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MEASURING SUSTAINABLE DEVELOPMENT

APPLICATION OF THE GENUINE PROGRESS INDEX TO NOVA SCOTIA

FULL COST ACCOUNTING OF HIGHWAYS:

INFRASTRUCTURE DEFICIT ACCOUNTING *In* HIGHWAY INVESTMENT ANALYSIS

Prepared for
Nova Scotia Department of Transportation and Public Works

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1. Definitions

Highway and road infrastructure deficit refers to deferred roadway investments that will increase future costs.

Under current accounting systems the amount actually spent in a year on roadway maintenance and reconstruction bears little relationship to the value of capital consumed in that year. If the system is wearing down faster than it is being rebuilt, current users are living off the investments of previous users and taxpayers who built up the capital stock.[1]

In other words, the amount of funding that government devotes to investment in transportation capital does not necessarily equal the amount of damage imposed by using that capital, or by wear from natural conditions such as weathering and aging.

Where roads are deteriorating, government is failing to invest at a level sufficient to compensate for present damage, and the facility will not continue to provide the existing level of service over the long run. Conversely, where infrastructure deficit is negative and capital facilities are being improved, government is investing at a faster rate than damage is being imposed.[2]

Where government is not investing enough to prevent deterioration of facilities, it will, at some future date, be forced to make a larger expenditure to bring capital stock back to appropriate service levels. Since the damage imposed on transportation facilities must eventually be repaired, the gap between current spending and needed investment can be considered "deferred investment" or "infrastructure deficit".

As Apogee Research points out in a study of deferred maintenance expenditures in Boston, Mass., and Portland, Maine:

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[1] Douglass Lee, *Full Cost Pricing of Highways,* Transportation Research Board, U.S. Department of Transportation, January 1995

[2] Definition from Apogee Research Inc., *The Costs of Transportation: Final Report,* prepared for the Conservation Law Foundation, Boston, March 1994

> *An important relationship exists between capital costs and deferred maintenance costs. An increase in capital expenditures reduces the amount of maintenance deferred. If the government is investing more than current damage in order to make up for past shortfalls or to build a cushion for future shortfalls, the cost of deferred investment may even be negative. If the government invests very little in its capital facilities, allowing them to deteriorate, deferred maintenance costs will be large.*[3]

2. Infrastructure Deficit Assessments in Highway Expenditure Accounting

The implications of including infrastructure deficit assessments in highway expenditure accounting are profound. In effect, it means nothing less than moving from the current-expenditure system now in effect to an investment-oriented accounting framework that sees highways as capital investments which are expected to produce a return over their expected life-span.

The present system, which "expenses" capital costs as if they were consumed in the same year as the expenditure, cannot accommodate assessments of past and future costs which are essential if infrastructure deficits are to be included in the accounting system. Currently, previous investments are effectively regarded as sunk costs.

There are significant benefits in shifting to an investment-based accounting system for highways. As Lee points out: "Ignoring sunk costs is a short-run perspective that is incompatible with the long-term existence of the highway system."[4] At the same time, policy-makers will want to understand the implications of moving to a system that assesses the actual rate of return on highway investments.

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[3] op. cit., page 155.
[4] Lee, op. cit., page 13.

In short, it is impossible simply to "include" infrastructure deficit assessments in the current accounting system. Instead, their consideration requires a fundamental shift in view of roadway investment accounting.

The only way that infrastructure deficits could be assessed *without* changing the accounting system altogether is simply to aggregate them over time as a cumulative backlog, as Halifax Regional Municipality currently does. But this does not allow a systematic annualized assessment of the rate of return on the investment in highway stock, nor a rational, graduated response to a potential deterioration of the capital asset.

Six fundamental implications of moving to an investment-based accounting system for highways are identified in the literature:

1) **Inclusion of Opportunity Costs of Capital in Assessing Roadway Costs**.

Accounting procedures of private corporations become a more appropriate model than current government practice. In particular this means including the opportunity cost of capital in assessing roadway values and rates of return. Transport Canada's *Special Infrastructure Project*, uses a 10% discount rate in its highway benefit-cost analysis, as recommended by the Treasury Board. This approximates the real rate of return on capital in the private sector.[5]

There is clearly an opportunity cost to funds committed to capital investments. Money deposited in a highway trust fund would earn interest at market rates. When the money is spent, that interest is foregone.

