Transportation Association of Canada

TAC Primer

Pavement Asset Design and Management

Introduction

Transportation infrastructure plays an important role in the social and economic development of a country, especially with increasing population. Today, Canada has more than 1,420,000 km of roads. Approximately 90%[1] of all goods and services are transported via trucks on Canadian roads and these roads must therefore be cost-effective, efficient and safe. With constrained budgets, the uncertainty of the impact of climate change on pavement performance, dwindling non-renewable road construction resources, and increasing traffic loading, the need for good pavement design and management practices in Canada is of critical importance for protecting the road and pavement infrastructure and their associated benefits to the economy.

Modern pavement engineering in Canada has accelerated significantly. Pavement structural design has evolved from a process based solely on experience, to one using empirical, mechanistic-empirical and mechanistic principles. The evolution of materials understanding and specifications has resulted in high quality, cost-effective pavement designs and rehabilitation alternatives. Road design and construction have progressed significantly to include a greater basis in science, emphasis on cost-effectiveness, and a more recent focus on recycling and environmental sustainability.

Pavement Engineering, Design and Management

Pavement engineering is a subset of civil engineering focusing on the pavement component of roadways. It uses engineering principles to design, construct, maintain and manage pavement infrastructures. Knowledge of

[1] Transport Canada. 2004. Interim Estimates of the Financial Costs and Revenues Associated with the Provision of Road Infrastructure in Canada, 2000: Transport Canada.

geology, materials, climate, traffic loading, performance, economics, structural loading, policy and modelling are all essential in pavement engineering. Automobiles and trucks are the prevalent mode of transportation in Canada, thus Canada relies heavily on the road network. It is essential that good pavement engineering be effective from a technical, economic and environmental stand point and employed throughout the life cycle of the pavement.

Pavement design is the process of selecting the appropriate pavement factors and input values that, combined, will result in the most cost-effective pavement to meet the needs of users. Many aspects need to be considered when undertaking pavement design such as using the available data elements for traffic loading, subgrade type, unit cost, etc., to develop a final product which meets all the constraints. A typical pavement design framework has inputs and outputs. The inputs can be alternative design options, design objects and constraints, reliability level, soil and material properties, traffic loads, climate factors, unit prices and design life. Using these inputs, the design method is chosen and outputs such as thicknesses and layer material types, performance predictions and life cycle economic evaluation are then created. These outputs establish the optimization, selection, and documentation for construction. Figure 1 shows the sequence for a typical pavement design framework.

