Decision Making for Maintenance and Rehabilitation of Municipal Pavements

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ABSTRACT

Municipalities in Canada spend in excess of $10 billion annually on aging infrastructure. Asset management systems, of which pavement management systems are a subset that have been in place for over 30 years, explicitly recognize the importance of maintenance and rehabilitation planning to ensure that our infrastructure assets remain viable. These systems also recognize the importance of costs in decision making, whether in terms of sound economic theory, optimum strategies, or cost-efficiency.

The main challenge facing municipalities is not which pavement preservation treatment should be used on a particular section, but rather, to justify that a preservation treatment is in fact necessary. The decision making (planning) process has a major impact on the condition of the pavement network and on the life-cycle cost of maintaining it. Planning should be based on well-documented pavement preservation needs. A successful priority planning process is a valuable decision-support tool. It can provide agencies with many benefits and management improvements including: an up-to-date inventory of the road network and its condition; a summary listing of current and future pavement maintenance and rehabilitation needs; trends in the condition of the pavement network; a prioritized listing of pavement maintenance and preservation needs using sound technical analysis; and a summary of unmet needs (infrastructure deficit).

This paper will present a logical process of identifying and prioritizing needs at the network level of the yearly management cycle and will focus on levels of service, pavement inventory, identification of needs, and the prioritization of needs.

SYNOPSIS

The engineering procedures described in this paper apply to planning and budgeting for the preservation of municipal pavement infrastructure. The procedures were developed for the *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*. This paper provides background information on the *National Guide to Sustainable Municipal Infrastructure* and the collaborative effort involved in its development, and describes the recommended procedures for priority planning and budgeting for pavement preservation that are now a part of the Guide.

The Federation of Canadian Municipalities is leading the development of the National Guide in partnership with the National Research Council of Canada. The objective of the Guide is to provide a single authoritative reference for infrastructure preservation, and aims to assist municipalities and other infrastructure owners with a decision-making and investment planning tool, as well as a compendium of technical best practices.

Every municipality that has a pavement preservation budget has also has a process that is used to establish it. This may be a simplified process where the budget is based mainly on last year's budget, or the process where the budget is based on customer-accepted pavement serviceability levels. The quality of the budgeting process has a major impact on the condition of the pavement network and on the cost of maintaining it. The paper describes how the planning and budgeting process for pavement preservation can be improved by using a transparent process that effectively translates well-justified pavement preservation needs into prioritized projects.

The process starts with establishing standards and service levels for pavement condition. Consequently, the identification of pavement preservation needs is not a creation of a wish list, but

documentation of maintenance and rehabilitation needs based on mandated standards and levels of service. First priorities are projects related to minimum safety standards. These are followed by projects related to minimum condition levels (based on approved service levels), next come projects that will provide the best return on investments (such as sections requiring preventive maintenance), and finally projects that are initiated to achieve a target level of service. The projects that do not make it into the budget represent a backlog of pavement preservation needs.

The process has general applicability for both small and large municipalities, and can easily be adapted to include other infrastructure assets such as culverts and bridges, sidewalks, park and recreational facilities, and buildings. It is intended for managers and technical personnel responsible for the identification of pavement preservation needs and budgets. It can also provide objective information on pavement preservation needs to senior decision makers and the public. It can be used to quantify the link between the budget and the level of service provided to the public, and to support funding requests for pavement preservation.

INTRODUCTION

Municipal and other owners of pavement networks are faced with two basic questions: how much money is needed for the upkeep of the network, and how to ensure that money goes where it is most needed. The priority planning and budgeting process described in this paper provides basic guidance on how to answer these two questions, and follows the principles, objectives, and methodology of asset management.

The priority planning and budgeting process is the subject of a best practice under development by the Canadian *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices* and its network of excellence.

Canada's more than 4,000 municipalities are responsible for the management of approximately 750,000 two-lane-equivalent kilometres of public roads – not including local streets – ranging from multi-lane expressways to two-lane gravel roads. These represent more than 70 percent of all Canadian roads. Federal and provincial agencies manage the remaining 30 percent. To assist municipalities and other infrastructure owners with the management of municipal infrastructure, including the pavement infrastructure, Infrastructure Canada – a federal agency – and the National Research Council (NRC) have provided financial support for the development of the *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices (InfraGuide)*. The Federation of Canadian Municipalities is leading this unique project in partnership with the NRC, with most of the funding provided by Infrastructure Canada ($12.5 million) and the NRC, and with in-kind contribution of more than 250 volunteers.

The InfraGuide is a Canadian national network of practitioners and collection of documents on best practices for all major components of municipal infrastructure, including roads, potable water distribution systems, sewers, and transit systems. The objective of the InfraGuide is to provide a single authoritative reference for infrastructure preservation, and aims to assist municipalities and other infrastructure owners with decision-making and investment planning tools and environment protocols, as well as with a compendium of technical best practices.

The InfraGuide can be viewed as a set of decision making, investment planning, and technical guidelines for infrastructure preservation, as well as a focal point for the Canadian network of practitioners, researchers, and municipal governments, and other stakeholders involved in infrastructure operations and maintenance. The technical guidelines are communicated as best practices, a 20 to 40 page outline of recommended state-of-the-art methods and techniques that address a specific topic. At the end of 2003, in the municipal roads area alone, eight best practices

have been completed and four others are under development. The eight completed best practices include:

- Timely preventive maintenance for municipal roads, a primer;
- Sealing and filling cracks in asphalt concrete pavement'
- Rut mitigation techniques at intersections;
- The construction of utility boxes in pavements;
- The restoration and repair of utility boxes in pavements;
- Road drainage, design alternatives and maintenance;
- Coordination of infrastructure works to minimize disruption and maximize value; and
- Priority planning and budgeting for pavement maintenance and rehabilitation, described herein.

