PRESERVING PAVEMENT ASSETS THROUGH REALISTIC POLICY OBJECTIVES AND LIFE CYCLE CONSIDERATION OF USERS, ECONOMIC EFFICIENCY, RESOURCE CONSERVATION AND ENVIRONMENTAL PROTECTION

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Paper prepared for presentation

at the Pavement Session

of the 2007 Annual Conference of the
Transportation Association of Canada
Saskatoon, Saskatchewan

ABSTRACT

Pavements represent a major asset in Canada’s transportation capital stock. Preservation of this asset requires good technology, good management and adequate financing. A framework for preservation should be part of an agency’s business plan and explicitly incorporate strategic policy objectives. Realization of these objectives depends on clear recognition of the stakeholders involved, measurable performance indicators and achievable implementation targets. Stakeholder groups include the road network service providers and both private and commercial users.

The development of measurable performance indicators should be comprehensive in terms of institutional, economic, environmental, safety, technical and functional considerations and should be tied to transportation values which are understood by the users.

Institutionally based policy objectives should include quality of service to users, preservation of investment, safety goals, productivity and efficiency, cost recovery, research and training, communication with stakeholders, and resource conservation and environmental protection.

Example preservation strategies are provided in the paper and comparisons made with suggested implementation targets indicate that the policy objectives and the targets are in fact realistic and achievable.

INTRODUCTION

The pavement engineering and management community in Canada has implicitly recognised that pavement assets are preserved through good technology, good management and adequate financing. Much of this is reflected in the Transportation Association of Canada’s widely used “Pavement Design and Management Guide” Added to the Guide’s use should also be realistic agency policies that explicitly address asset preservation, user impacts, life cycle economic efficiency, resource conservation and environmental protection.

These policies are really the foundation for the various services and value for investment that the actual owners/users receive from the road authority or its designated service(s) provider(s).

In the United States, extensive attention has been focussed on pavement preservation in the past few years. For example, Caltrans has supported the establishment of a new California Pavement Preservation Center at California State University in Chico, which has established linkages/partnerships with the National Center for Pavement Preservation at Michigan State University in Okemos, the Texas Pavement Preservation Center in Austin and the National Concrete Pavement Technology Center at Iowa State University in Ames(see FHWA’s March, 2007 Issue of “FOCUS”; www.tfhrc.gov/focus.htm). While these centers are concerned primarily with preservation treatments and programs which extend pavement life, an important point is that major support and interest has been provided at the federal, state and local agency levels, and by industry.

It is hoped that a similar degree of interest and support for pavement preservation will be forthcoming in Canada, and certainly the fact that a session at this conference is directed to the subject should be helpful.

The overall purpose of this paper is to provide a framework for preservation of pavement assets by articulating a set of realistic policy objectives, describing associated performance indicators and suggesting implementation strategies or targets. More specifically, the following are addressed:

- The driving forces underlying policy development and implementation strategies
- Establishment of quantifiable performance indicators related to these policies and to providing measures for the implementation targets
- Defining a set of policy objectives applicable to both provincial and municipal agencies
- Example preservation strategies and illustration of their application to a pavement network
- Conclusions and recommendations toward further development of a "culture" of preserving pavement assets

FRAMEWORK FOR ASSET PRESERVATION

The framework and key elements of preserving our civil infrastructure assets through an integrated approach of realistic policy objectives tied to performance indicators and in turn implementation strategies should be part of an agency's business plan. Moreover, the implementation strategies should incorporate life cycle consideration of users, economic efficiency, resource conservation and environmental protection. As well, these strategies should have a monitoring or assessment mechanism, using performance indictors.

A basic framework to represent the foregoing is shown in Figure 1. it indicates that the elected body, with public input, has the overall responsibility for accepting and overseeing the agency's business plan. The business plan may well derive from a mission statement. In the transportation area, based on sampling provincial/state and municipal web sites, it is common to see the terms….safe…..comfortable….effective…, which must then ultimately be reflected in the actual implementation of strategies. For example, Alberta Infrastructure and Transportation mission statement and its business plan states the following:" Improve the safety, efficiency and effectiveness of provincial highway infrastructure" (1). Note that the term "improve" is used, which not only implies preservation but also the strategic objectives and implementation strategies identified in Figure 1.

Regarding pavements specifically, the basic premise would be that these are a vital part of the agency's suite of infrastructure assets and preservation is an overarching objective for value, level of service, safety and resource utilization.