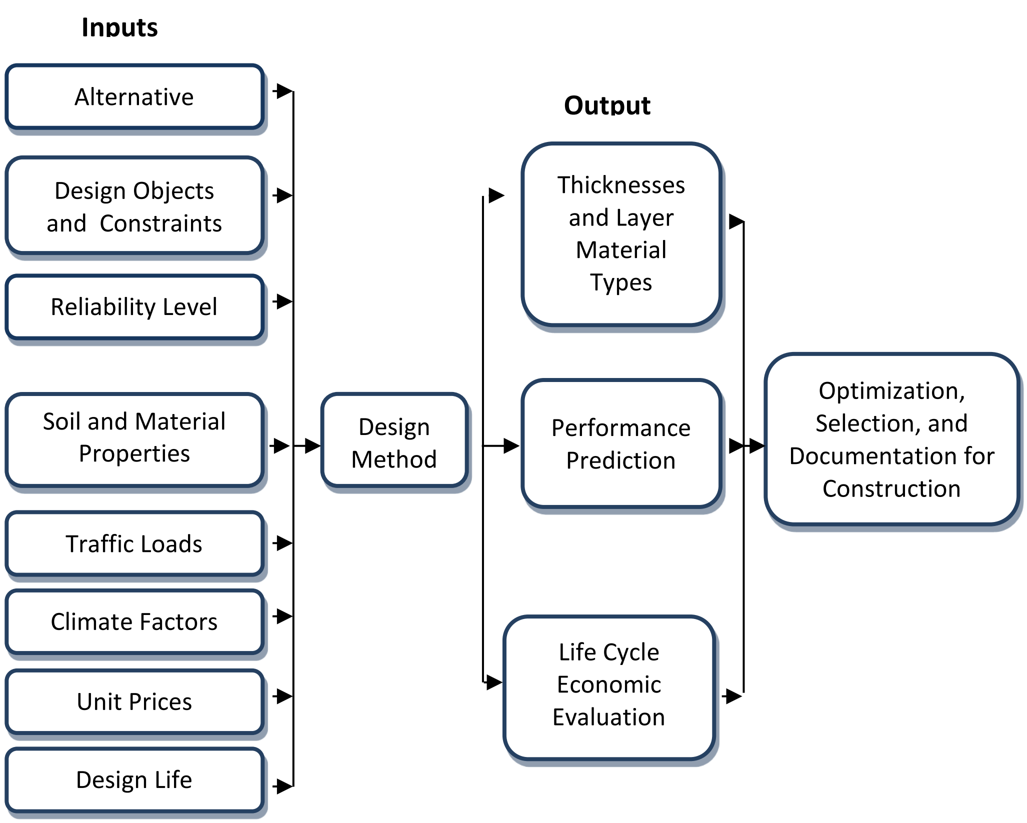

Figure 1 – Pavement Design Framework

Pavement management involves a coordinated set of activities and is related to good pavement engineering practices. The activities involved with pavement management include inventory data collection and integration, performance modelling, project and treatment selection including optimization and programming. Pavement management is important as it provides cost savings and enables an organized coordinated management strategy to evaluate performance, assess budgetary impacts and optimize pavement investments. Figure 2 summarizes the key activities associated with the pavement life cycle.

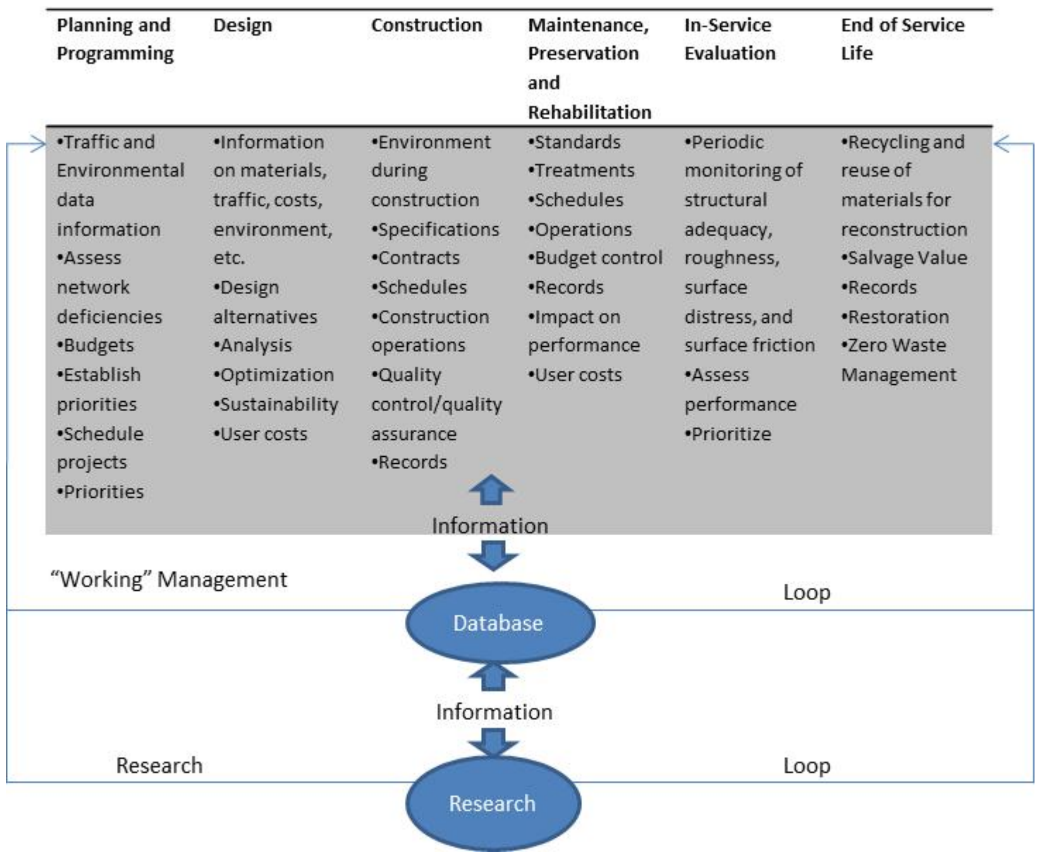

Figure 2 – Framework and Major Activity Classes in a Pavement Life Cycle

Pavement management operates on two levels: project level management and network level management. Project level management deals with the design, construction and maintenance associated with a particular section of roadway. Network level management deals with establishing priority programs and schedules of works, and developing a final budget.

