Development of a Pavement Degradation Fee Structure for the City of Toronto

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Paper prepared for presentation

at the Urban Pavements: Better, Faster, Safer Session

of the 2013 Conference of the

Transportation Association of Canada

Winnipeg, Manitoba

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A B S T R A C T

Utility cuts contribute to a reduction in overall service-life of pavements. This results in an additional financial burden of costly rehabilitation and maintenance work by municipalities to maintain prematurely deteriorated pavements. Cities are allowed to recover the costs they incur as a result of allowing utility companies to use its roads to install their distribution systems. The City of Toronto, faced with this dilemma, decided to recoup such costs by developing a fair pavement degradation fee structure that is technically justified and legally defensible.

The paper will discuss the following topics:

- Background and terms of reference for the pavement degradation fee study
- The experimental design
- Quality assurance measures that guaranteed reliability of field information gathered
- The statistical tests that were used to identify impacts
- The economic evaluation undertaken to estimate the value of the impacts
- The development of the pavement degradation fee structure.

The paper presents the final fee structure and a quick comparison with other jurisdictions' charges with explanations of potential differences.

A. Background and Terms of Reference for the Study

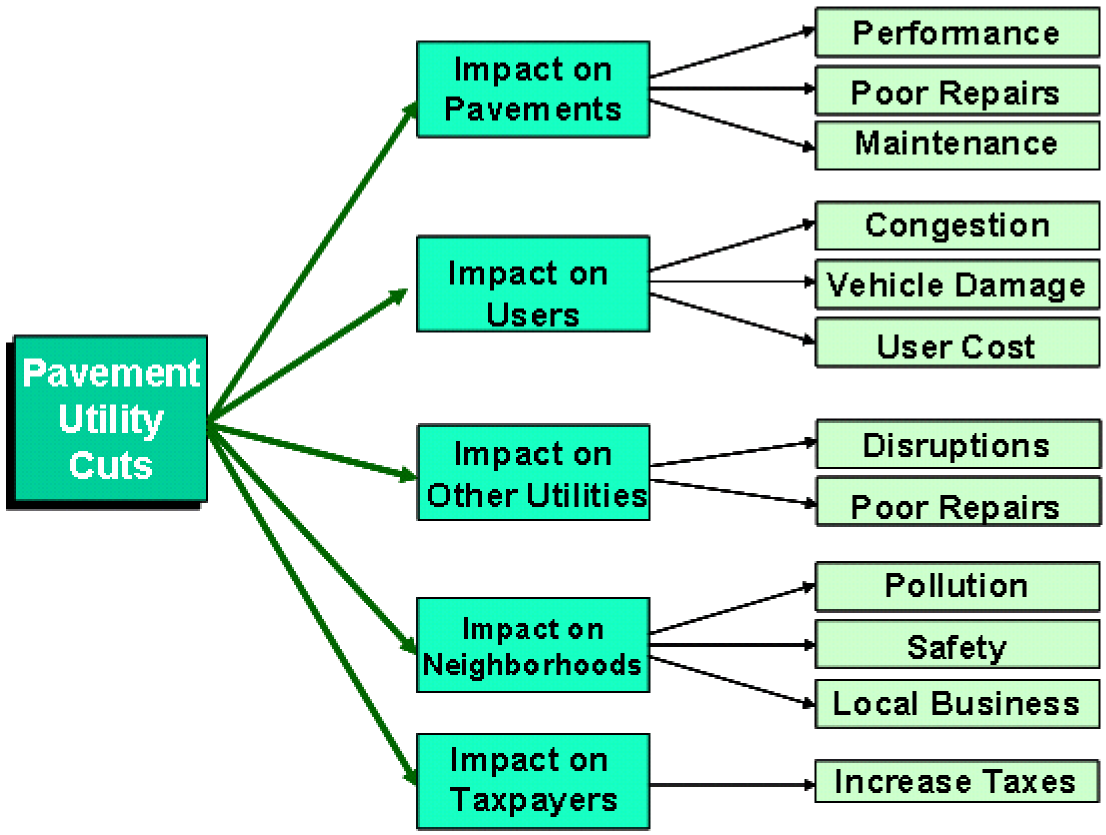
The City of Toronto has more than 5,600 centreline kilometres of roads which are vital to the economic health of the city and the service to our residents, businesses and visitors. It is important, therefore, that these roads are maintained in an acceptable condition for all users. This means that the roads must be safe to use, comfortable to ride or walk on and look in reasonably good shape.