These and other best practices are posted on a website www.infraguide.gc.ca in English and French. The website offers a comprehensive source of information on the InfraGuide, solicits public and peer review comments before the final publication of best practices, and features a "get involved" section, recruiting comments, reviewers, and committee members.

The paper has the following objectives:

- To provide background information on the National Guide to Sustainable Municipal Infrastructure;
- To describe collaborative process used to develop the guide, and in particular the best practice for planning and budgeting for pavement preservation;
- To outline the recommended best practice for priority planning and budgeting process for pavement maintenance and rehabilitation; and
- To outline main implementation steps and challenges.

BEST PRACTICE DEVELOPMENT

The InfraGuide's extensive collaborative process to develop best practices is based on the recognition that a network of volunteers representing all stakeholders can produce a better product than any one group or individual could on their own. The development of the InfraGuide is directed by a steering committee and involves a collaboration of municipal participants and contributors from over 300 municipalities. Municipal representatives participate through working on the committees, surveys and interviews, and peer review groups. Each area of the InfraGuide (roads, potable water, sewers, etc.) is directed by a technical committee. The best practices are developed by working groups with directions from technical committees. This way the existing knowledge and experience is harnessed to serve municipal and other users (Figure 1).

Figure 1 Development of the InfraGuide is a Collaborative Effort

The best practice on priority planning and budgeting process utilized information obtained through mail-in questionnaire completed by 56 representatives of Canadian municipalities and through in-depth telephone or in-person interviews with about 25 Canadian municipalities. The municipalities selected for in-depth interviews were known for using progressive pavement maintenance and rehabilitation techniques and pavement management practices. The municipalities were located in all regions of the country and included both small and large municipalities.

THE NEED FOR A BEST PRACTICE ON PRIORITY PLANNING AND BUDGETTING

Every Canadian municipality prepares a budget to preserve pavements, and every municipality has some sort of planning that precedes budgeting (Muntz, 1994). The objectives of the process are (a) to establish the amount of money available or needed and (b) to decide on the best way to invest the money in the pavement infrastructure. The quality of the planning and budgeting process has a major impact on the condition of the pavement network and on the life-cycle cost of maintaining it. The link between planning and budgeting is important. Planning should provide the basis for, and substantiation of, the budget. The budget should be based on well-documented pavement preservation needs.

As part of the municipal survey questionnaire, we asked municipal representatives a series of questions to obtain a better understanding of how municipal agencies select pavement preservation projects. For example, the presence of a functional pavement management system (PMS) is one of the prerequisites for the judicious selection of pavement preservation treatments. Based on the survey of 56 municipalities, about 50 percent of municipalities had a PMS (Figure 2). It was also noted that the existence of a PMS is not confined to large municipalities only.

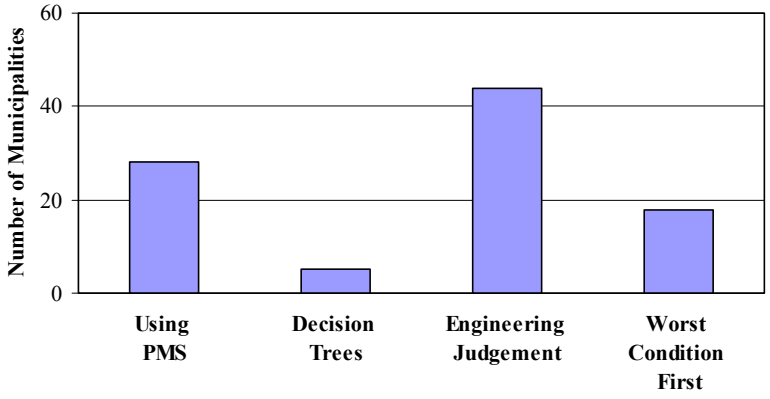

Figure 2 Existence of Pavement Management Systems for Canadian Municipalities

Smaller municipalities often depend mainly on the knowledge of a local municipal or county road superintendent or engineer. Pavements often receive maintenance on the worst-first basis or only when a hazard exists (Figure 3).

The *Pavement Design and Management Guide* developed by the Transportation Association of Canada (TAC, 1997), as well as the *Pavement Management Guide* developed by the American Association of State Highway and Transportation Officials (AASHTO, 2001), provides useful information on pavement management processes including data requirements, data collection methods, pavement performance prediction, selection of maintenance and rehabilitation treatments, priority analysis, and other pavement management topics.

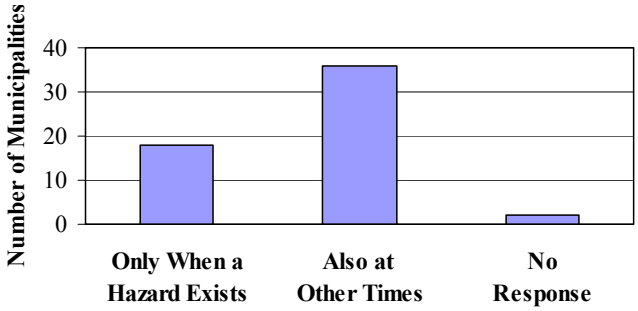

Figure 3 Maintenance Priorities for Canadian Municipalities

The best practice on priority planning and programming balances the different needs and interests of different audiences (i.e., strategic overview for decision makers and operational detail for technical personnel). It does not contain rigorous detailed procedural information and is limited, as other best practices, to about 30 pages. It concentrates on the description of the establishment of the level of service, identification of needs, prioritization, and budgeting activities. These activities have a direct impact on the effectiveness of pavement preservation investments, and ensure that the right pavement sections are treated at the right time.