According to Douglass Lee:

> *If the original investment was worthwhile, it should be earning – over its lifetime – a rate of return at least equal to the market rate for low-risk investments. If the asset continues to be used as a highway, then implicitly it is worth what it cost, including interest on the outstanding balance. To fail to charge users enough to cover the interest, then, is a subsidy to users, in the form of a zero-interest loan.*

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[5] Blanchard, Ghislain, *Highway Benefit-Cost Analysis: A Review of Evidence,* TP 12790E, Transport Canada Policy and Coordination Economic Analysis, page 15, footnote 12. Treasury Board guidelines are from *Benefit-Cost Guide,* 1976.

> *An upper bound on the opportunity cost, using this method, would be the (depreciated) replacement cost of the facility, times the current interest rate. A neutral approach, then would be to measure the replacement costs of the existing system, annualize that cost, and recover that amount each year.*[6]

In sum, a capital asset that continues to function as a highway has an opportunity cost that can best be approximated as its annualized replacement cost, without regard for when the expenditures were made. Since a less than normal rate of return would imply that the long-run costs are not justified, a 10% interest rate is therefore included in highway costs assessed through an investment-based accounting system.

2) Adjusting Prior Under-Pricing of Highway Costs

From the perspective of an investment-based accounting system for highways, it can be seen that road facility costs have previously been significantly underestimated and under-priced. Including both deferred investments (infrastructure deficits) and the opportunity cost of road and highway investment funds adds substantial value to road facilities.

A Congressional Budget Office review of U.S. highway maintenance strategies identified the under-pricing of infrastructure as a key problem:

> *Below-cost pricing leads users to request more infrastructure services than they are willing to pay for, while planners get an exaggerated perception of investment needs from these misleading signals about infrastructure demand.*[7]

3) Using Benefit-Cost Analysis to Identify Priority Projects

Transport Canada's *Special Infrastructure Project* concluded that:

> *Benefit-Cost analysis should be an important part of the highway investment decision-making process….Minimal engineering geometric design and operational standards will not consistently identify investment projects that are cost-beneficial. Consistent application of*

[6] Lee, op. cit., pages 13-14.
[7] Congressional Budget Office, *New Directions for the Nation's Public Works,* cited in Transport Canada TP 12790E, page 22.

> *benefit-cost analysis is the only reliable way to determine whether particular projects are cost-beneficial….Selecting projects based on economic criteria could substantially improve the highway investment net returns.*[8]

In other words, an additional criterion is added to highway investment decisions by the change in accounting mechanisms. In addition to normal design, traffic flow and engineering considerations, projects are selected according to the rate of return they are likely to yield on the projected investment.

The fundamental technique is identical to investment analysis in the market economy in which private firms decide the nature, timing and scope of investments according to expected returns over time. Highway benefit-cost analysis models have generally included benefits to users such as time, vehicle operating cost and accident savings, and costs to government of future pavement management and maintenance resulting from the projected investment. Long-term benefits and costs are quantified in monetary terms.

4) Estimating Generated Traffic

Just as investment-based accounting assesses accumulated infrastructure deficits and the rate of return on *past* expenditures, it likewise assesses potential *futur*e costs from current investments. Thus, new roadway capacity and highway improvements are likely to generate or induce additional traffic in the future, partly through changed land use patterns.

Thus, for example, the twinning of Highway 103 may encourage the further development of the Hammonds Plains / Tantallon area, which in turn will likely produce additional highway traffic. Such additional traffic can produce future costs by increasing maintenance needs and by placing more demands on feeder roads, such as the St. Margaret's Bay Road, thus generating demands for further improvements and capacity expansion.

[8] Transport Canada, op. cit., pages 13 and 23.

Models have been developed to include such future costs in benefit-cost analyses of projected highway investments.[9] These can be investigated at a later stage in the work.

5) Roads as Public Utility Investments

Investment-based accounting would regard roadway capital expenditures similarly to capital investments in other utilities, including investment in new capacity for electricity or gas generation, sewage and waste treatment, or telecommunications.

For example, a new landfill has a given life span and produces a rate of return dependent on usage practices. Activities that encourage a lengthening of that life span, such as recycling and composting, are necessarily encouraged, according to this model, as a further investment in capacity. Conversely, charges may be levied on activities likely to reduce the life expectancy of the landfill.