It is also useful to recognise the driving forces which underlie the extent and impact of policy objectives and the associated implementation strategies. These are schematically portrayed in Figure 2. Concerning pavement preservation, availability of resources would likely dominate

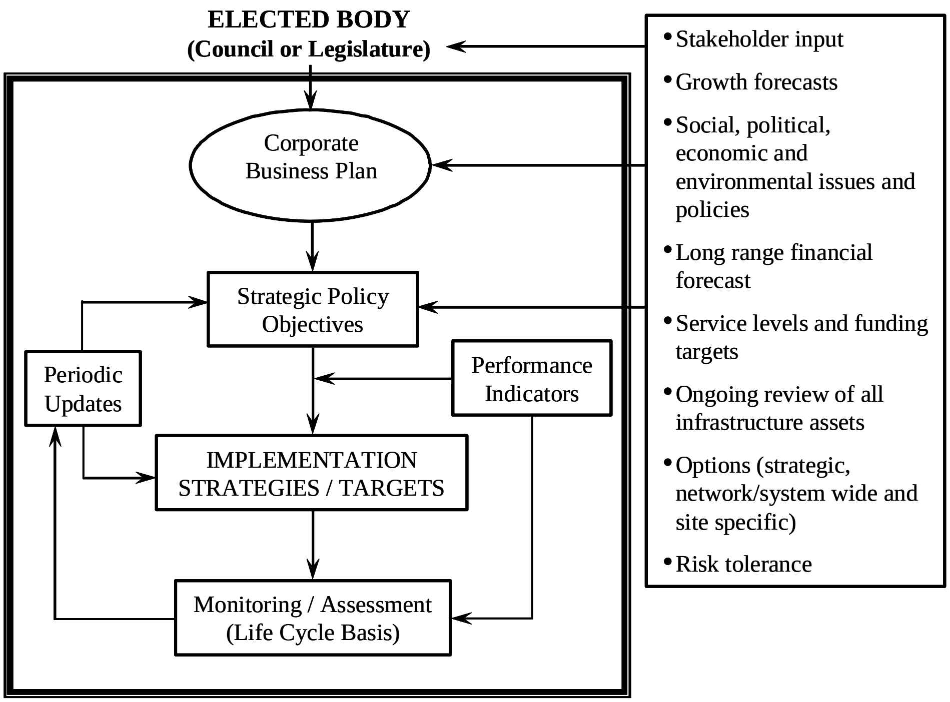

Figure 1 Framework for Infrastructure Assets Preservation

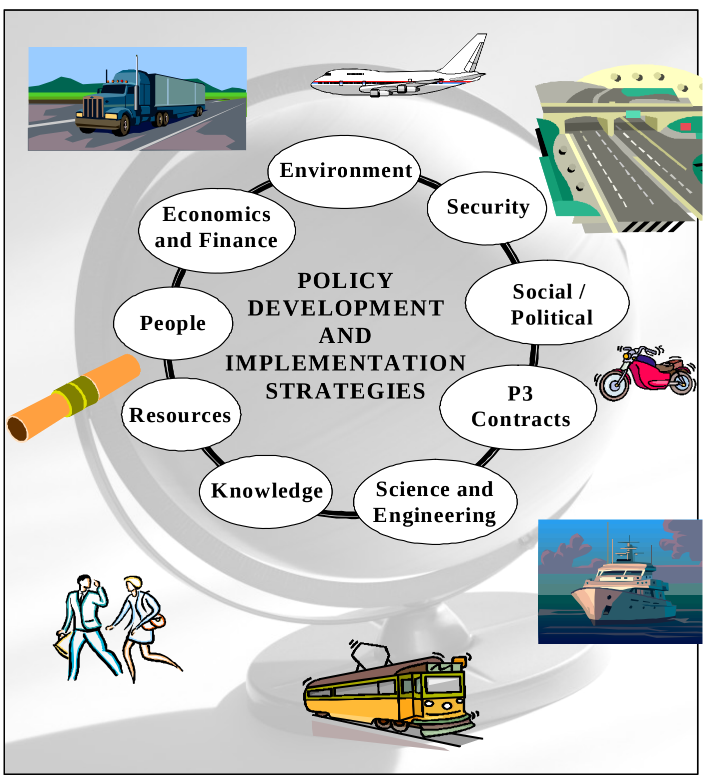

Figure 2 Driving Forces Underlying Policy Development and Implementation Strategies

BASIS FOR ESTABLISHGING POLICY OBJECTIVES AND PERFORMANCE INDICATORS

The establishment of realistic strategic policy objectives for preservation of road assets, and realisation of these objectives, requires development of the following:

- Clear recognition of the stakeholders involved, including the road service provides, the road users and the owners (e.g. the public).
- The establishment of quantifiable performance indicators which are tied to basic values or expectations from the transportation system including the pavement network.
- The establishment of achievable implementation strategies or targets.

The following sections elaborate on these development requirements and establishment of quantifiable performance subsequent sections describe a set of institutionally associated policy objectives and example implementation targets.