The best practice for priority planning and budgeting process should be used together with other asset management tools and best practices dealing with the management of infrastructure needs. The key applicable best practices include *Timely Preventive Maintenance for Municipal Roads – A Primer,* several other best practices referenced in the following sections, and *Reference Manual of Pavement Preservation Treatments* (forthcoming).

OUTLINE OF THE BEST PRACTICE

This section provides an abbreviated version of the best practice for priority planning and budgeting process for pavement maintenance and rehabilitation and illustrates the scope and type of the information provided in best practices.

Decision Framework

Decision making for pavement maintenance and rehabilitation should be integrated into a yearly management cycle of planning, budgeting, engineering, and implementation activities. There are eight basic steps in the yearly management cycle: review or establishment of levels of service, pavement inventory, identification of needs, prioritization, budgeting, project design, project implementation, and performance monitoring (Figure 4).

Step 1 involves reviewing or establishing the levels of service regarding pavement condition. This activity takes into account a number of factors (such customer preferences, strategic directions, financial resources, and the condition of the pavement network).

Step 2 is to establish a pavement inventory. Every municipality needs to know which assets it owns and their condition to manage the assets effectively.

Step 3 is the identification of needs. Each pavement section is reviewed to determine the appropriate pavement preservation treatments to be carried out in the future. The process yields a list of candidate pavement preservation projects.

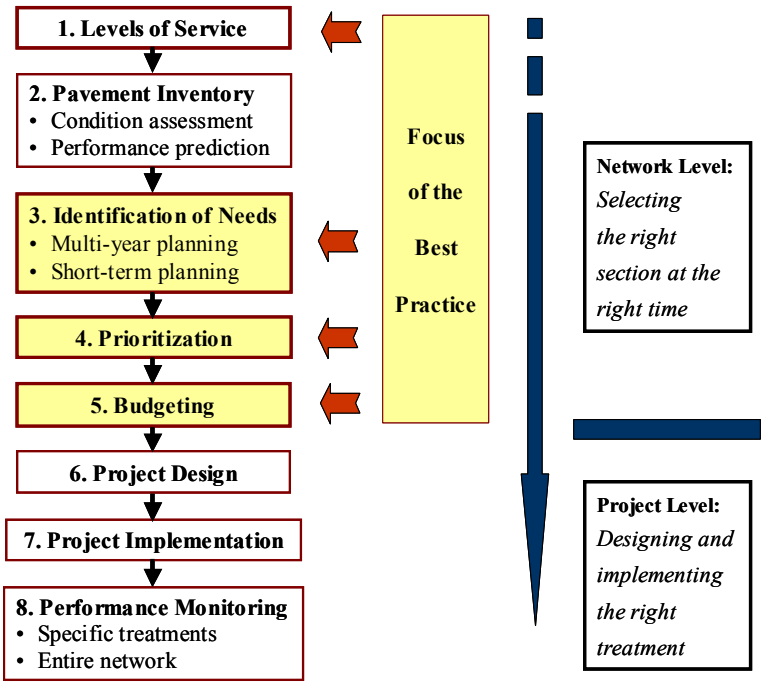

Figure 4 Decision-making Framework for Pavement Preservation

The prioritization in Step 4 is one of the most important elements in the management cycle. It determines which of the candidate projects will become recommended priorities.

Step 5, budgeting, secures the budget and controls spending. Also, as part of the budgeting process, projects are programmed and packaged to minimize inconvenience to the travelling public and to improve implementation efficiency.

The first five steps of the management cycle represent network-level management activities as shown on the right side of Figure 4. The objective of these activities is to ensure that the right pavement sections receive treatment at the right time. The rest of the steps (6 to 8) represent project-level activities that ensure that the right sections receive the right treatment.

The project design in Step 6 provides technical direction for the most cost-effective treatment, including type of materials, layer thickness, and construction procedures. Step 7, project implementation or the construction stage, must be supported by quality control and quality assurance procedures. Step 8, performance monitoring, provides feedback on how the process is working.

Levels of Service (Step 1)

At the start of the priority planning process, it is important to consider the objectives. What level of service is the road department expected or mandated to provide? Many municipalities, such as the City of Winnipeg, strive to preserve pavements at the current condition or current level of service. Winnipeg has also carried out an innovative study to obtain input from local residents on required pavement condition. The study involved residents riding in city-driven passenger cars and evaluating the condition of the pavement for typical city streets. Such studies are essential for

agencies that want to provide services that meet the needs and expectations of its customers: the roadway users (Hamilton (2003).

The development of service levels starts with strategic infrastructure planning. The purpose of strategic planning is to coordinate various infrastructure needs and major infrastructure investments to achieve the social and economic goals of the municipality. The resulting strategic directions and plans should drive all major infrastructure initiatives, including pavement preservation. Strategic planning is the subject of the best practice *Planning and Defining Municipal Infrastructure Needs*.

Figure 5 illustrates how strategic directions radiate and influence the selection of indicators and benchmarks, levels of service values, and ultimately the selection of trigger values and design criteria.

