LIFE-CYCLE COSTING

Asphalt Pavements In Ontario

When it comes to pavement design, there is one over riding question: which design is most cost-effective. But with all the asphalt materials available, how do you make the right choice? The answer lies in life-cycle costing and one basic principle — the alternative with the lowest cost is not always the least expensive over the design life of the pavement.

The Ontario Hot Mix Producer Association's study into life-cycle costing, prepared by John Emery Geotechnical Engineering Limited, is an extensive examination of pavement economics. The study covers five different asphalt designs: conventional asphalt, modified asphalt, stone mastic asphalt, deep strength asphalt and composite pavements. It also covers maintenance and rehabilitation costs, the impact of maintenance on motorists' costs, 30 and 40 year economic horizons and the effect of different discount factors.

Do more durable paving materials save money in the long run? How often should maintenance work be done? The conclusions:

- Advanced materials such as engineered asphalt cements and stone mastic asphalts save maintenance and rehabilitation costs. This substantially reduces life-cycle costs despite higher initial construction costs
- Timely, systematic pavement maintenance and rehabilitation plays a key role in improving asphalt performance and reducing total life-cycle costs

"... the road which is truly the cheapest is not the one which has cost the least money, but the one which makes the most profitable returns in proportion to the amount expended on it."
Gillespie in the Principles and Practice of Road Making (written in 1847)

In 1995, the Ontario Provincial Auditor recommended that the Ontario Ministry of Transportation incorporate improved life-cycle costing procedures into design and construction decisions.

SOME EXAMPLES OF LIFE-CYCLE COSTING*

A 5 KILOMETRE, 2 LANE MUNICIPAL ROAD WITH MODERATE TRAFFIC

Modified asphalt vs. conventional asphalt

Initial cost increase	$60 thousand
Life-cycle cost savings	$35 thousand

A 10 KILOMETRE, 4 LANE ROAD IN THE CITY OF TORONTO WITH HIGH TRAFFIC

Stone mastic asphalt vs. conventional asphalt

Initial cost increase	$220 thousand
Life-cycle cost savings	$417 thousand

A 20 KILOMETRE, 4 LANE ROAD FOR THE MTO WITH VERY HIGH TRAFFIC LEVELS

Stone mastic asphalt vs. conventional asphalt

Initial cost increase	$700 thousand
Life-cycle cost savings	$494 thousand

**** 30 year analysis period using a 4% discount rate and considering user costs***

LIFE-CYCLE COSTING ⇨

The Six Major Life-cycle Cost Components

When designing roads, every engineer asks the basic questions: what is the initial cost, how much does it cost to operate and how long is it going to last. Life-cycle costing brings all those elements together into a true cost of pavement.

THE SIX MAJOR LIFE-CYCLE COST COMPONENTS		Influence on Life-Cycle Costs
Initial Costs	■ design, build and construct ■ cost of hot mix (standard mixes or enhanced pavement designs like stone mastic asphalt or modified/engineered asphalt)	moderate to high
Maintenance Costs	■ routine maintenance such as crack sealing and patching to extend pavement service life	moderate
Rehabilitation Costs	■ resurfacing and reconditioning to restore pavement to acceptable service levels	moderate
User Costs	■ cost of delays due to construction and maintenance	low to moderate
Residual Value	■ value of the remaining service life of the road (the economic analysis may cover 40 years compared to the road's expected life of 50 years).	low
Salvage Value	■ value of reusable components at the end of the analysis period	low

Initial Costs:

The initial construction and paving costs, including the cost of hot mix, are based on current bid prices for the Ontario Ministry of Transportation, City of Toronto and selected municipalities. The relative ranking of pavement alternatives in life-cycle costing is relatively insensitive to slight changes in unit costs.

INITIAL PAVEMENT COSTS – ($ thousands per lane-kilometre)
(30-Year analysis based on MTO unit costs)

	Light Traffic Level 1	Moderate Traffic Level 2	High Traffic Level 3	Very High Traffic Level 4
Conventional	89	103	109	127
Modified/Engineered	94	109	115	135
Stone Mastic	-	-	118	136
Deep Strength	-	-	-	130
Composite	109	166	179	200

On-Going Costs:

Over the thirty or forty years a pavement is in service, maintenance and rehabilitation result in both direct costs for the owners and indirect user costs for motorists. Delays and disruptions due to road maintenance, while more subjective, are nevertheless necessary in any life-cycle cost analysis.