Some of the specific activities involved in network level management include:

- Data acquisition (field data on roughness, surface distress, structural adequacy, surface friction, geometrics, etc., plus traffic, costs and other data) and data processing;
- Criteria for minimum acceptable serviceability, maximum surface distress, minimum structural adequacy, etc.;
- Application of deterioration prediction models;
- Determination of present needs and future needs; evaluation of options and budget requirements; and
- Identification of alternatives, development of priority programs and schedule of work (rehabilitation, preservation, reconstruction).

Some of the specific activities involved in project level management include:

- Subsectioning, detailed field/laboratory investigation and other data processing;
- Technical (modelling deterioration) and economic analysis of within-project alternatives;
- Selection of best alternatives, detailed quantities, cost, schedules, etc.; and
- Implementation (construction).

Principles of Asset Management

All network level management systems, including pavement management systems, should feed into a strategic level management system called asset management. Capital assets, managed by the three levels of government in Canada include water supply, electrical supply, wastewater systems, vertical infrastructure such as buildings and many other asset groups. However, transportation assets (i.e. roads, rail, airports, traffic control, transit, utilities, ports, etc.) are generally the largest component of the civil infrastructure. The provinces and municipalities are responsible for the majority of these assets in Canada.

Agencies responsible for roads not only have to manage systems focusing on the development and implementation of road, bridge, and geographic information management applications, they also have to manage assets other than pavements. These include fixed assets within the right-of-way (ROW), as well as fixed and unfixed assets outside of the ROW.

Fixed assets within the ROW include:

- pavements,
- bridges,
- drainage structures,
- land & landscaping/vegetation,
- grading (cut/fill),
- signs, signals and loop detectors,
- monitoring equipment (cameras, road weather information systems (RWIS), etc.),
- guardrails and barrier walls,
- fences and noise barriers,
- culverts,
- pavement markings,
- lighting,
- sidewalks (including bike paths),
- curb and gutter,
- utilities (cable, electrical, gas, phone, water),
- weigh scales and weigh-in-motion devices.

Assets outside of the ROW (fixed or unfixed) include:

- quarries and pits,
- maintenance depots (regional/district buildings, salt sheds, fuel tanks, etc.),
- buildings (central offices),
- material stockpiles,
- laboratories,
- communication equipment,
- computer hardware,
- vehicles and equipment, and
- parts inventory.

The overall framework for asset management is shown in Figure 3.

