accessibility, stakeholder group interests, etc.), or may be in the form of an implicit operating environment of policies, standards and regulations.

Figure 1 indicates that the general principles of asset management are applicable to all levels, which is a self-evident requirement, and that a decision support process plus training and knowledge management/succession planning functions should be included.

The decision support process should be based on the corporate data base and the executive information system derived from the data base. Essentially, decision support provides the necessary graphs, tables, forecasts, recommendations, etc. appropriate to the key elements identified in the strategic level of Figure 1, and similarly to the key elements in the network level. For example, at the strategic level, the major decision would likely be one of determining the tolerable shortfall between investment needs and financial forecasts; in other words a likely funding for the network level. At the network level, the major decision would involve approval of the works and associated programs.
Figure 1 Life Cycle Framework [2]
2.1 Life Cycle Analysis in Asset Management

Life cycle analysis is an essential component of asset management systems, which conventionally is primarily life cycle cost analysis (LCCA) but can be extended to other aspects such as resource conservation, social and environmental impacts, etc. Benefits in LCCA, if included, would normally be in the form of discounted user cost savings.

The major elements which should be incorporated into a framework for life cycle analysis of roads include the following: (1) Functional class of road (local, collector, arterial or freeway) (2) Life cycle period (short, medium and long term) (3) Public sector or private sector (4) Most appropriate LCCA method (5) .

Table 1 provides a framework for the applicability of LCCA method(s) according to the foregoing elements. While the preferred or likely method(s) are based largely on opinion, they can provide guidance to those having the responsibility for LCCA. It may be noted that Table 4 does not include the benefit cost ratio method, largely because it is susceptible to misleading results in certain situations, such as where benefits could also be construed as costs.

<table>
<thead>
<tr>
<th>Functional Class of Highway</th>
<th>Local</th>
<th>Collector</th>
<th>Arterial</th>
<th>Freeway</th>
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<tbody>
<tr>
<td>LCCA Period</td>
<td></td>
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<tr>
<td>Short Term</td>
<td>C/E²</td>
<td>C/E</td>
<td>C/E</td>
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<td>PWC</td>
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<td>Long Term</td>
<td>-</td>
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| Notes:                     | 1. Short term up to 30 years; medium term 30 to 50 years; long term beyond 50 years  
2. C/E is cost-effectiveness method; PWC is present worth of costs method; AC is annual cost method; IRR is internal-rate-of-return method

3. LONG TERM SUSTAINABILITY REQUIREMENTS

Sustainability is defined in dictionaries, with various meanings, and in 1987 the Bruntland Commission of the United Nations defined it as (available on Wikipedia and United Nations web site):
“sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”

This is the most widely quoted definition, but poses the question of applicability to, in this case, life cycle management of road assets. In a broad sense, it involves the “triple bottom line” of economic social and environmental responsibility.

In the United States, The Green Roads rating system (www.greenroads.us), developed at the University of Washington can be applied to the materials and resources component for pavement life cycle assessment, regional provision of materials, recycle content, reuse, and construction waste management.

Notwithstanding sustainability being one of the most overused words in the English language today, applied to almost everything to imply environmental and ecological responsibility, the concept is actually particularly important to long life road assets. The designers and builders of today’s roads will not be there in 50 years. What they do regarding use of materials resources, future recyclability, functionality, geometry, planning of interventions, etc. can have a substantial impact over a long life cycle.

In essence, but perhaps implicitly, sustainability also includes long term management and stewardship of the assets as well as adequate resources for preservation of the assets and provision of serviceability and safety. This implies a requirement for continuity and sustainability in a number of areas, as depicted in Figure 2, and discussed in the detail in [4, 5].

Figure 2 Requirements for Sustainability in Long Life Assets

3.1 Sustainability Requirements re Adequate Resources/Preservation of Investment
It is essential that in order to attain long term sustainability in road networks adequate resources (financial, material, human and other) are available over the life cycle involved (See Figure 2). Otherwise, preservation of the investment will not occur no matter how well the management framework is configured. One measure of assessing or ensuring the assessment is a continued or periodic tracking of asset value. This can involve book value/historical cost, commonly used in financial accounting (eg., a past based method) vs written down replacement cost (eg., a current based method). A detailed discussion of asset valuation, with examples, is provided in [6].
3.2 Sustainability Requirements re New Ideas and Innovation
Without a continuing generation of new ideas and innovation, any management system is likely to stagnate and progress will not occur. It has been contended [7] that innovations generally come from (a) creative individuals, or (b) organizations, or (c) focus groups, but that, arguably, the first category is often more prominent in quantum advances.