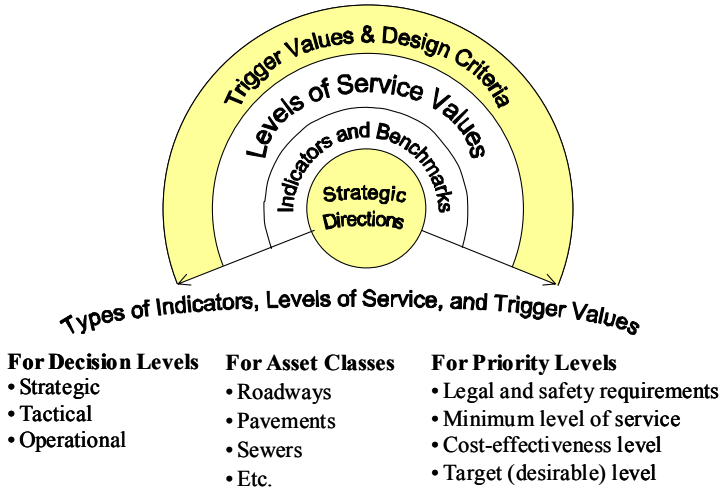

Figure 5 Strategic Directions Influence Levels of Service, Trigger Values, and Design Criteria

Indicators and benchmarks are used to translate strategic directions into measures required for infrastructure planning and decision making. A framework for the development of performance measures and indicators is outlined in the best practice *Developing Indicators and Benchmarks*.

In addition to the types of indicators and benchmarks, it is also necessary to establish the level of performance indicators and measures, or levels of service. The methodology for establishing the levels of performance indicators is described in the best practice *Developing Levels of Service*. A city or municipal council should review and approve the policies on levels of service used by a road department. This way, all subsequent pavement preservation needs are derived from and are mandated by the approved levels of service.

The final step in the process of translating and quantifying strategic directions is the establishment of trigger values and design criteria that support levels of service. Trigger values are used, usually on an operational level, to decide when a pavement preservation action should be carried out whereas design criteria are used to set specific infrastructure design parameters (e.g., pavement type or width).

Performance measures, levels of service, and trigger values can be formulated for different decision levels, asset classes, and priority levels as shown at the bottom of Figure 5. The levels of service established for different priority levels can be also used to determine prioritized needs.

Figure 6 shows, as an example, characteristic types of levels of service and trigger values used in pavement management.

Minimum safety-related levels of service are typically defined in terms of individual pavement defects, such as potholes, cracking, and wheel track rutting. For example, a standard may state that potholes on an arterial roadway should not be larger than 600 cm^2 in area and 8 cm deep. If such potholes appear, they should be filled within a specified time period (Anderson, 2002). A section with a history of developing such potholes should be scheduled for rehabilitation to meet minimum safety levels of service. Minimum or mandatory levels of service are also called *service standards*.

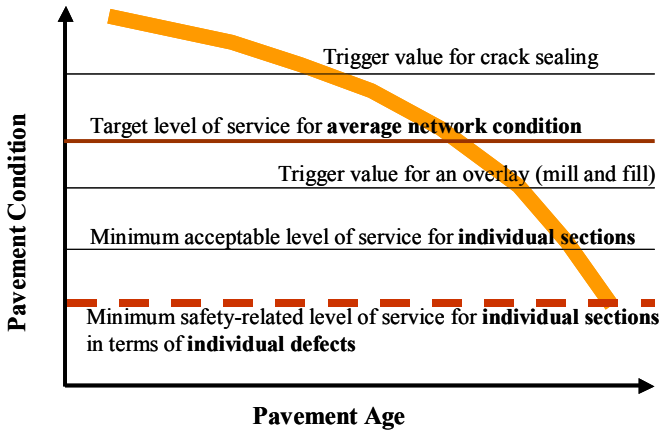

Figure 6 Types of Service Levels and Trigger Values

The minimum acceptable level of *service* is the minimum condition for individual pavement sections. The sections at or below this level should be improved at the first opportunity. Usually, different minimum acceptable levels of service are assigned to different roadway classes.

Trigger values are usually associated with specific pavement preservation treatments (such as sealing cracks in asphalt concrete pavement or sealing joints in concrete pavement) and are related to the need to apply a preservation treatment at the right time to be effective, or before the pavement reaches a condition where a different, more expensive treatment would be required. There are also general trigger values. For example, City of Regina guidelines recommend the range of Pavement Condition Index (on a scale from 0 to 100 where 100 represents a new pavement) to be 50 to 70 for overlays, 30 to 50 for partial reconstruction, and <30 for total reconstruction. The City of Edmonton has also established trigger levels for identifying rehabilitation candidates before the repairs become too expensive.

Target levels of service represent a desirable level of service for the entire pavement network or a portion of the network. For example, the average condition of arterial roadways may be set to be at least 70 on a scale from 0 to 100 while, at the same time, the maximum percentage of arterial roadways in "poor" condition (e.g., below 40) should typically be less than 10 percent.

Pavement Inventory (Step 2)

Pavement inventory is the key building block for pavement decision making. The inventory must include the description (size and type) of pavement assets as well as their current and future condition.

Inventory Data

The challenge is to decide what to include in the pavement inventory and how the data should be stored and displayed. Also, a pavement inventory should be organized as part of a roadway inventory, or even better, as part of a municipal asset inventory.

Current trends in the storage and display of inventory data include automated mapping, the use of geographical information systems, and of video data. Lee and Deighton (1995) developed a mapping system for Cornwall, Ontario that can display various infrastructure data, such as pavement or water main data, on a common map. The U.S. Department of Transportation (2001) developed the *Data Integration Primer* that explains principles and options for developing integrated databases.

The first step in developing an inventory is to divide the network into a number of uniform sections or links. For example, a section should have a uniform pavement structure, performance, and traffic volumes. The sections may be one city block long or several kilometres long. As a minimum, the pavement inventory should include the following:

- the location, roadway class, length, width, and area of the pavement section;
- the date of the original construction and the dates of subsequent rehabilitation treatments;
- a description of the original pavement structure and the subsequent pavement preservation treatments;
- pavement condition (past and current); and
- traffic data (e.g., estimated annual average daily traffic and the percentage of commercial vehicles).

Condition Evaluation

Pavement condition evaluation serves two purposes: to identify maintenance and rehabilitation needs, and to monitor the health of the pavement network.