Stakeholders Groups

Several distinct groups of stakeholders are directly involved either as service providers or service users, as schematically indicated in Figure 3 (2). The road network service provider would in most municipal, provincial/state/territorial or federal situations be the transportation/road authority. However, in privatized (e.g. "P3's") situations, such as the Highway 407 ETR in Toronto, the service provider is the investor or concessionaire, or managers on their behalf. This situation would also apply to the P3's of road maintenance contracts in various Canadian provinces.

It is important to note the emphasis on SERVICE. In fact, Gohier presents a strong argument that this is a "missing link" in asset management, where the emphasis is mostly on technical and financial dimensions (3). He argues that "…service, not assets should be the driver". The approach in Figure 3 is to a large degree in accordance with Gohier's argument, not withstanding that the focus of this paper is not on asset management per se, but on asset preservation which should of course be an integral part of asset management.

Establishment of Performance Indicators

To effectively manage any asset requires measure (s) or indicator (s) of performance, which should be objectively based, consistent and quantifiable (4, 5). However, operational realization, with direct ties to policy objectives on the one hand and implementation targets on the other hand can be a challenge. Suggested, institutionally based objectives, performance indicators and implementation targets are subsequently described.

It is important though that an underlying rationale exists, that the performance measures are related to transportation values and that objectivity and consistency have been achieved.

The underlying rationale for performance indicators is that they are an integral element of asset management, as indicated in the asset management framework's strategic level in Figure 4. note also in Figure 4 that Level (s) of Service Targets represent a key element at the strategic level,

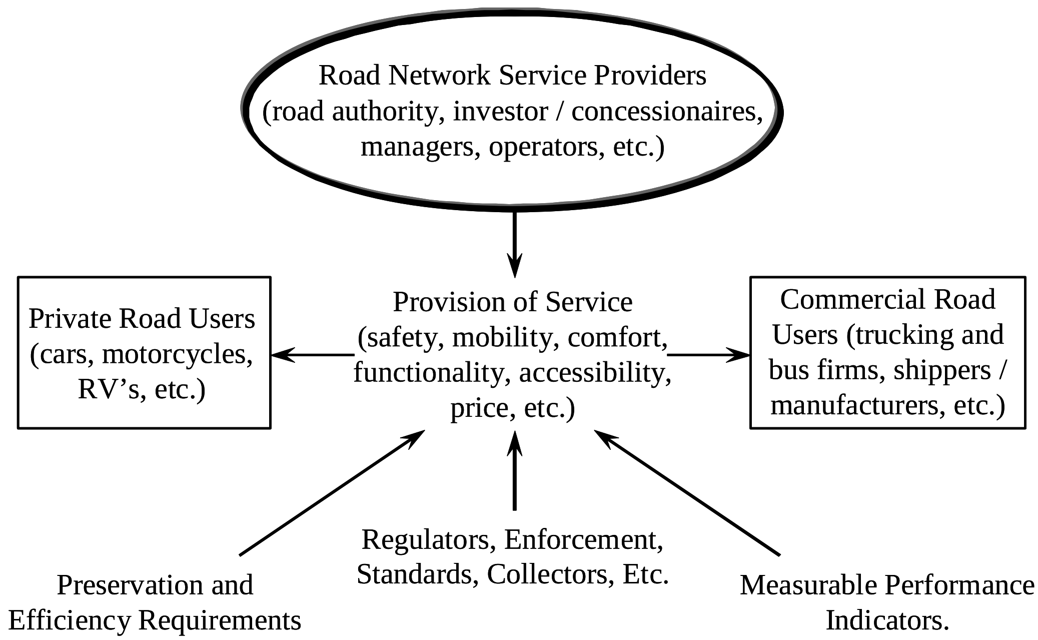

Figure 3 Stakeholder groups, provision of service expectations and related factors