Cuts into the roads by utility companies lead to serious deterioration of our roads. These are the cuts to the pavement made by the utility companies, such as Toronto Hydro, Enbridge, Bell, telecom companies, and even our own Toronto Water Division, to install, repair or expand their underground services. The repairs or patches to these utility cuts can result in a very uneven pavement that is uncomfortable to drive, cycle or walk on and is usually visually intrusive. At times, the patches can settle to a point where they create a hazard.

It is recognized that these utility companies provide valuable and essential services to the residents and businesses of our City and, accordingly, it is necessary to accommodate their needs as much as possible. However, each year the City issues permits for more than 38,000 utility cuts to our roads and that number is growing annually. To put this into perspective, this number of utility cuts totals over 200,000 square metres of pavement or the equivalent of the width of Yonge Street (a major street that divides Toronto into East and West areas) from Lake Ontario to Steeles Avenue (a total length of 17 kilometres). The disruption of this number of utility cuts to businesses, residents and visitors of Toronto is significant (See Figure 1, below) and the impact on the service-life of the road network is substantial.

Recognizing the extent of utility cut activity in our City and the resulting disruption to our communities, in 2006 City Council requested the Transportation Services Division to undertake a study of the impact of utility cuts on our pavements and, more specifically, the development of a "Pavement Degradation Fee Schedule." These fees would be an additional fee charged to the utility companies for the cuts that they make to the road pavements that would allow the City to recover the costs that it incurs due to the resulting reduction in the pavement service-life as well as increased maintenance expenses. All fees collected are then placed in a reserve fund and dedicated to road reconstruction, resurfacing and maintenance.

Figure 1: Impact of Utility Cuts



Expanding markets and the proliferation of new utility companies due to deregulation have increased the rate of cuts and consequently resulted in increase in public complaints from motorists, residents and businesses. Managing utility cuts from the time a permit is issued until the time of permanent utility cut restoration brings with it some difficult challenges and issues. It became apparent that the utility cut management process needed some improvements.

Major changes to the process included:

1. Introduction of Pavement Degradation Fees (PDF);
2. Dedicating PDF funds towards improving road conditions;
3. Introduction of new and revised permit fees;
4. Development of a criteria to trigger the requirement for milling and paving of an entire lane or road impacted by utilities to restore the structural integrity and ride quality of the road;
5. Improving inspection and enforcement, including training of staff involved in these areas;
6. Improving field operations through increased resources; and
7. A commitment to introduce new technology to further enhance efficiency.

This paper will address the first item: the introduction of pavement degradation fees.

City of Toronto is not the first jurisdiction to institute pavement degradation fees. Other cities across Canada like Vancouver, Ottawa, District of Saanich and London, to name a few, have implement fees of their own. In some cases, utility companies have legally challenged the local municipalities' authority to charge a pavement degradation fee. After such legal challenges, the decisions rendered by the courts usually included some additional advice for the local jurisdiction, which can be summarized in three statements:

- Municipalities are entitled to charge utility companies for the damages they incur due to utility cuts;
- The fee charged must be commensurate with the damage created by the utility cuts; and
- Municipalities have to demonstrate to the courts, using their own data, that the damage is attributable to the utility cuts.

The City's terms of reference for the study undertaken in the development of its pavement degradation fees took into consideration the above lessons that were learned from the court challenges.

B. The Statistical Experimental Design

Pavement performance is affected by a number of factors, which include:

1. *Engineering Design* – making the right decisions, under prevailing conditions and constraints, affecting the choice of material type and quality, thickness of layers, and mix design.
2. *Quality of Construction* – relates to the use of durable materials and using appropriate construction methods (e.g., during compaction, material handling, etc.). Construction quality is highly linked to the quality of inspections undertaken.
3. *Drainage* – the system of surface and subsurface treatments that are put in place to ensure that the pavement stays dry: making sure moisture does not get into the structure and, in the event that it does, the moisture is promptly removed. Moisture if not properly addressed can destroy the structural integrity of the pavement and reduce its service-life.
4. *Traffic* – the volume and mix of traffic, particularly the accumulation of axle applications of heavy vehicles (e.g., tractor-trailers, buses), normally converted to a common unit called Equivalent Single Axle Load (ESAL).
5. *Climate* – varying temperature, rainfall (resulting in moisture accumulation) and the number of freeze / thaw cycles.
6. *Deficiencies present (i.e., Number of cuts, cracks and potholes)* – most of these provide an opportunity for moisture to reach the sub-base.