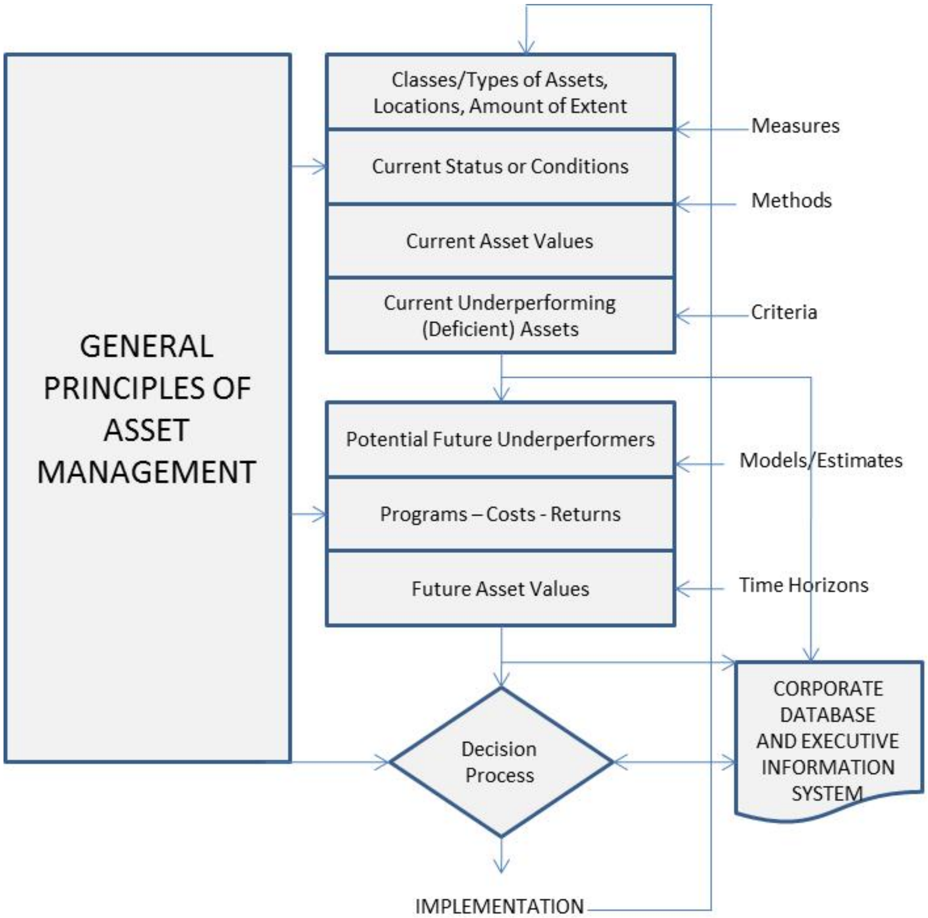

Figure 3 – Overall Framework for Asset Management

Pavement Asset Design and Management Guide

TAC has published a *Pavement Asset Design and Management Guide* (PADMG), replacing its 1997 *Pavement Design and Management Guide,* with up-to-date information about Canadian pavement design and management practices.

In addition to information on asset management, pavement engineering, design and management, the PADMG also provides guidance on other key elements of pavement design and management practices.

Data Requirements and Collection Methods The data requirements for pavement management are related to establishing current pavement condition and predicting future condition and investment needs. Significant advances in sensor technologies, computer capabilities, spatial referencing and decreasing costs associated with computer storage has facilitated the cost-effective collection of extensive and detailed information. Importance of accurate traffic, environmental and construction data in pavement design and management requires proper location referencing, sectioning and data classification. Current data collection and analysis practices include manual, semi-automated and fully automated methods.

Network Level Needs Analysis and Priority Programming

Pavement management plans provide an overview of the system, including the current condition of the network and the expected future condition based on planned preservation and rehabilitation activities. It is suggested that needs analysis, priority programming and decision making for pavement preservation and rehabilitation be integrated into a yearly management cycle of network inventory update, condition analyses, planning, budgeting, engineering and implementation activities. Potential technology improvements provide opportunities for improved optimization and modeling techniques that consider new materials and construction techniques, and linking performance with agency objectives.

Materials

The quality and usage of the materials in construction, routine maintenance, preservation and rehabilitation, influence the performance of the pavement. A sound knowledge of materials and the impact of those materials on pavement performance are necessary for proper design and maintenance.

Component materials of pavements include subgrades, granular bases, base stabilization materials, bituminous materials and mixes such as hot mix asphalt and warm mix asphalt, Portland cement materials and mixes such as Portland cement concrete mixes, soil cement and pervious concrete, and recycled materials.

Flexible Pavement Design

A pavement is a structure of superimposed layers of selected and processed materials that are placed on the foundation soil or subgrade. The main structural function of a pavement is to support the wheel loads applied to the road and distribute them to the underlying subgrade. The major factors considered in pavement design are the volume and composition of traffic, subgrade type and strength, climate, the range of construction materials available, the desired serviceable life, and the thickness of each layer. Flexible pavement is confined to one constructed of bituminous bound materials and unbound granular materials. Typical flexible pavements in Canada consist of one or more bituminous layers (binder course and/or surface course), granular base and subbase placed over subgrade.

Methods of flexible pavement design can be classified into the methods that:

- incorporate standard sections;
- involve a relationship between some measured pavement response such as deflection and thickness; and
- use calculated critical stresses, strains and/or deflections.