Viewing roadways in this way is not possible while capital costs are "expensed" as if they were consumed in the same year. Instead, viewing roadway expenditures as long-term investments will necessarily produce strategies of travel demand management and transportation pricing designed to extend the life expectancy of the investment and reduce activities that will shorten it.

6) User-Pay Strategies

As is clear from the above, investment-based accounting allows for more precise and discriminatory policy-making that distinguishes user activities according to their contribution to overall costs. As in other public utilities, this approach to roadway expenditures encourages variable, internal pricing mechanisms to ensure that the investment pays for itself and produces a reasonable rate of return. Thus gas, electricity and telecommunications are largely priced according to usage, and rising landfill fees are designed to

[9] See for example Lee, Douglass, Lisa Klein, and Gregorio Camus, *Induced Traffic and Induced Demand in Benefit-Cost Analysis,* U.S. Department of Transportation, June 1998; Mackie, Peter, "Induced Traffic and Economic Appraisal", *Transportation,* volume 23, 1996; Williams, H.C., and W.M. Lam, "Transport Policy Appraisal with Equilibrium Models I: Generated Traffic and Highway Investment Benefits," *Transportation Research B,* volume 25, no. 5, 1991, pages 253-279.

encourage waste reduction, separation of organics and other conservation strategies.

Such an accounting mechanism would lead to assessments of the portion of road expenditures covered by licenses, registrations and fuel taxes and to the designation of such user fees to road construction and maintenance. Fees would be adjusted to reflect the full costs of transportation with the aim of making roads pay for themselves over time.

The shift in view would perhaps affect municipal accounting practices most profoundly, since the lack of synchrony is greatest there. Roadway expenditures are generally the largest capital expenditure item in municipal budgets, but property taxes are the principal source of revenue. For example, Halifax Regional Municipality spends $11 million a year maintaining roads and streets, more than any other single expenditure, but relies on property taxes for 73% of its operations.[10]

In other words, once projects are evaluated in terms of benefit-cost analysis, action will necessarily be taken to reduce costs and increase benefits. The use of economic criteria to evaluate investments, in addition to traditional engineering considerations, will generate efficiency strategies that rely on a transition from fixed, external costs to internal costs that vary according to usage and damage imposed.

Is the Shift Worthwhile?

These considerations may be daunting to decision-makers. Indeed, raising the issue of infrastructure deficit assessments and including deferred maintenance in roadway accounting practices does challenge the existing system in a profound way. However, it can only be an important and positive step towards a more accurate assessment of true costs.

In fact, given government fiscal and budgetary restraints, the costs of not making the shift are too great. Not only does the treatment of previous investments as sunk costs and the expensing of capital costs as current consumption violate standard accounting procedures. But, more practically, long-term costs will mount if government budget cuts lead to an ongoing

[10] Halifax Regional Municipality, *Budget 1996-1997,* Revenue and Capital Expenditures, at http://www.region.halifax.ns.ca/Budget/budcap.html and Budget/budrev.html

deterioration of the highway system. Accumulating infrastructure deficits can lead to increased delays, accidents and vehicle operating costs.

Conversely, evaluating long-term investment decisions and priorities through benefit-cost analysis can lead towards a more sustainable transportation system with a more stable roadway infrastructure.

Perhaps the final argument for moving forward in this direction is that Transport Canada has already begun to do so, and Nova Scotia could take a lead among the provinces in introducing the new accounting systems. Transport Canada's *Special Infrastructure Project* has computed a life-cycle cost of Canada's road infrastructure to reflect the economic cost of road provision, including the opportunity costs associated with capital tied up in road infrastructure.[11]

Transport Canada's model includes both depreciation and interest on capital based on estimates of the Canadian highway capital stocks and the rate of return on a similar risk investment assuming an 8% real interest rate. Capital depreciation is based on Statistics Canada estimates. Capital depreciation and interest costs as well as operating and maintenance costs are added for a total life-cycle cost estimate of $15.9 billion in 1993, compared to annual expenditures of $10.8 billion in the same year.

3. Methods of Assessing Infrastructure Deficit, and Sample Estimates

Perhaps the two most well-developed models for assessing deferred roadway investments are those used by the United States Department of Transportation's Federal Highway Administration.[12] The two models in effect provide upper and lower bounds on estimates of required annual roadway investments. They have been continually refined and improved over the years and are widely used in transportation studies in that country.