7. *Lack of Maintenance* – the protection of the pavement structure from moisture penetration and accumulation. A build up of moisture could be the result of clogged drainage pipes or unsealed cracks at the surface, etc.

It is generally valid and safe to say that good pavement performance is the product of good design, the use of durable materials, good compaction and a sub-grade that is kept dry.

To include all of the above variables in an analysis requires an excessively large sample. The more variables included in the design of the experiment, the greater is the number of observations needed to obtain reliable statistical conclusions. In order to minimize the sample size, a strategy of identifying paired segments, one with and one without cuts, from the same road sections was implemented. This approach was chosen and thus reduced the number of variables to only one – i.e., whether the section was cut or not. A pair-wise comparison t-Test was used to determine significance in performance between the two types of segments.

The one challenge faced was how to find those segments with zero cuts. A given road section may upon inspection not reveal any visible surface cuts, but that does not necessarily eliminate the fact old utility cuts may be present and hidden from sight due to a recent pavement rehabilitation or resurfacing. In order to ensure that hidden cuts were not present, subsurface investigations would have to be carried out. Ground Penetrating Radar (GPR) was used to investigate all selected sections to ensure the quality of the samples.

C. Data Collection

A nested approach (i.e., continuous sub-sampling) was used to reach the final sample data set. The initial study sample included all arterial roads and from there the sample was reduced by using a step-by-step filtering process. Ultimately, the desired paired sample data was generated. The five step approach is further detailed below.

The first step involved defining the list of pavement sections that could be possible candidates for further examination and analysis. Arterial roads comprised of both flexible and composite pavement types would be examined. Of those pavements, only those that could yield paired-wise segments would be considered for further examination. For example, roads that are newly rehabilitated would most likely not have any utility cuts and therefore were not considered. Pavements that were in extremely poor condition with utility cuts throughout their length would not likely yield sections of pavement with zero cuts and therefore were also excluded. Only pavements having a mixture of pavement area with and without utility patches would be considered for further study.

In step two, a further verification by way of a windshield survey was done of the roads selected in step one; to confirm that they were still good candidates for further study. In addition, the sample list was further refined by making sure that the list was comprised of roads not clustered in one specific area of the city but rather geographically scattered across the city. This would ensure a better representative sample of the road network and eliminate any anomalies that could skew the results.

In the third step, some detailed field information would have to be acquired in order to do further performance and economic analysis. To collect the level of detail required for this study a consultant was retained, who examined approximately 138 km of road, of varying pavement structures (i.e., **flexible pavements**: asphalt surface with granular sub-base, and **composite pavements**: asphalt surface with a concrete base and granular sub-base). The consultant divided each roadway section into 25 metre long segments. The investigation also included the use of Ground Penetrating Radar (GPR) to confirm whether or not utility cuts existed under the surface of the roadway, which would not be visible after a road has been resurfaced. Wherever the GPR registered a 25 metre section with zero cuts, that section was then matched by another one having cuts. In this manner, the paired section list was then created. From that list the consultant was asked to select a random 10% sample of all eligible sections to be the representative sample.

As part of the fourth step, the two-paired segments of each road section were then windshield surveyed, by qualified evaluators, and detailed mapping of pavement surfaces was done to determine the extent and severity of distresses in the various pavement segments, both with and without utility cuts. This allowed for the Pavement Quality Index (PQI) to be calculated for each segment.

Finally, in the fifth and final step, all the paired segments (95 pairs in total) and their assessment details were consolidated into one file and provided to the City for review to ensure completeness of the data. Once the data was deemed complete, it was used to do further analysis.

D. Quality assurance measures that guarantee reliability of field information gathered and Analysis

A number of measures were used to ensure that there was no bias in the information. This included:

1. Separating the arterial road sections from the local and collector roads sections.
2. Samples for composite and flexible pavements were separated from each other because the impact of utility cuts on each of the pavement types is significantly different due to the way each is designed and performs.