To identify maintenance and rehabilitation needs, particularly preventive maintenance needs, the condition evaluation must be timely, (usually annual or biennial) and detailed. The requirements for the condition evaluation for preventive maintenance purposes are presented in the best practice *Timely Preventive Maintenance for Municipal Roads*. Briefly, condition evaluation requires the identification of individual pavement defects, such as transverse cracks, and the evaluation of their severity and extent. If the condition evaluation meets the preventive maintenance requirements, it will also meet the rehabilitation requirements.

Monitoring of the health of the pavement network must be objective and repeatable to produce true trends. It typically involves assessment of roughness and pavement distresses. Some agencies classify pavements into three or five categories (from very good to very poor); others use composite performance indicators. For example, the City of Edmonton in Alberta is using a pavement quality index that combines the influence of roughness, distresses, and structural adequacy. Monitoring of the network condition should be done about every second year for high traffic volume facilities and about every third year for local roads and streets.

Pavement Performance Prediction

Performance prediction is a critical requirement for the identification of future pavement preservation needs. Pavement performance depends on many local factors and is not easily transferable from municipality to municipality.

Figure 7 shows the importance of pavement performance prediction. The present condition rating of the two pavements shown in Figure 7 is the same. However, pavement B has a higher rate of deterioration than pavement A. Thus, pavement B will reach the minimum acceptable service level sooner, and will require a pavement preservation treatment earlier. The predicted rate of pavement deterioration can also be used as one of the factors to prioritize and select candidate sections for treatment.

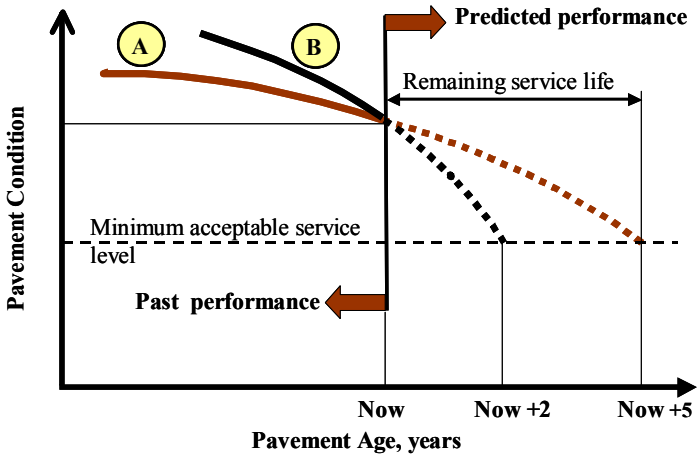

Figure 7 Basic Concepts of Pavement Performance Prediction

Long-term predictions (for five or more years) involve how long the existing pavements will last before they require a treatment (as shown in Figure 7), as well as how the individual sections will be rehabilitated during the intervening years, and how these rehabilitation treatments will perform. The best practice contains a three-page appendix with a brief outline of the pavement performance prediction required for multi-year planning and prioritization analysis.

Identification of Needs and Prioritization (Steps 3 and 4)

The identification and prioritization of needs for larger municipalities cannot effectively be accomplished without the aid of specialized computer software. There are many pavement management software products on the market that can be purchased and customized by municipalities. Municipalities also frequently retain consultants to assist in customizing or operating the software.

Two types of identification of needs are described in the best practice:

- the multi-year identification of needs for time horizons of about five years or more; and
- the short-term identification of needs for shorter periods.

Short-Term Identification of Needs and Prioritization

Because of the complexity of multi-year planning procedures, it may be easier for municipalities just starting to implement pavement management systems to use short-term planning and prioritization procedures. Figure 8 shows the connection between the level of service, identification of needs, prioritization, and budgeting for short-term planning and prioritization.

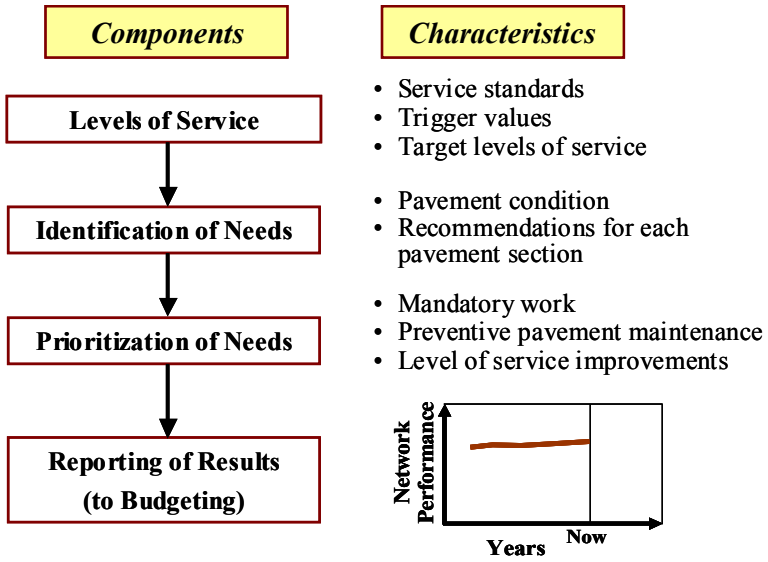

Figure 8 Short-term Planning and Prioritization

The following step-by-step description of identification of needs, presented in the best practice, represents a typical process. The process combines all pavement preservation needs together (maintenance as well as rehabilitation treatments). Although some municipalities prepare separate budgets for maintenance (operating) and rehabilitation (capital) work, perhaps for administrative reasons, for cost efficiency and technical reasons, it is preferable to have only one integrated process for the identification and prioritization of all pavement preservation needs.