[11] Blanchard, Ghislain, *Road Infrastructure Expenditures, Fuel Taxes and Road Related Revenues in Canada,* TP 12795E, Transport Canada Policy and Coordination Economic Analysis, June 1996.
[12] U.S. Department of Transportation, Report to Congress, *1997 Status of the Nation's Surface Transportation System: Condition and Performance,* Federal Highway Administration, Washington D.C., 1997.

Lower bound estimates of required expenditures are derived from a "Maintain User Costs Scenario" (MUC), the goal of which is simply to keep the cost to the users of the highway system from increasing over time. In the U.S. Department of Transportation's 1997 Report to Congress, 1995 is taken as the base year for this scenario, which would make only those highway improvements necessary to maintain user costs at the 1995 level. These costs include delay, accident and vehicle operating costs.

This scenario does not depend on benefit-cost analysis, since an arbitrary level of costs is designated as appropriate from the start. Since actual U.S. highway capital expenditures fell short of the MUC requirements by $5 billion or 13%, this infrastructure deficit could produce a higher starting level of costs in the following year's MUC scenario if it were based on the same premise of maintaining costs from year to year. Accumulating infrastructure deficits could lead to a gradual erosion of standards along with system deterioration.

Upper bound estimates of infrastructure deficit or deferred investment are derived from the "Maximum Economic Investment Scenario" (MEI), which represents the highest level of investment that is economically justifiable, and would correct all highway deficiencies to the maximum level considered cost-effective.

This economic assessment does depend on benefit-cost analysis, using the U.S. Department of Transportation's Highway Economic Requirements System (HERS). This system defines benefits as reductions in direct highway user costs, agency (government) costs, and societal costs. Highway user benefits include reductions in travel time, accidents and vehicle operating costs. Agency benefits include reduced maintenance costs and the residual value of the projects. Societal benefits, not included in the 1997 report to Congress, would include reduced vehicle emissions.

Only those projects are included in the MEI scenario that have a benefit-cost ratio greater than 1.0. The HERS model implements improvements with the highest benefit-cost ratio first, so that total returns on investment continue to increase while marginal and average rates of return gradually decline. Actual U.S. highway spending was $35.6 billion or 93% below the MEI level, representing an upper bound estimate for U.S. infrastructure deficit.

Transport Canada uses a computerized mainframe benefit-cost model of highway investments on free flow facilities, HUBAM, that was completed in the mid-1980s.[13] The model also includes time, safety and vehicle operating costs, but excludes environmental costs. Transport Canada recognizes that "the benefit-cost framework needs to be expanded to account for the highway effects that are currently not quantified," particularly environment and logistics which are recognized as "the most significant omissions."

One significant improvement to the United States HERS model in recent years is the inclusion of travel demand elasticity estimates, which recognize that when roadway capacity is increased and traveling costs decrease, traffic volumes are likely to grow. In other words, generated traffic, as described in 2 (4) above, is included in the model. The effect of elasticity on the MEI scenario is therefore to increase the volume of traffic and to project a corresponding decrease in transit demand as highway investments are improved to MEI levels.

This scenario draws attention to another current limitation of benefit-cost analyses in that highway improvements are always compared to a simple status quo base case rather than to alternative options. Thus, a decision to expand capacity on Highway 103, for example, is unlikely to be compared to the benefits and costs of expanding transit options.

Sample Application of MUC Method to Determine Infrastructure Deficit

Apogee Research Inc.'s *The Costs of Transportation: Final Report* used the Department of Transportation MUC model in a full-cost analysis of transportation in Boston, Mass., and Portland, Maine.[14] In this case, required roadway investments were defined as those which would prevent the backlog of unfilled construction and repair needs from expanding. This minimal investment scenario would maintain existing system performance and accommodate expected traffic growth,

An assumption of the study in assessing infrastructure deficits was that costs in no case included investments designed to improve conditions and performance above those currently found. Where conditions were

[13] Transport Canada, op. cit. TP 12790E, pages 5, 7 and 13.
[14] Apogee Research, Inc., op. cit., pages 155-157

substandard at the time, they would remain so in projecting investment requirements.