Direct and indirect on-going costs are highly dependent upon the type of asphalt used to construct a road. The maintenance and rehabilitation program used in the life-cycle costing analysis, for example, shows five patching activities scheduled for a Traffic Level 4 road built with conventional asphalt. In contrast, the schedule only provides two patching activities for roads built with modified/engineered asphalt or stone mastic. Lower maintenance costs and avoiding disruption for motorists are what will ultimately justify the increased construction costs of advanced asphalt materials.

Regardless of the type of asphalt used, regular, routine maintenance makes economic sense. According to an MTO study, timely sealing of cracks can extend pavement service life by two to five years. The life-cycle cost analysis used in this study assumes that owners will maintain roads properly using high quality materials and approved methods.

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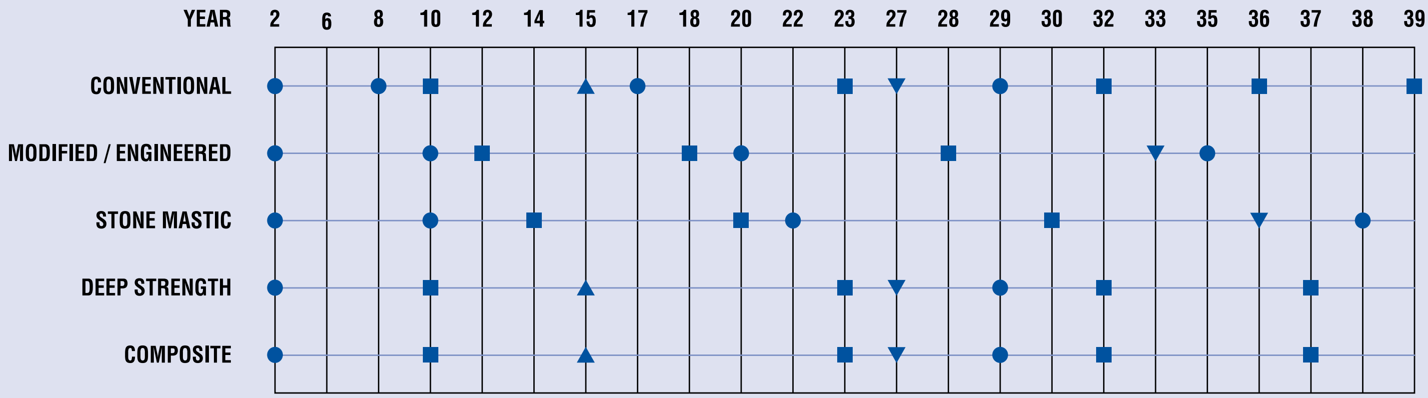
Since maintenance and rehabilitation work is disruptive, the life-cycle cost analysis include the impact of these activities on motorist. However, the usual practice of scheduling major work for after peak hours to minimize inconvenience and disruption is taken into account. Some analyses include the impact that badly maintained roads have on vehicle operating and maintenance costs. This study, however, assumes that all roads are equally well-maintained and therefore any incremental differences for users are minimal.

MAINTENANCE & REHABILITATION SCHEDULE — TRAFFIC LEVEL 4 ROAD



● ROUT AND SEAL ■ PATCH ▲ M1 - Mill 50mm ~ OVERLAY 50mm SURFACE COURSE ▼ M2 - Mill 50mm ~ OVERLAY 50mm BASE COURSE ~ 50mm SURFACE COURSE

Present Worth Analysis

Any investment analysis must include the value of money. This is particularly important when analyzing roads with useful lives spanning up to forty years. While there are a number of ways to analyze economic date, all equally valid, many agencies (including the Ontario Ministry of Transportation) use the present worth method. Present worth analysis discounts all costs, putting them on an equal basis in current dollars. The discount rate is generally the difference between interest rates and inflation (historically about 3 percent). The study uses 4 and 6% discount rates.