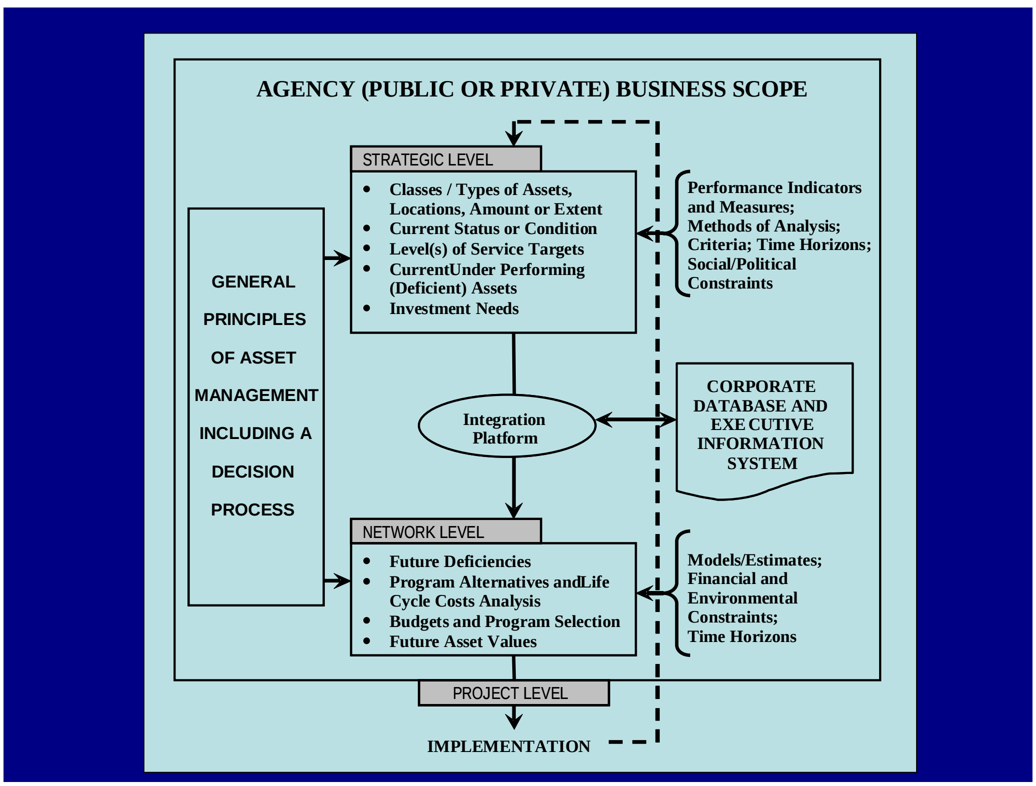

Figure 4 Overall Framework for Asset Management

which is in accordance with Gohier's assertion (3). In a more specific sense, the suite of performance indicators should be comprehensive enough to incorporate institutional, economic, environmental, safety, technical and functional considerations, and enable the following:

- A monitoring mechanism for assessing policies
- Use as a tool in resource allocation
- Provision of information to users or customers
- Provision of data or information to track condition, costs, safety, etc.
- Use as a diagnostic tool in early deterioration of assets

In essence, a suite of performance indicators must enable a balanced view of the overall efficiency and effectiveness of a transportation system, certainly including the pavement network. A practical demonstration of the use of objectively based performance indicators in 10-year performance specified, network contracts in Australia and New Zealand has been provided by Yeaman (6).

The development of performance indicators should ensure that they are tied directly to the expectations of the transportation system in terms of values, particularly as they can be understood by users or customers. Cowe Falls and Haas (2) have described such values for the overall highway system. The following listing (with example or common units) as it relates to pavement preservation is excerpted from their work:

- Safety (fatalities and/or injuries per 10^6 vehicle-km
- Mobility (average trip time or travel speed; delay as a percent of trip length)
- User benefits (reductions in accidents, travel time, vehicle operating costs)
- Comfort/convenience (smoothness)
- Environmental protection(atmospheric levels of CO_2, CO, NO_2, ozone, particulates)
- Operational effectiveness(response time to incidents and/or complaints/inquiries)
- Institutional effectiveness
  a) Asset value(increase or decrease)
  b) Program delivery (savings in construction, maintenance; reductions in traffic disruption)
  c) Productivity (units of transportation, such as vehicle-km, per unit of cost; improvement in any performance indicator per unit of cost

Achievement of objectivity and consistency, previously noted as an important aspect of developing performance indicators, is realized essentially through the units in the foregoing listing. In a strategic sense, this realization is brought about on an institutional basis by realistic implementation targets, as subsequently described.

POLICY OBJECTIVES AND IMPLEMENTATION STRATEGIES/TARGETS

The foregoing discussion on a basis for establishing policy objectives and developing quantifiable performance indicators can now be translated into an actual set of realistic policy objectives and associated implementation strategies or targets. Table 1, adapted from the "Investment Analysis and Communication Challenge for Road Assets" in the 7th International Conference on Managing Pavement Assets, Calgary, 2008 (7) lists a set of eight realistic policy objectives applicable to both provincial/state and municipal agencies. As well, it lists the performance indicators by which these objectives can be measured, plus achievable (example) implementation strategies or targets. The latter are not intended to be universally applicable and thus they should be considered as examples.

While the quality of service to user's objective in Table 1 may be viewed as having the highest priority, safety goals and preservation of investment could be viewed as close if not equal priorities but there is no intention herein of ranking them.

The implementation strategies or targets associated with these objectives are based largely on current practices and to a degree on the experience and opinion of the authors. Nevertheless, they are considered reasonable and achievable, within limits.