Rigid Pavement Design

Rigid pavements are made of Portland Cement Concrete (PCC).

Concrete pavements and joint design have evolved considerably over time, and are now designed based on theoretical studies including finite element analysis, laboratory tests, experimental pavements and performance evaluation of existing pavements. Thickness design of rigid pavements has advanced to incorporate mechanistic principles that have greatly improved the in-service performance of these pavements. The most common concrete pavement in Canada today is a dowelled plain jointed concrete with short slab lengths.

Developments in the design of concrete pavement joints have been ongoing, with the most significant change being the use of shorter joint spacing. Shorter joints reduce the incidence of random cracking, which further reduces the effects of slab curling and warping.

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Concrete pavement design has become more mechanistic-based with design tools such as StreetPave and most recently the MEPDG.

Low Volume Road Design and Management

Low volume roads are an important part of Canada's infrastructure serving rural and urban transportation needs. Low volume roads range from agricultural field access roads to residential streets to important northern highways providing access to and from resource operations.

Of the over 900,000 kilometres of two-lane public roads in Canada, approximately 585,000 kilometres are either gravel, treated or of earthen design [Alberta 2010]. Other types of surfacing on low volume roads include TBS, plant and road mixed CMCL surfaces, and chemically stabilized surfaces. Management systems have been developed for these types of roads and can ensure cost-effective routine maintenance, preservation and rehabilitation.

Routine Maintenance, Preservation and Rehabilitation Treatments

There are different types and levels of action to cost-effectively maintain pavement infrastructure at an appropriate level of service. In Canada, there is no common convention for classifying pavement routine maintenance, preservation and rehabilitation activities. Agencies across Canada describe these activities as emergency, routine, reactive, minor and major maintenance, preventive maintenance, corrective maintenance, preservation, restoration, and rehabilitation. The specific activities within these categories also vary from agency to agency.

The selection of feasible treatments is usually based on a pavement surface condition evaluation, pavement performance, experience and safety concerns. The choice is also influenced by the availability of materials, contractor capability and cost-effectiveness. The selection of a feasible treatment and the timing of its implementation are important toward the effective management of a pavement network.

While there is a large amount of information on implementation procedures for routine maintenance, preservation and rehabilitation treatments, the effectiveness of individual treatments is still empirically based.

Life Cycle Cost Analysis for Pavement Designs

Most Canadian transportation agencies incorporate some form of economic analysis into their pavement design, preservation and rehabilitation design process. Economic analysis provides many benefits [USDOT 2003] including:

- Cost-effective design and construction;
- Best return on investment;
- Understanding of risk for complex projects; and
- Documentation of the decision process.
- Various methods and procedures are performed as an economic comparison for feasible alternatives based on the initial cost and future routine maintenance, preservation and rehabilitation costs of a road. These methods can also incorporate non-agency and user costs. Comparisons can be made to

determine the most cost-effective design for the selection of pavement type, pavement cross section, and rehabilitation options.

Agencies use these processes to determine the best long-term solutions for selecting pavement strategies. Many of these principles are closely intertwined with the procedures used within PMS to reduce the cost of projects as well as entire networks.

Role of Construction

Construction is the process of building or assembling civil infrastructure. Successful construction management accomplishes this in the most efficient manner by carrying out the construction to meet the desired specifications.

Major aspects associated with constructing a high quality pavement are:

- Relationships with other pavement management activities;
- Key construction management elements;
- Quality Control (QC) and Quality Assurance (QA); and
- Documentation and information.

Each agency has its unique construction methods, equipment, materials, environment and capability.

Maintenance Management

Maintenance treatments and applications have a direct impact on the design life of a pavement and are an essential component of good management practice.

The amount of maintenance required to keep a pavement at some planned serviceability level can be a measure of the effectiveness of programming, design, maintenance treatments, and/or construction quality. In turn, maintenance activities and expenditures provide feedback for programming, design, future maintenance and construction. For this reason, maintenance should be carefully planned, systematically implemented and well documented. Doing so can enable road managers to easily retrieve information, and accurately assess material costs, methods and their effectiveness.