The following motivating factors for innovation have been suggested [7]:

- Challenging problem
- Improving practice
- Prospect of reward
- Curiosity
- Risk willingness
- Industry demand

but that the following barriers can also exist:

- Micro management
- Risk averse
- Limited resources
- Short term outlook
- Institutional inertia
- Comfortable with business as usual

3.3 Sustainability Requirements re Institutional Efficiency and Effectiveness
Public, and certainly private, institutions have to be productive and in turn efficient and effective (see Figure 2). Various measures have been proposed in this regard, including an annual percent increase in cost-effectiveness of programs, maximum annual percent turnover, and communication effectiveness with stakeholders [2].

3.4 Sustainability Requirement re Data and Information/Analysis
The continuity of reliable data on road sections and networks is essential for both PPP’s and in-house management. This has been demonstrated in numerous publications and textbooks on infrastructure management [8]. As well, the development of performance models relies on long term data and information/analysis, as demonstrated in the Long Term Pavement Performance (LTPP) program [9].

3.5 Sustainability Requirement re Technology Improvements
The technical and economic efficiency of road transportation is related to a continuing improvement of existing technologies, as well as the development and implementation of new technologies. Included are the many advances in automation, from electronic toll expressways to construction equipment and procedures to new materials. The importance of identifying the need and priorities is illustrated, for example, in “Reinventing the (Pavement Management) Wheel” [5]

3.6 Sustainability Requirement re Retention and Renewal/Knowledge Management
Continuity in retention and renewal of skilled people is an ongoing issue in both the public and private sectors. It is the subject of numerous studies, documented experience and benefit analyses. For example, a comprehensive study by the National Cooperative Highway Research Program [10] documents a range of experience and provides recommendations. Another study identifies knowledge as an asset and thus suggests knowledge management should be integrated to asset management [11].

4. REALIZING LONG TERM SUSTAINABILITY
Realizing long term sustainability is synonymous with continually improving the technical, social and economic, and institutional and leadership components. The U.S. Federal Highway Administration’s initiative on “Development of a Pavement Management Roadmap” [1] provides direction for future research and development in various focus areas, within the following themes:

- Theme 1: Use of Existing Technology and Tools
- Theme 2: Institutional and Organizational Issues
- Theme 3: The Broad Role of Pavement Management
Theme 4: New Tools, Methodologies and Technologies

These themes and the results of the Roadmap Project, together with an earlier set of suggestions on the Future of Pavement Management Systems [12], provide a context for a set of technical, social and economic, institutional and leadership improvement needs toward achieving long term sustainability. These are listed as follows:

- Technical improvement needs, such as:
  - Longer lasting better quality pavements
  - Seamless interfacing of the strategic, network and project levels
  - Advanced performance models which can separate traffic and environmental effects, among other factors
  - Better performance models for maintenance interventions, preservation treatments and rehabilitation
  - Making effective use of the long term pavement performance (LTPP) database (4)
  - Establishing data integration and data fusion protocols
  - Establishing risk exposure procedures in assessing strategy alternatives

- Economic and social improvement needs, such as:
  - Quantifying and communicating the benefits of PMS
  - Commitment from all levels of management to long term sustainability
  - Very long-term life cycle analysis protocols
  - Quantifying the benefits, or extra costs, of varying risk exposure, including that associated with research and development
  - Incentive programs for improving PMS processes and application in both private sector and Public-Private-Partnership (P3) contracts
  - Development of realistic performance indicators for both engineering use and stakeholder understanding

- Institutional and Leadership improvements needs, such as:
  - Guidelines for knowledge management and succession planning involving people, technology and information
  - Overcoming the challenges of institutional inertia (eg. barriers) to change
  - Seamless integration of PMS with asset management
  - Adapting PMS to P3’s, particularly in long term network contracts
  - Establishing and integrating agency policy objectives with measurable performance indicators and realistic implementation targets

5. CONCLUSIONS

Pavement management in many regions has become a mature process. Essential to continued success is a stable and comprehensive framework. Equally important is long term sustainability. This includes “green roads”, but it also requires adequate resources and preservation of investment plus continuity in institutional efficiency and effectiveness, new ideas and innovation, proper data and information/analysis, technology improvements and retention and renewal/knowledge management.

Realizing long term sustainability certainly requires the foregoing, and because this is synonymous with continually improving the technical, social and economic and the institutional and leadership components, a list of such improvements is provided in the paper.

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