The issue of what life cycle is applicable to the foregoing objectives and implementation strategies really has two aspects: 1) A full life cycle, from short term to the foreseeable future for the objectives listed and preserving pavement assets, and 2) program life cycles ranging from 5 to 10 year periods for the implementation strategies, depending on road class and periodic assessment for updating needs.

EXAMPLE PRESERVATION STRATEGIES

The implementation target for smoothness (Table 1) is suggested as 90% or greater of the network in good or fair category. A commonly accepted measure for smoothness is the International Roughness Index, IRI, as described in Ref (8). Various preservation treatments which are commonly used by road agencies are listed in Table 2. These are accompanied by suggested IRI "trigger levels", in terms of m/km, at which a treatment should be applied. Of course this does not answer the question of which treatment is optimal. That is the function of network priority programming under budget constraints, a subject which is covered in detail in the Transportation Association of Canada's Pavement Design and Management Guide (8).

Table 2 also provides approximate IRI rates of increase, as a function of traffic volume, which were used to determine the expected service lives of the four preservation treatments listen in the table. These IRI rates were calculated from a data base of 1293 pavement sections (spanning 3240 center line km) in the "Challenge" of Ref (7). While the statistics are not shown herein, the R^2 values for the IRI vs. age relationships from which these IRI rates were determined, range from 0.89 to 0.82.

Table 1 Suggested Institutional Policy Objectives, Performance Indicators and Example Implementation Strategies/ Targets (Modified from Ref (7))

Policy Objectives	Performance Indicators	Implementation Strategies/Targets
1. Quality of Service to Users	• Network level of service (smoothness, functionality and utilization) - % good, fair or poor • Provision of mobility (average travel speed by road class) • Annual user costs ($/km)	• Maintain at 90% or greater of network in fair or better category • Greater than 50% of speed limit • Total user costs/total network km increase at no more than CPI increase
2. Safety goals	• Accident reductions (%)	• Reduction of fatalities and injuries by 1% or greater annually
3. Preservation of investment	• Asset value of road network ($)	• Increase (written down replacement cost) annually of 0.5% or greater
4. Productivity and efficiency	• Cost effectiveness of programs (ratio) • Annual turnover (%)	• 1% or greater annual increase (ratio of level of service to users weighted by km of road network divided by total road network expenditures) • 5% or less annually through training, work environment and advancement opportunities
5. Cost recovery	• Revenues ($)	• Annual increase at no less than rate of inflation
6. Research and training	• Expenditures (% of budget)	• Annual commitment of 2.5% of total program budget
7. Communication with stakeholders	• Satisfaction survey sampling (%)	• Greater than 75% of respondents satisfied or very satisfied
8. Resource conservation and environmental protection	• Recycling of reclaimed materials (asphalt, concrete, etc) - % • Monitoring of emissions (construction, materials production, etc) - established standards	• Maintain at 90% or greater • Maintain at levels < 90% of standards

The basis then exists for establishing ranges of IRI for categories of smoothness from excellent to poor. Table 2 provides four suggested categories and associated ranges of IRI. These could be further subdivided by traffic volume ranges, as for the trigger levels in Table 2, but should be sufficient as is for approximations.

Comparison of Network Smoothness with the Implementation Target

Analysis of the data base in Ref (7), which involved two classes of highways, termed as interurban and rural, provided a distribution of IRI values as shown in Figure 5. It is clear from Figure 5a that the interurban network, consisting of freeways and major aterial highways, has more than one third as excellent (IRI<=1.00), about one quarter as good (IRI>1.00 and <=1.50), one fifth as fair (IRI>1.50 and <=2.00) and less than 10% as poor. Thus, the target of having 90% of the network in fair or better condition with regard to smoothness (Table 1) is met by the interurban network. In essence, this is a realistic target, and a real, existing network is involved, as described in detail in Ref (7).

The rural part of the network (Figure 5b), consisting of lower volume arterial and collector highways, has about one quarter as excellent, one third as good, one fifth as fair and a little more than 10% as fair. It is visually obvious in comparing Figure 5a and Figure 5b that the rural network condition is somewhat lower than the interurban network, which would be expected. Also it is slightly below the target of 90% of the network being in fair or better condition. So again, this seems to be a realistic target, but in future updates, it may be appropriate to vary the target by class of highway.

The "snapshot" of Figure 5 does not of course address the policy objective of preservation of investment (see Table 1) in terms of asset value. To address this objective requires a periodic asset valuation so that the value of the network can be tracked over time. Asset valuation has become a major requirement in the accounting of public assets (e.g. GASB34 in the United States and the Public Sector Accounting Board's (PSAB) new financial reporting model for governments and their tangible capital assets to be implemented in 2009). Unfortunately, asset valuation is not a simple issue in that there are several approaches, which can give quite different results even for the same.