The method adopted was simply to subtract current investment expenditures from needed investment projections. To compare alternative modes of transportation, the result was then divided by the annual miles traveled, to determine deferred investments per mile. Since national Department of Transportation figures were extrapolated to Boston and Portland, the same result was reached: Infrastructure deficit was assessed as 1.2 cents per vehicle mile for expressways and 1.5 cents per vehicle mile for other roads.

If the level of deferred maintenance in Nova Scotia were equivalent to that in the United States, the total infrastructure deficit for the province would be $162 million per year in 1997 Canadian dollars, based on 625,000 vehicles travelling an average of 18,925 km a year at a deferred investment cost of 1.3 cents per kilometer.[15] It should be borne in mind that this reflects only a scenario in which current user costs do not increase.

Halifax Regional Municipality currently uses an estimation which more closely approximates the U.S. Department of Transportation's MEI scenario. The Pavement Management System (PMS), currently under review, determines what it would cost to repair all streets to their best condition. Field assessment data is entered into a computer, which assigns a condition score to each street assessing what condition the street is in and what the computer program suggests as the treatment required. The goal of the PMS is to determine the most cost-effective capital street investments to increase or maintain the value of the existing network.[16]

The HRM's "Annual Backlog" assessing the costs of repairing all streets to their best condition, was over $65 million in 1996 for the core area of HRM , compared to actual expenditures of $11 million, producing an infrastructure deficit of $54 million. It should be noted that this figure is not comparable to the provincial estimate given above because the two scenarios represent upper and lower bound investment requirements that are vastly different.

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[15] Annual kilometers driven per year in Nova Scotia are from Statistics Canada, *Fuel Consumption Survey,* catalogue 53-226 for 1985, augmented by 3.8% to reflect increase in average kilometers driven per year for 1995, from Transport Canada, *Transportation in Canada, Annual Report, 1996,* catalogue no. T1-10/1996E. Motor vehicles from Nova Scotia Registry of Motor Vehicles annual report. 1997 dollar estimate derived using Statistics Canada's CANSIM database for the Nova Scotia Consumer Price Index.

[16] Halifax Regional Municipality website: http://www.region.halifax.ns.ca/Regops?engserv/Conserv/backlog.htm

These examples illustrate the challenges of measuring and assessing infrastructure deficits. Projected investment requirements should clearly be presented as a range of options as represented by the MUC and MEI scenarios. More accurate estimations are also derived by including environmental considerations and travel demand elasticities in benefit-cost analyses, and by comparing benefits and costs across alternative options and transportation modes in addition to the status quo base case scenario.

4. Policy Implications I (General): Benefit-Cost Analysis in Highway Investment Decision-Making

When economic benefit-cost analysis is applied retrospectively to prior highway investments, an alarming number of projects are found to be not cost-beneficial. Of 27 Nova Scotia highway projects reviewed by Transport Canada as part of its *Special Infrastructure Project,* 18 were determined to have costs that exceeded benefits when government expenditures were balanced against user savings in time, accident and vehicle operating costs and against future government maintenance costs.

For all the Atlantic provinces, Transport Canada concluded:

> *Good highway projects will typically have large time and VOC (vehicle operating cost) savings, sufficient traffic to justify their costs, and service levels and project costs that are incremental-cost justifiable…. Unfortunately, the number of cost-beneficial projects has been disappointingly low…*
>
> *There is no economic argument that allows the positive net present value of cost-beneficial projects to be used to "offset" and justify the negative net present value of non cost-beneficial projects. The lost opportunities, either in the private or public sector, from the resources diverted to non-cost-beneficial projects are forever a reduction to social welfare and wealth…*

> *A significant amount of resources have been dedicated, under federal-provincial agreements, to projects that are not cost-beneficial. Furthermore, most of the projects identified as required on the NHS (National Highway System) to raise the infrastructure to national minimum engineering standards were not cost-beneficial.*[17]

Using the 10% discount rate recommended by the Treasury Board, as described earlier, only about $2 billion, or 17%, of the proposed $12 billion worth of improvements on the National Highway System were determined to be cost-beneficial.

In other words, responsible investment of public funds, that have an opportunity cost in foregone alternative investments, requires that benefit-cost analysis be used to identify priority highway projects. As recommended by Transport Canada, current models must be expanded to include consideration of environmental and logistical benefits and costs, and to allow comparisons with alternative transportation options and with incremental improvements beyond the status quo base case.