A decision must be made as to what types of treatment should be included in the needs. In general, all roadway maintenance and rehabilitation activities that can be planned at least a year in advance should be included. Such activities may include, for example, ditching, repair or replacement of culverts, sealing cracks and joints, machine patching, asphalt concrete overlays, and full-depth repairs of Portland cement concrete pavements.

Each roadway section in the inventory is reviewed to determine if the section requires a pavement preservation treatment in the next few years. Many sections may not require any treatment, some sections may require a preventive maintenance treatment (e.g., crack or joint sealing), and some may require other types of maintenance or rehabilitation. The candidate treatments can be identified using engineering judgment, agency-specific guidelines and decision trees, and general guidelines.

The best treatment for the given section is selected. Typically, the selected treatments are generic (e.g., one-lift overlay or a multi-lift asphalt overlay), particularly if the treatments are selected by software. The selection of the treatments must be realistic and must consider the appropriate levels of service. It is important to realize that the identification of needs is not a creation of a wish list, but a documentation of the needs that are necessary on the basis of approved and mandated standards and levels of service.

Each section, and its recommended treatment, are described in terms of location (and road class), treatment type, recommended construction year, estimated cost and, very importantly, priority level. The priority level shows the main reason why the treatment is recommended for implementation. One of the following priority levels should be assigned to each recommended pavement preservation treatment:

- minimum safety-related levels of service need be met;
- minimum acceptable levels of service need be met;
- there are preventive maintenance and cost effectiveness concerns (includes projects where timing is very important to achieve cost effectiveness); or
- projects are initiated to achieve a target level of service.

The individual treatments are sorted by the priority levels (A to D) and by roadway classes. The resulting list represents the total documented and mandated needs for the preservation of the road system.

If it is expected that some projects may not be funded because of limited funding, the list needs to be prioritized. Projects that address minimum safety-related levels of service are typically considered mandatory and are not prioritized. The same applies to carry-over projects that need to be completed and already approved projects.

There are many ways to prioritize projects. The priority levels, together with roadway classes already convey basic priorities. Thus, projects that belong to priority level B (minimum acceptable level of service) and apply to expressways may have higher priority than projects that belong to priority level D (target levels of service) and apply to residential streets. It is easier and preferable to prioritize projects that belong to the same priority level and roadway class than to prioritize projects across priority levels and roadway classes. Typical prioritization criteria include the following considerations that can be applied individually or in combination:

- pavement condition (in relation to the level of service);
- roadway class;
- traffic volume and percentage of commercial vehicles; and
- cost effectiveness (benefit-cost ratio).

Multi-Year Identification of Needs and Prioritization

Multi-year prioritization analysis can consider several treatment options in each analysis year (FHWA, 1997). The concept is illustrated in Figure 9 for one pavement section. For illustrative purposes, of the many options that can be generated for different years, only two alternatives are assumed to exist. The first is a single lift resurfacing three years from now; the second is a two-lift resurfacing nine years from now. With multi-year prioritization analysis, these two alternatives (pay now or pay later) can be evaluated on an equal footing, while still considering other projects.

Multi-year planning also improves engineering and economic decision making, because it enables the agency to evaluate the long-term impacts of accelerating or postponing projects from one year to another, to evaluate the trade-offs between lower-cost treatments that have to be paid for now versus costlier treatment that will need to be paid for later, or the impact of diverting funds to preventive maintenance.

An important feature of multi-year prioritization analysis is its ability to prioritize (or optimize) competing treatments using the cost effectiveness of individual treatments. To do this, each treatment is characterized by its cost and benefit. The cost aspect of the treatment should be based on its life cycle cost as much as possible (Zimmerman et al., 2000). However, in practice, agencies use only initial treatment costs and perhaps routine maintenance costs, because the exact nature of the treatments is not known in the planning stage (at the network level).

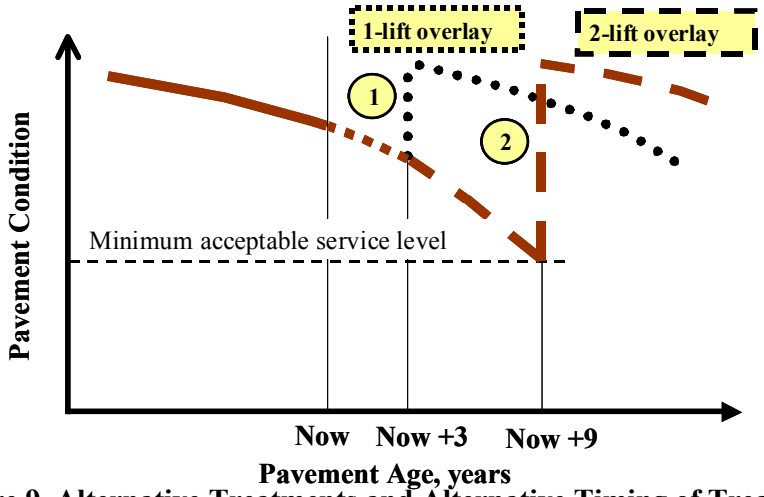

Figure 9 Alternative Treatments and Alternative Timing of Treatments

Benefits, or effectiveness of the treatment, are based on the additional pavement life the treatment is expected to provide, and may include the reduction in user costs. For example, if two projects provide the same benefit in terms of additional pavement life, the project on the roadway serving a higher traffic volume may be chosen first.

The candidate projects included in multi-year analysis should also include preventive and other maintenance activities. The cost effectiveness of these activities can be compared with the cost effectiveness of activities recommended for other priority levels. Consequently, the distinction between funding for preventive maintenance and funding for target levels of service can be made directly through cost-effectiveness analysis.

Depending on funding, the projects not funded one year are considered for funding in the subsequent year (or years). By changing the amount of funding, the amount of work will change, and so will the condition of the pavement network. However, regardless of the funding, the list of prioritized projects still represents the best value for the money.