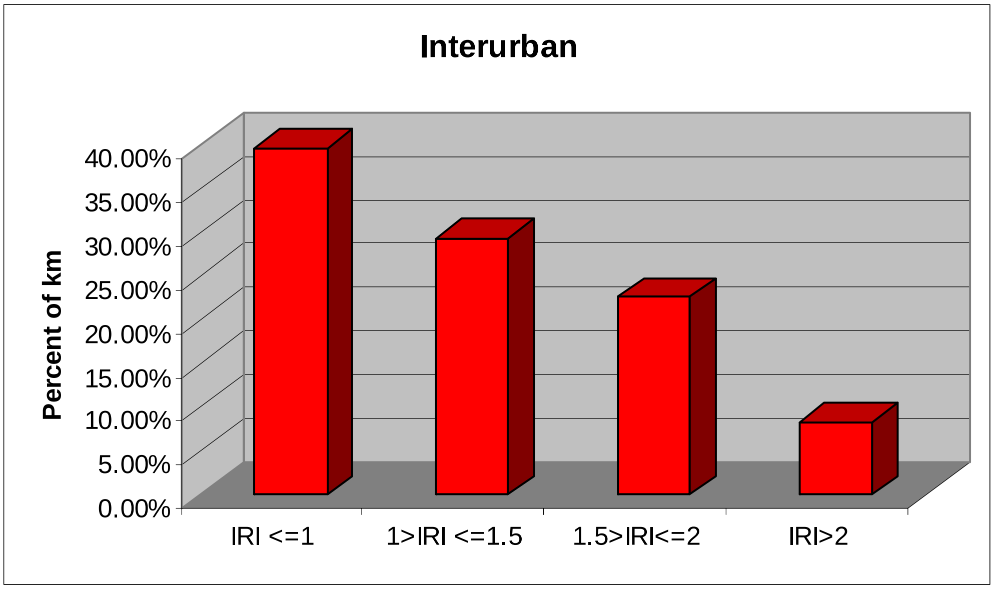

Figure 5a Distribution of IRI Values from the "Challenge": Interurban Sections Derived from Ref. (7)

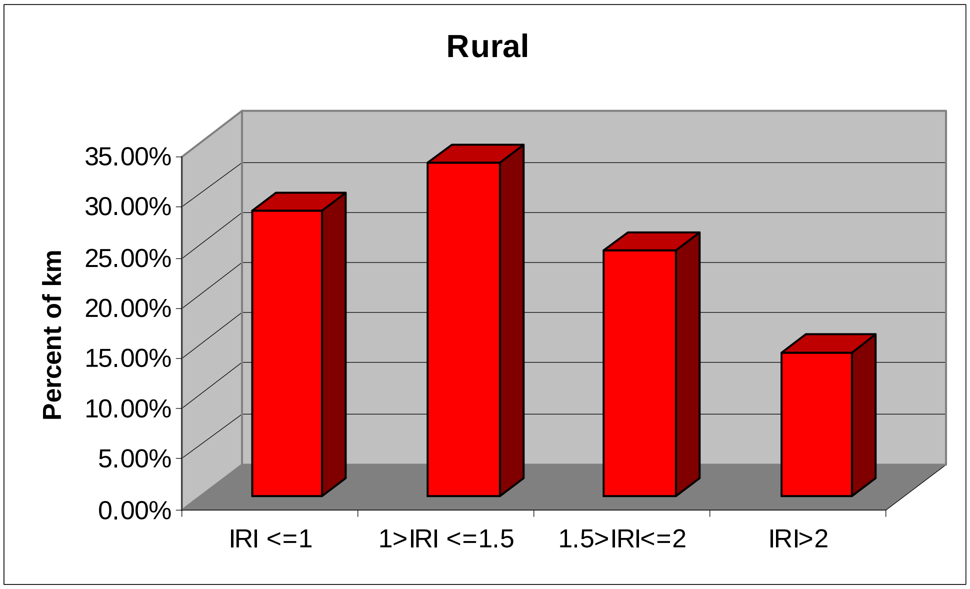

Figure 5b Distribution of IRI Values from the "Challenge": Rural Sections Derived From Ref. (7)

Table 2 Example Pavement Preservation Treatment Alternatives (Excerpted from Ref. 7)