Once again, it is possible for Nova Scotia to take a lead in a development that is already under way, and which certainly prefigures the more accurate accounting systems of the future. It can help to ensure wise investments that can contribute to sustainable transportation in the province and to a significantly higher rate of return on existing investments, from which future generations can benefit.

The cost savings can be significant from an investment perspective. The Transport Canada study found that, among the projects reviewed, cost-beneficial highway projects had a positive net return of $400 million, while those that were not cost-beneficial had a negative net return of $400 million. It was also found that between 70-80% of benefits from highway projects were accounted for by savings in time and vehicle operating costs.

Above all, benefit-cost analyses can help identify the specific features of particular proposed projects that would yield the greatest returns. For instance, as Transport Canada points out, many marginal projects have included particular design features that were not cost-beneficial. If projects

[17] Transport Canada, op. cit., TP 12790E.

were stripped of these uneconomical features, many would have met the benefit-cost threshold:

> *If highway projects wer designed so as to maximize user benefits (net of costs), as opposed to achieving minimal engineering design standards, more cost-beneficial projects might have been identified.*[18]

The United States Congressional Budget Office (CBO) review of U.S. federal highway investments may point the way to the direction of the future. The study found a significant difference in the rate of return between maintenance and new construction. The rate of return on maintaining the current condition of federal-aid highways was 30-40%, while the rate of return on new construction was very much lower and in some cases negative.

The CBO concluded that the evidence demanded a shift from new construction towards rehabilitation and maintenance aimed at "keeping roads in good order and the costs of road transport low."[19]

Perhaps most importantly from a practical perspective, benefit-cost analysis can actually identify the types of projects most likely to yield higher rates of return. The Transport Canada study classified the projects reviewed in the following categories: by-pass, 4-lane, intersection, new road, paving gravel, perimeter highway, reconstruction, resurfacing, and upgrading. Thus upgrading projects tended to yield a far higher rate of return than paving gravel projects, in which costs significantly outweighed benefits. Needless to say, circumstances will vary by province and project, but the method allows a more precise and accurate assessment of particular project features that are cost-beneficial.

In sum, including economic as well as engineering considerations in roadway investment decisions is a clear policy outcome in moving from a current expenditure-based to an investment-based accounting system. The real issue, beyond simply identifying the magnitude of accumulated infrastructure deficit, is prioritizing remedial actions designed to protect and enhance existing investments and to ensure that planned investments yield a commensurate flow of benefits.

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[18] ibid., page 17.

[19] Congressional Budget Office, *New Directions for the Nation's Public Works,* cited in Transport Canada TP 12790E, page 21.

Quantitative assessment of the magnitude of infrastructure deficits, while a necessary step, does not in itself point the way to cost-effective remedial action. A dollar spent on one project may yield four dollars worth of long-term benefits, while the same dollar spent on a different project may yield only $1.50 worth of benefits, or produce a net loss of benefits over time, as the Transport Canada found. *Qualitative* comparative assessments of alternative projects are essential to determine how to narrow the infrastructure deficit gap in the most economical and effective way.

In an era of continuing fiscal restraint and government spending limitations, economic benefit-cost analysis is therefore a timely and useful method to remedy infrastructure deficits in a cost-effective way.

5. Policy Implications II (Specific): User-Pricing to Reflect Infrastructure Investment Costs

There is clearly only one primary purpose to infrastructure deficit assessment, and that is to maintain the roadway system in good condition. This can be accomplished in two ways: by investing in maintenance and repair, or by slowing deterioration of the capital stock. While the latter can be far less costly than the former, our current accounting mechanisms focus primarily on roadway expenditures rather than prevention.

Focusing on infrastructure deficits necessarily raises preventive measures as a viable cost-effective option. If the life-span of our roadway assets can be extended, the deficits can be significantly reduced. Deferred investment analysis therefore leads to a consideration of pricing mechanisms designed to protect prior investments and to increase their rate of return.

This can only be done by considering the primary causes of depreciation and deterioration of highway capital stocks. In other words, what are the main causes of road wear and damage that will necessitate future maintenance and repair expenditures?