Compare, for example, two roads. The first costs $20 million to build and has annual maintenance and user costs of a $1 million a year. The second costs 50% more to build but annual maintenance costs are only $300,000. The net present cost of the first road is $39 million while, over the same thirty-year period, the second road's net present cost is $34 million — significant savings that would more than justify the extra capital cost.

Most life-cycle cost analyses, reflecting the trend toward longer-lasting pavements, use a thirty to forty year analysis period. Generally pavements with longer design lives have lower life-cycle costs because major rehabilitation can be postponed.

Putting Costs on an Equal Footing

The life-cycle costing analysis takes all pavement costs and puts them on an equal economic footing using net present worth analysis. As the table shows, the initial cost is by far the largest component

CONVENTIONAL PAVEMENT ($-thousands per lane-kilometre)

	Conventional AC	Engineered/Modified AC	SMA Surface Course
Initial Cost	127	135	136
Present Worth of:			
■ Rehabilitation Cost	31	15	17
■ Maintenance Cost	12	12	11
■ User Delay Costs	14	9	8
■ Residual Value *	(10)	(1)	(4)
■ Salvage Costs*	(2)	(2)	(2)
Total Present Worth	**172**	**167**	**166**

Notes: Based on MTO unit costs, Traffic Level 4, 30-year analysis, 4% discount rate

* Residual and salvage costs are shown as negative (bracketed) numbers, representing cost savings (i.e., there is residual value and salvage value in the roads at the end of the analysis period).

Life-Cycle Costing – Asphalt Pavements In Ontario

Life-Cycle Costs

The life-cycle cost analysis procedure does not produce a single definitive answer for pavement design. The OHMPA life-cycle costing study looked at 160 different combinations of traffic levels, discount rates, unit costs and analysis periods, both with and without user costs. What is appropriate under one set of circumstances is not necessarily appropriate under another. However, some general conclusions can be made:

- composite pavements (concrete with asphalt overlay) are the least cost-effective alternative
- higher unit costs and higher user delay costs (as in the City of Toronto) favour higher initial cost alternatives such as SMA and modified asphalts
- the life-cycle cost of stone mastic asphalt is comparable to conventional and modified asphalts. Note that SMA is still at the implementation stage. Increased usage should lower initial costs with a commensurate improvement to life-cycle costs
- higher discount rates favour lower initial costs
- when user delay costs are included, asphalts requiring less frequent maintenance are favoured.
- since modified/engineered asphalts reduce permanent deformation and thermal cracking, lower maintenance costs make them competitive on a life-cycle cost basis
- conventional asphalt ranks at or near the top for light and moderate traffic levels

PAVEMENT LIFE-CYCLE COSTS – WITHOUT USER COSTS ($ thousands per lane-kilometre)*

	Traffic Level 2		Traffic Level 4	
	Initial Cost	Life-Cycle Cost	Initial Cost	Life-Cycle Cost
Conventional	103	133	127	159
Modified/Engineered	109	131	135	158
Stone Mastic	–	–	136	158
Deep Strength	–	–	130	160
Composite	166	198	200	232

PAVEMENT LIFE-CYCLE COSTS – WITH USER COSTS ($ thousands per lane-kilometre)*

	Traffic Level 2		Traffic Level 4	
	Initial Cost	Life-Cycle Cost	Initial Cost	Life-Cycle Cost
Conventional	103	138	127	172
Modified/Engineered	109	135	135	167
Stone Mastic	–	–	136	166
Deep Strength	–	–	130	173
Composite	166	204	200	245

*Based on MTO unit costs, 30-year analysis, 4% discount rate

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The Ontario Hot Mix Producers Association study into asphalt pavement life-cycle costing was completed in June 1997 by John Emery Geotechnical Engineering Limited. This summary is for information purposes only. Contract and design requirements should always be confirmed by qualified personnel. Copies of the complete life-cycle costing study are available from OHMPA. Any comments, questions or suggestions, please call 905-507-3707.

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