Treatment	**Applicability**	**Expected Effect in Terms of IRI**[1]	**Expected Service Life to Trigger Level**[2]	**Remarks**[3]
Thin Overlay (40 mm)	Structurally adequate pavement but surface distress and/or roughness at trigger level; low volume road (<=2000 AADT)	IRI improvement ~ 1.0 m/km if done at IRI trigger level	<= 10 years	Can be applicable as a defer strategy for structurally inadequate pavements scheduled for widening or reconstruction
Cold mill and thin overlay	Structurally adequate but surface distress and/or roughness at trigger level; low volume (<= 4000 AADT)	IRI improvement ~ 1.0 m/km if done at IRI trigger level	< 15 years and probably 12 to 13 years	Cold milling used basically for reprofiling, not strengthening
Cold mill and overlay (25mm mill and 75 to 100 mm overlay	Strengthening need and sever surface distress(AADT <8000)	IRI after construction ~ 0.75 m/km	<=15 years	Strengthening need based on deflection testing and appropriate structural design
Structural overlay, >= 100 mm	Structurally deficient pavement for traffic volume demand (AADT >8000)	IRI improvement ~ 1.0 m/km if done at trigger level	<= 18 years	Structural design based on deflection testing and appropriate design method

Other potential, but less commonly used treatments include cold mill and inlay, hot in-place recycling, micro surfacing, cold in-place recycling-and where preservation is not an option, full-depth reclamation or reconstruction- see Ref(7). But commonly used preventive maintenance treatments, with a preservation effect of extending service life up to 5 years, include crack sealing and chip seals/surface seals if carried out on structurally adequate pavements AND surface distress is relatively low in severity

1. IRI Trigger Levels, m/km, for AADT		2. Annual Rates of Increase of IRI, m/km/yr After Treatment		3. Categories of Smoothness in Terms of IRI ranges	
< 500	3.0	AADT > 8,000	0.069	Excellent	<= 1.00
500 – 1500	2.6	< 8,000	0.07	Good	<= 1.50 and > 1.00
1500 – 6000	2.3	> 1,500	0.091	Fair	<= 2.00 and > 1.50
6000 – 8000	2.1	< 1,500	0.101	Poor	> 2.00
> 8,000	1.9				

infrastructure element. An example, applied to a pavement network, is described in a subsequent section.

SAFETY GOALS

Safety goals have been previously identified as among the top three priorities in the list of policy objectives (Table 1). Perhaps no area of the highway field has received more attention than safety, and a vast amount of literature exists on the subject. In fact, the "ISTEA" legislation passed by the U.S Congress in 1991 mandated the development and implementation by the States of six distinct management systems, two of which were PMS (Pavement Management System) and SMS (Safety Management System).

Safety continues, however, to be treated largely as an area separate from the other management systems, partially because it is impacted by many external factors like weather, visibility, vehicle characteristics, driver behaviour and capabilities, highway geometrics, speed, etc. and often interactions of these factors. That is why Table 1 suggests an implementation target of 1% or greater annual reduction of fatalities and injuries, rather than targets for individual factors.

Regarding pavements, the TAC Guide (8) identifies the following components related to safety, which can be directly incorporated into pavement management:

- Surface friction
- Surface condition(ruts, potholes, cracks, faults, spalls, etc)
- Light reflectivity of the pavement surface
- Lane markings
- Debris or foreign objects(particularly for airport pavements)

Figure 6 illustrates schematically how these factors could interact, with the worst care scenario being an intersection of all factors (e.g., the shaded portion). In other words, this would represent a situation of low surface friction, poor surface condition, poor light reflectivity and inadequate lane markings, and the existence of debris on the road surface. Obviously, this would also be a worst case scenario for the safety goals policy objective and the implementation target of measurable accident reduction.

PRESERVATION OF INVESTMENT

The third top priority policy objective in Table 1 is preservation of investment, which can be measured by asset value. Pavements are tangible or capital assets and these were among the set of highway elements in a comprehensive TAC study on measuring and reporting highway asset value (2). This study illustrated that asset valuation is a complex subject and that the method(s) used can result in widely varying results; for example book value/historical cost commonly used in accounting vs. written down replacement cost which, as a current vs. past based method, can also be quite applicable to most highway elements.

A further, in-depth study on asset valuation method, with example application to a pavement network, was carried out by Cowe Falls (9). She evaluated nine different methods, including four variations of GASB34, using a network of 113 pavement sections for which cost data, performance model estimates, etc. were available. A base year of 1993 was used as the "current year", and predictions were made for 1999, as a "future year", for which actual data was available for verification. The purpose was not only to compare current asset values but to predict future asset value as an asset management function (see Figure 4).

A summary comparison of the "future year, predicted and actual/measured value of the network is provided in Table 3. The numbers illustrate a very high book value/historical cost (BV/HC) compares to the others, which was due to distorted construction costs from a boom period during when these sections were constructed (in the 1980's). An opposite situation can also occur, which suggests that book value/historical cost should be viewed with considerable caution in valuing pavement assets.

Written down replacement cost, WDRC, for current value (base year) is comparatively much lower because the construction costs had decreased by about one third or more from the 1980's BV/HC bases.