Usage, weathering and aging all contribute to road deterioration, and are therefore potential indicators of emerging infrastructure deficits. Investment requirements will differ according to all three factors. Transport Canada's estimates of highway capital stocks have determined that highway infrastructures have aged significantly from 9 years in 1961 to 14 years in 1993. Nova Scotia has the oldest infrastructure in the country.[20]

Colder climates increase road maintenance costs. In Norway 42% of annual roadway expenditures are related to climatic impact, with 15% attributable to costs of resurfacing resulting from studded tires and another 17% due to costs of clearing roads from snow and ice. By contrast, only 15% of maintenance expenditures in southern European countries are attributable to climatic impact.[21]

A comparative World Bank study has determined that road deterioration from weathering varies from about 1% per year in mild, warm climates like Tunisia to 7% a year in freezing climates like Colorado.[22] Nova Scotia roads are subject to two differing climatic systems, but are clearly in the upper range of estimates here due to freezing and thawing cycles that increase maintenance costs.[23]

Despite the fact that marginal maintenance costs of road wear are higher when aging and weathering are present, the most serious damage occurs when these factors interact with heavy loads. Aging and weathering leave a pavement more vulnerable to damage by heavy loads, thereby raising the extra maintenance cost caused by those loads.

Wet subsoils are less resistant to the force transmitted through a pavement from a heavy axle. Cracks in the road surface are widened by frost, allowing water to damage lower parts of the highway structure, thereby lessening its ability to withstand future loads. Asphalt also loses its flexibility over many years, becoming brittle and more likely to crack under loads.[24] It is therefore

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[20] Transport Canada, *Special Infrastructure Project,* The Canadian Road and Highway System Capital Stock.
[21] Kageson, Per, *Getting the Prices Right: A European Scheme for Making Transport Pay its True Costs,* European Federation for Transport and Environment, May 1993, page 150
[22] Paterson, William, *Road Deterioration and Maintenance Effects: Models for Planning and Management,* Highway Design and Maintenance Standards Series, Johns Hopkins University Press for the World Bank, 1987, pages 306-316, cited in Small, Kenneth, Clifford Winston and Carol Evans, *Road Work: A New Highway Pricing and Investment Policy,* The Brookings Institute, Washington, D.C., 1989, page 20.
[23] N.S. Department of Transportation and Public Works, personal communication, August 5, 1998.
[24] Small, op. cit., pages 19-20.

the interaction of weathering with heavy axles that causes the most severe problems.

The most significant single factor in producing road wear and damage is heavy loads, with a heavy truck imposing maintenance costs hundreds of times greater than a car.[25] Tests in 1958 and 1960 by the American Association of State Highway Officials determined that road wear increases by approximately the fourth power of vehicle axle weight, but more recent studies consider that the "third-power" equivalence is more accurate.

The following analysis is from *Road Work*, by Small, Winston and Evans.[26] The dominant element in maintenance cost is the periodic overlay that is required when a pavement becomes worn. The pavement is designed to withstand a certain number of passages of axles of a standard weight and configuration before requiring such an overlay.

The standard is a single axle of 18,000 pounds; the damaging power of an axle with some other load or configuration is then defined in terms of the number of "equivalent standard axle loads" (esals) causing the same damage. One component of marginal cost, therefore, is the shortening of the period between overlays, which is determined by two factors:

1) The equivalence factor for an axle rises *very* steeply with its load, roughly as its third power, according to Small. Thus, for example, the rear axle of a typical 13-ton can causes over 1,000 times as much structural damage as that of a car. If illegally loaded to 19 tons, it would cause at least three times more damage. For all practical purposes, structural damage to roads is therefore caused by trucks and buses, not by cars.

2) It is the weight per axle that matters, not total vehicle weight. A 50,000-pound two-axle dump truck causes more road wear than a huge twin-trailer rig spreading 100,000 pounds over seven axles. For this reason, a major goal of road-pricing policy designed to decrease the rate of road wear would be to reduce the heaviest *axle weights.* Current charges do

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[25] Litman, Todd, *Transportation Cost Analysis: Techniques, Estimates and Implications,* Victoria Transport Policy Institute, Victoria, B.C., September, 1997, page 3.6-3.