The results of multi-year prioritization can show the relationship between the pavement investment and the resulting level of service provided to the community. An example of this type of analysis is illustrated in Figure 10, which shows the consequences of changes in proposed funding levels. A 10 percent growth in funding, sustained for several years, will result in achieving the desirable target level of service in 2007.

Multi-year prioritization software typically supports different levels of detail. A municipality can start with a simplified system and improve it with experience and as more data become available. The simplification can be accomplished through:

- limiting the length of the planning period;
- simplifying the pavement prediction procedures;
- restricting the number of candidate treatments per section; and
- using simple prioritization indicators, such as pavement condition and traffic volumes, rather than a cost-effectiveness ratio.

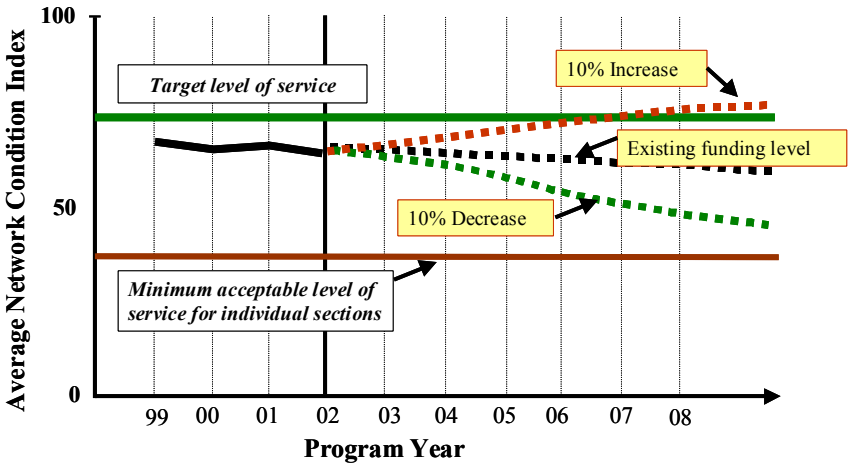

Figure 10 Consequences of Different Funding Levels

Prioritized pavement preservation needs provide important input for the preparation of annual and multi-year budgets. However, budgets must also consider many other funding needs and programming considerations

Budgeting (Step 5)

The selection of projects to be included in the budget should be based on the efficient allocation of resources to different programs (e.g., infrastructure preservation, expansion of capacity, environmental protection, and increased safety) and to different assets (e.g., pavements, bridges, sewers). The efficient allocation of resources, and the ability to evaluate the consequences of different budget allocations, is a principal premise of asset management.

Budgeting builds on the results of planning and prioritization activities, and produces a budget — a financial document that determines how the money will be invested in the infrastructure. Budgeting combines technical and financial decision making as illustrated in Figure 11.

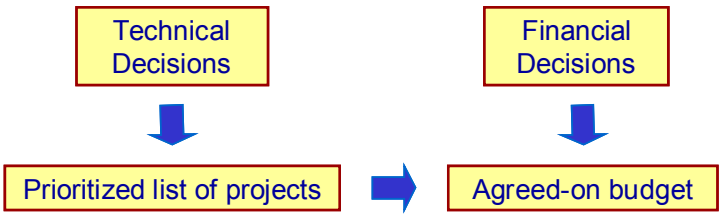

Figure 11 Budgeting as a Combination of Technical and Financial Decisions

A municipal budget consists of many line items. Some municipalities have a separate budget entry for maintenance and for capital projects. This may serve a useful administrative purpose. However, it is desirable that both budget entries are based on prioritized needs where maintenance and rehabilitation activities are in synergy.

While historical budget allocations assist in providing an overall indication of available resources, the main input to the budgeting process should be the list of documented and prioritized needs and not last year's budget.

Programming and Budgeting

The primary budgeting activities are schematically illustrated in Figure 12.

Programming and packaging of projects must take into account the following needs and considerations:

- Prioritized pavement preservation needs;
- Other roadway needs including other roadway components (e.g., culverts, bridges, and sidewalks), operational improvements (e.g., widening at an intersection and system expansion), and safety improvements;

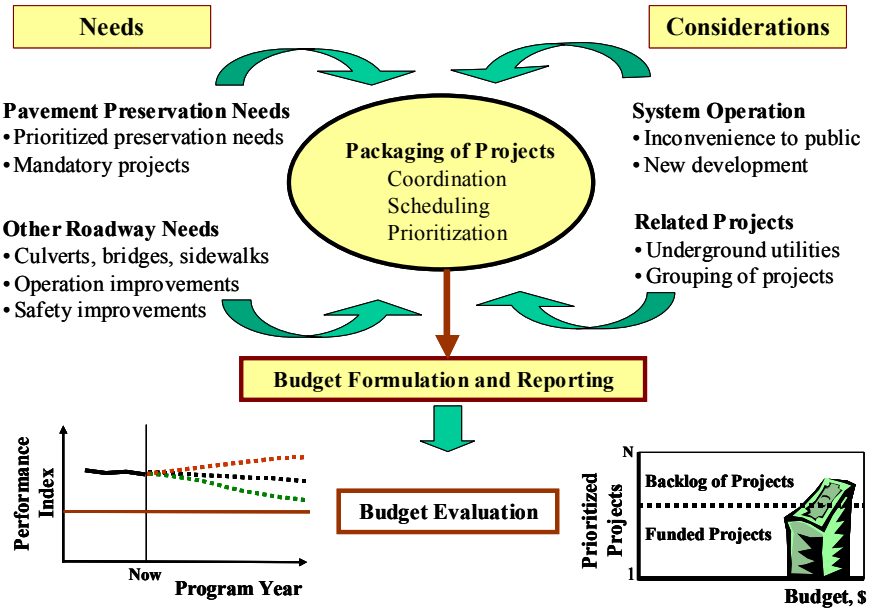

Figure 12 Key Budgeting Activities

- System operation including staging projects to minimize inconvenience to the public and advancing projects because of new residential and industrial development; or
- Related projects, such as work on underground utilities, should be coordinated to minimize disruption to the public. This is the subject of a separate best practice: *Coordination of Infrastructure Works to Minimize Disruption and Maximize Value.*

The results of the budget allocation can be quantified and reported using the following means.