The values in Table 3, and the much more comprehensive analysis of Ref (10) which included statistical significance tests suggest the following:

- Agencies who are carrying out asset valuation need to clearly recognise that considerable variation can exist between methods, particularly past based vs. current, BUT it is dangerous to generalise from one situation (e.g. the example of Table 3) to another era or jurisdiction or infrastructure element.
- If asset value is used as a performance indicator for pavement preservation (Table 1) it is important that agencies are able to report how well they are retaining or improving asset value as a result of proper management and funding. It is also important to select a valuation method that is easily sustained and managed, understandable and not data and/or analytically burdensome.

CONCLUSIONS

Preservation of pavement assets should involve a "culture" of institutionally based realistic policy objectives that explicitly incorporate quality of service to users, safety goals, asset value, productivity and efficiency, cost recovery, research and training, communication with stakeholders and resource conservation and environmental protection. Realisation of these objectives depends on measurable performance indicators and in turn achievable implementation targets. Examples from an existing pavement network demonstrate that the implementation targets suggested in the paper are both realistic and achievable.

Table 3 Total Asset Value in Pavement Network: "Future Year" Prediction vs. Actual Extracted From Ref. (10)

Method	Base Year Current Value ($ million)	"Future Year" Predicted Value ($ million)	Actual (Measures) Future Year Value	Difference (Predicted Value Measured)
BV/HC	155	155	155	0
WDRC	46	-	-	-
RC	81	113	105	8 (8%)
WDRC(SL)	-	72	67	5 (8%)
NSV_a	-	104	96	8 (9%)
WDRC(Eng)	-	64	53	11 (21%)
NSV_b	-	91	71	20 (28%)

Notes: BV/HC = Book Value/Historical Cost; WDRC = current written down replacement cost; WDRC(SL)= WDRC based on a financial straight line model; NSV_a = net salvage value using a simple decision tree for rehabilitation; NSV_b = NSV using a multi-point decision tree; WDRC(Eng.) is WDRC based on an engineering deterioration model; RC = replacement cost

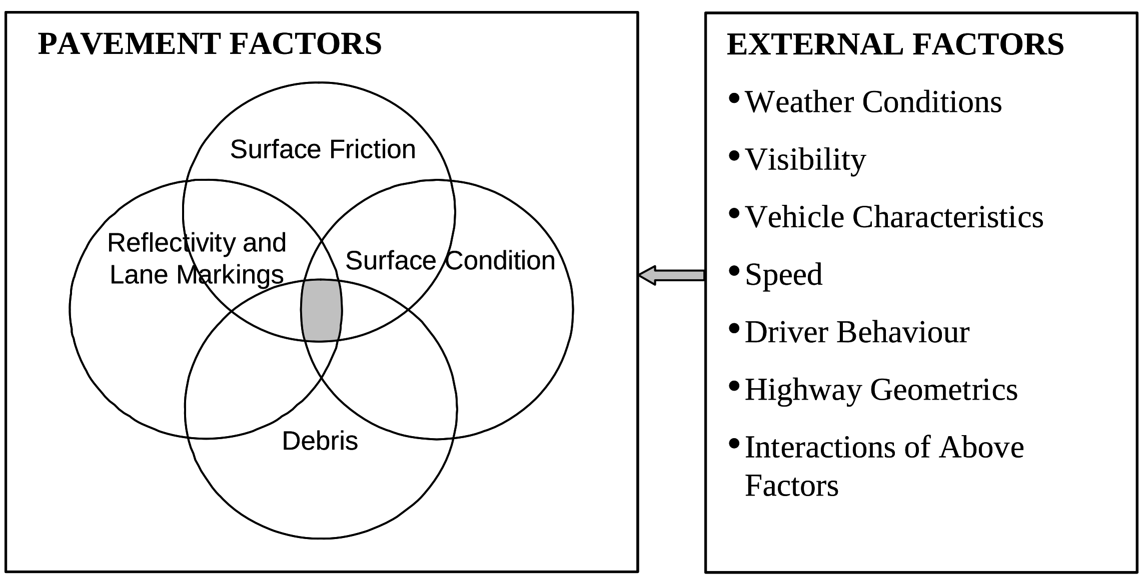

Figure 6 Pavement Factors and External Factors Relevant to Incorporating to Pavement Management

ACKNOWLEDGEMENT

This paper has made use of the “Challenge” in the forthcoming 7th International Conference on Managing Pavement Assets, Calgary, June 2008. Availability of the extensive database and other information in the Challenge terms of reference is gratefully acknowledged. Sincere appreciation is also extended to Ms. Shelley Bacik, Research Administrative Officer in the University of Waterloo’s Center for Pavement and Transportation Technology, CPATT, and Ms Alya Ali Taib, Actuarial Science Major, for their work on producing this paper.

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