The type and degree of maintenance required to maintain a pavement at or above some planned level of serviceability is a measure of the rationale inherent in the programming, design and quality of construction employed.

Sustainability and Climate Change

Sustainability is considered as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [Bruntdland 1987]. Sustainability in the context of this subject refers to promoting environmentally friendly practices that should be considered along with technical, social and economic benefits. Sustainability impact factors areas include: virgin material usage; alternative and recycled material usage; pavement in-service monitoring and management; noise; air quality/emissions; water quality and energy usage and their relationship to typical pavement routine maintenance, preservation and rehabilitation practices. It is expected there will be many advances with respect to incorporating sustainability and climate change into Canadian best practices.

Climate change has the potential to have a major impact on pavements and long-term performance. Several changes to the transportation sector are necessary to address the effects of climate change. Planning for new infrastructure will require modification in engineering design to ensure that new roads can withstand the change in length and frequency of weather events. Monitoring will be required for areas vulnerable to receding permafrost, flooding or landslides. Further development and evaluation of real-time pavement monitoring systems such as Road Weather Information Systems (RWIS), thermistor strings, strain gauges, moisture probes and others, is needed to better understand the relationship between pavement performance and climate change.

Some future needs have been identified in the area of pavement sustainability, some of which include sustainability research related specifically to post-construction operations.

However, an assessment tool to properly quantify sustainability in pavement engineering and management is required.

Emerging Technologies and Issues

The field of pavement design and management is constantly evolving. Through construction, preservation and rehabilitation, theoretical analysis, long-term performance studies and integrated programs of laboratory and field research, new and improved pavement technologies are being developed. The continuing challenge faced by the transportation industry is their integration into pavement engineering. However, this challenge also represents future opportunities. Some areas of opportunity include:

- Improvement not only of the technical tools for effective asset management but also the provision of innovative methods of communicating asset management results to stakeholders through the use of improved information technology systems and delivery mechanisms;
- Provision of access to quality data, the adaption of existing analysis tools, the communication of pavement management results in a clear and effective manner in accordance with agency goals and objectives, the integration of pavement management into the decision process, and the use of a new generation of technology so agencies are less dependent on manual labour for data collection;
- More comprehensive and efficient methods for collecting and interpreting traffic data;
- Improved optimization and modelling techniques, new materials and construction techniques and better ways to link performance with agency objectives;
- Incorporation of reclaim, re-use and by-product materials into pavement structures, which will continue to be an important component in advancing pavement materials technology, particularly with the increasing emphasis on sustainable design and construction;
- More advanced knowledge of pavement materials, which will allow the use of mechanistic design tools;
- Better verification of pavement design methodologies based on good quality, long-term data on pavement performance;
- Implementation of the Mechanistic Empirical Pavement Design Guide (MEPDG) including incorporation of improved pavement material characterization for performance prediction and the development of realistic data for default values in the MEPDG, reflecting the diversity of Canadian conditions;
- More understanding of how sustainability can be incorporated into flexible and rigid pavement design and rehabilitation;
- Construction quality target alignment with the pavement design process since construction quality has a significant impact on pavement performance;
- Technically sound evaluation procedures to accurately assess the effectiveness of new pavement preservation and rehabilitation techniques and to predict the field performance of new materials and procedures;
- Development of new and innovative inspection technologies to quantify and record the quality of construction materials and to assist in providing accurate information to refine design choices and life cycle models;
- Better integration of pavement maintenance and pavement management through asset management, along with the development of detailed guidelines and procedures for using maintenance information;

- Development and integration of sustainability metrics into pavement engineering and management;
- The development and evaluation of real-time pavement monitoring systems such as Road Weather Information Systems (RWIS), temperature sensors, strain gauges, moisture probes, etc. to better understand the relationship between pavement performance and climate change; and
- Documentation of best practices such as through the new TAC *Pavement Asset Design and Management Guide* (PADMG).

Disclaimer

The information in this primer has been extracted from a Transportation Association of Canada publication entitled *Pavement Asset Design and Management Guide*. Every effort has been made to ensure that all information in this primer is accurate and up-to-date; however the Transportation Association of Canada assumes no responsibility for errors or omissions. The primer does not reflect a technical or policy position of TAC.

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