3. The final samples for further statistical analysis were randomly identified through field investigations.
4. Making sure that the sample sections were from across the city, experiencing various traffic loadings and environmental conditions.
5. GPR was used to verify if utility cuts were hidden below the surface of the pavement.
6. The consultant's pavement ratings were calibrated with the ratings of City staff in order to create consistency between observed impacts, in terms of pavement's PQI.
7. The statistical aspects of the data selection and analysis were reviewed by a certified statistician to ensure proper application of statistical procedures (i.e., peer review)

E. Statistical tests required to identify impacts

The data for each pavement segment was analyzed using widely accepted statistical methods, which examined a number of factors (pavement age, pavement type, etc.) to determine to what degree utility cuts impacted pavement performance and whether there was a correlation to some of these factors. The steps used are further detailed below.

First, a series of plots of the data and their respective means were produced. Then the significance in the difference in means was tested. The tests were used as the bases to determine at what data aggregation level such significance exists.

Secondly, the Student t-Test was used to assess if there was any difference in PQI for paired pavement segments with and without utility cuts. This method is widely used as a standard in evaluating impacts. A typical test result table, from the analysis, is shown in Figure 2, below.

Figure 2

Results of Statistical Testing for Higher Mean Differences

($\alpha = 0.05$)

t-Test: Paired Two Sample for Means
Flexible Pavements: 0 – 15 years old

	Variable 1	*Variable 2*	*Difference*
Mean	**8.500555556**	**7.269722222**	**1.230833333**
Variance	1.332611111	2.129042778	
Observations	36	36	
Pearson Correlation	0.719069695		
Hypothesized Mean Difference	0.75		
df	35		
t Stat	2.829983222		
P(T<=t) one-tail	**0.003829607**		
t Critical one-tail	1.689572855		
P(T<=t) two-tail	**0.007659214**		
t Critical two-tail	2.030110409		

The above t-statistic shows that for flexible pavements (0 to 15 years old), the difference in the mean PQI is significant. Since the segments share the same characteristic (i.e., design, material, construction, geography, etc.) the difference in the means can be assumed to be a reliable indicator of the influence of utility cuts on a pavement.

Thirdly, sensitivity testing was carried out. This test is normally carried out with a Hypothesized Mean Difference (HMD) of 0.5; the above test shows significance even at HMD of 0.75 – which means that the significance is strong.

Finally, the test was repeated for each significant group within each pavement type and a table of impacts was generated.

After completing the analysis, there was a clear indication that:

1. there was a strong statistical significance between the performance of pavements with and without cuts;
2. pavement service-life is reduced when utility cuts are introduced and was observed for both composite and flexible pavements; and
3. the impact on service-life varied by road class, pavement type and age of the pavement.

Based on the above findings, there was sufficient information to proceed with the development of a Pavement Degradation Fee structure, which is presented below.

F. Economic Evaluation: Estimating the Value of the Impacts

The next steps in developing the PDF structure entailed carrying out both a performance and economic analysis. Through the performance analysis, the amount of lost pavement serviceability due to utility cuts, over the entire life cycle for different pavement types, was estimated. Once the loss in pavement serviceability was calculated, this figure was then used in the economic analysis to estimate the financial impact due to utility cuts. The concept of "lost pavement serviceability" is illustrated in Figure 4, below.

Graph # 1 of Figure 4 illustrates the typical performance curve (i.e., PQI versus pavement age) for a composite type pavement. The curve shows that a new pavement starts at a PQI rating of 9.8 out of 10, and as it deteriorates with time it eventually reaches a point in time where it must be then resurfaced, and those cycles, shorter in duration, repeat themselves until the pavement eventually needs to be reconstructed. The City of Toronto's Transportation Services has developed similar performance curves for a variety of different pavement types, based on pavement structure and traffic loadings. In Graph # 2 of Figure 4, the performance curve for the same pavement, but with utility cuts introduced, is plotted. As can be seen, the performance curves, over the life cycle of this pavement, are lower than that of a typical pavement without utility cuts. The impact of the utility cuts causes the pavement to deteriorate sooner, resulting in the advancement of resurfacing work and ultimately the premature reconstruction of the road.