- Show the consequences of different budgets in terms of pavement condition as illustrated in Figure 10.
- List the specific projects that will not be done because of funding limitations.
- Track the quantity of unfunded needs, and the changes in unfunded needs, from year to year.
- Monitor network performance trends. For example, the City of Calgary monitors long-term trends in terms of network size, network condition, and annual spending per square metre of pavement.

Project Design and Implementation (Steps 6 and 7)

The priority planning and budgeting process determines which sections should receive pavement preservation treatments and during which year, the approximate type of the treatment (e.g., a thin overlay), and the estimated cost of the treatment. Project design determines the actual treatment type and provides additional details required for the construction of the project (such as the layer thickness, type of material, and construction methods). It often uses the results of physical tests of the existing pavement materials. The systematic way to approach the design of pavement maintenance and rehabilitation treatments is through life cycle cost analysis (LCCA). LCCA takes into account the cost of the initial constructions as well as all subsequent maintenance and rehabilitation treatments and, if relevant, user costs. An example application of LCCA is provided in the best practice *Timely Preventive Maintenance for Municipal Roads*.

Over the years, many agencies have developed various technical design aids, such as pavement design and rehabilitation procedures, manuals, specifications, and guidelines. The *National Guide to Sustainable Municipal Infrastructure* has contributed to this effort by developing a *Reference Manual of Pavement Preservation Treatments* (forthcoming) describing over 25 pavement maintenance and rehabilitation treatments.

The two main decision-making concerns during the implementation stage are the selection of construction agents (in-house, contractors) to carry out the work and inspection procedures during construction.

In addition to quality control and quality assurance procedures, many municipalities use construction warranties. Warranties provide a catch-all provision to ensure basic construction quality. Warranties are important for pavement preservation treatments where the construction procedures and the selection of materials are difficult to specify and enforce (e.g., for sealing cracks in asphalt concrete pavements and for micro-surfacing). Several Canadian municipalities use one to three year warranties for "thin" paving jobs and up to five year warranties for rehabilitation and reconstruction work.

Performance Monitoring (Step 8)

Periodic pavement performance monitoring is important for both individual projects and for the entire pavement network. For example, the cities of Edmonton and Toronto periodically evaluate past pavement preservation treatments, particularly treatments that are new. This enables them to expand, change, or discontinue the use of a particular treatment based on the cost effectiveness of the treatment. Regular condition evaluation of all the pavement sections in the network can provide a clear indication of the long-term trend in the health of the network.

IMPLEMENTATION

The main implementation steps and challenges include the following.

- System benefits – Management and technical leadership must be convinced that the process will provide benefits to the residents, and to the agency.
- Support by council – Acceptance and support by municipal council is vital.
- Management commitment – The implementation of the process takes time and may be labour intensive. The process may change the way the pavement preservation business was done and may affect agency staff. Long-term commitment and support by management is required for successful implementation and operation of the process.

- Establishing technical aspects – The process must be technically sound and reflect local conditions (e.g., environment, material availability, and contracting industry). Because the process is typically a computer-assisted decision support system, it will require ongoing software support.
- Long-term commitment – The benefits of the process increase with time and with experience. For example, it takes several years of data collection to obtain pavement performance trends and calibrate pavement performance models. The availability of good inventory data is necessary to make the process work. The continued desire to succeed on the part of all principal participants is required.
- Ongoing support – Identifying and prioritizing needs incurs costs and requires trained personnel.

CONCLUSIONS

The collaborative approach used for the development of best practices contained in the *National Guide to Sustainable Municipal Infrastructure (InfraGuide)* harnesses experience of Canadian municipal agencies and promotes the acceptance of the InfraGuide.

The best practice on priority programming and budgeting should be of interest to management and technical personnel responsible for the identification of pavement preservation needs and the development of budgets. Benefits of this practice can be realized in several ways.

- It provides procedures on how to determine, document, and justify funding needs for pavement preservation;
- It provides directions on how to prepare prioritized, needs-based budgets, and how pavement preservation needs can be translated into funded projects using a logical, systematic, planning and budgeting process;
- It promotes the use of best practices and provides a benchmark for pavement preservation decision making for both small and large municipalities;
- It can provide objective information on pavement preservation needs, and on long-term implication of budget decisions, to senior decision makers and the public. It can be used to support funding requests for pavement preservation by showing the relationship between the budget and the level of service provided to the public; and
- It promotes the cost-effective use of pavement investments to return maximum benefits to the community.

The use of the best practice can provide the municipality with specific products including:

- an up-to-date inventory of the road network and its condition;
- a summary listing, for each section of the network, of current and future pavement maintenance and rehabilitation needs;
- a prioritized listing of pavement maintenance and preservation needs using sound technical analysis (separate listings can be produced for different roadway classes, such as arterials and collectors, and for different priority levels, for example minimum acceptable condition level, preventive maintenance/cost effectiveness, and improvement of service levels);
- a prioritized listing of needs and projects, section-by-section, for budgeting considerations (a budget plan);
- trends in the condition of the pavement network; and
- a summary of unmet needs (infrastructure deficit) in terms of specific projects.

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