[26] Small, op. cit., pages 11 and 12. See also Appendix, pages 22-36, for detailed calculations on how the equivalence is derived.

not do this, with Nova Scotia registration fees for heavy commercial vehicles rising by total weight rather than axle weight.[27]

Examples of Road Pricing Designed to Reduce Road Wear Costs

In order to foster better use of existing highways' load-carrying capabilities, some European countries have introduced heavy-vehicle user charges that rise steeply with axle weights. This can foster a shift to truck types that distribute the weight more evenly among more axles, thus prolonging the life span of the highway stock.

If the basic principle of user charges is accepted, it may also promote a partial shift to rail for some types of goods. Small and his colleagues conclude that combining such charges with increases in road durability would not excessively harm the trucking industry. The Swedish example below illustrates that conversions will be the option of choice.

At a time of accumulating infrastructure deficits, such user charges may become a more appropriate policy tool. A Norwegian study for the European Federation for Transport and Environment assembled calculations from several countries and concluded that heavy traffic accounts for about 60 percent of wear on roads and between 30 and 40 percent of total maintenance costs.[28]

a) Sweden

In 1989, Sweden's kilometer tax was changed from a weight-distance tax to a weight-axle-distance tax.[29] This gave an incentive to truckers to increase the number of axles on lorries and trailers. When the kilometer tax was differentiated according to axle weight, the tax for a 30-tonne three-axle trailer increased significantly to SEK 57,260 for a distance of 100,000 km, compared to only SEK 36,320 for a 30-tonne four-axle truck.

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[27] Nova Scotia Department of Transportation and Public Works, Registry of Motor Vehicles, *Vehicle Sizes and Weights Manual.*
[28] S. Oftedal, *Taxation and Infrastructural Costs of Heavy Goods Transport,* European Federation for Transport and Environment, 1993, cited in Kageson, op. cit., pages 139 and 141.
[29] Idem.

A trailer reconstruction industry grew in the country as owners recognized the significant annual savings that could accrue from the conversion. From the government's point of view, the socio-economic saving was equivalent to that of the truck owner, since the difference in taxation reflected the actual difference in wear and tear as calculated by the Swedish National Road Administration (SNRA).

If Nova Scotia were to move towards truck registration fees differentiated by axle weight, the SNRA study could be used to determine a provincial fee scale commensurate with actual road damage and repair costs, to ensure that cost recovery is as complete as possible. The degree to which costs are currently not recovered represents a hidden public subsidy to the trucking industry and a disadvantage to rail freight. If environmental costs are included, that subsidy is probably significantly larger.

The Swedish example is instructive in demonstrating that the trucking industry in that country effectively adjusted and adapted to the new tax scheme and user charges. In fact, initial financial incentives to truckers for multi-axle conversion of existing vehicles, is analogous to the investment made by Halifax Regional Municipality in composting bins. In both cases, initial costs and subsidies are likely to yield substantial long-term benefits in extending the life of the capital infrastructure.
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b) Great Britain

The British Department of Transport currently identifies cost components of road facility maintenance incurred by particular classes of vehicles, and charges these cost items to the relevant vehicle classes. Responsibility is calculated according to five parameters which reflect one of the most complete user-charge systems in practice:

1) Annual vehicle kilometers traveled are used to allocate costs, like policing, which are not related to vehicle size and weight.

2) Average gross vehicle weight kilometers (vehicle kilometers multiplied by average vehicle weight) are used for bridge maintenance and other costs dependent on gross vehicle weight.

3) Standard axle kilometers are used to allocate costs of repairing road surfaces, as described above.

4) Maximum gross vehicle weight kilometers (maximum permitted weight multiplied by annual kilometers traveled) are used to allocate part of capital expenditures on roads, since roads must be designed and built to higher standards for heavier vehicles.

5) Passenger car unit (PCU) kilometers measure the amount of road space used by different vehicles and is also used in allocating a portion of capital expenditures. A heavy truck, for example, has a PCU of 2.5.

Britain puts 15% of the cost of new road investments directly on heavy vehicles, while the remaining 85% is allocated by PCU km, so that lorries and buses bear about 27% of total capital costs.[30]

When roads are seen as long-term investments, in the same way as other public utilities like landfills, for example, consideration of such user fees is a likely policy outcome. Including infrastructure deficits in an investment-based accounting system therefore has major policy implications in efforts to improve the rate of return on road investments and reduce government costs.

[30] Kageson, op. cit., pages 140-141.