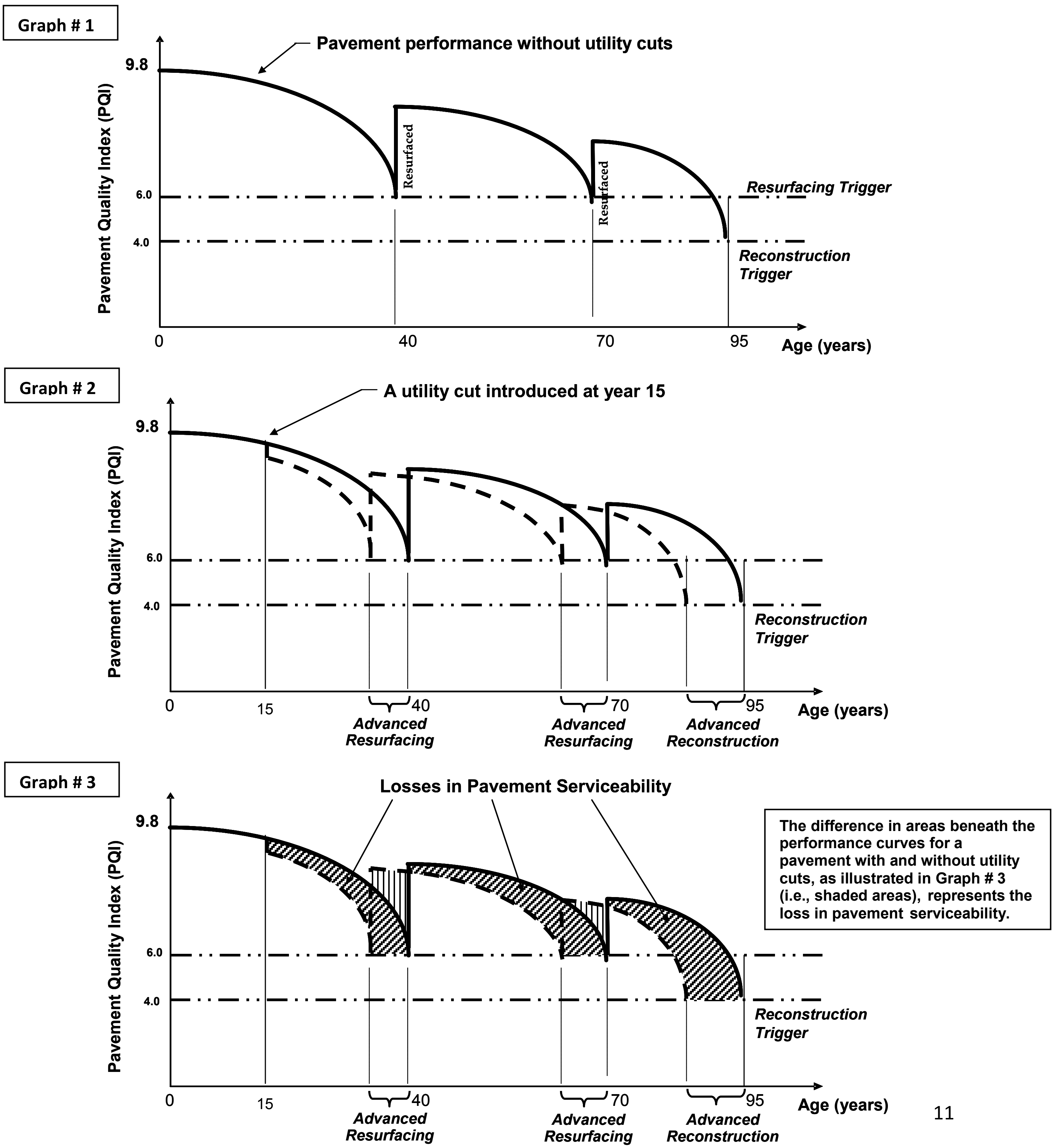
To estimate the "lost pavement serviceability", the difference in the areas under each of the two performance curves (with and without utility cuts) was calculated and represented by Graph # 3 of Figure 4. This difference in area under the curves represents the lost serviceability, expressed as a percentage of the original area under the curve for the pavement without utility cuts.

$$\textbf{\% Loss of Serviceability} = \frac{\textbf{[Area under 'no cut' curve – Area under 'cut pavement' curve]}}{\textbf{Area under 'no cut' curve}}$$

The economic loss to the City was assumed to be proportionate to the loss in serviceability. For example, if building a square metre of pavement costs X dollars for a given serviceability expectation (i.e., area under the performance curve), then the economic loss to the City is equal to the ***percentage loss of serviceability*** multiplied by X dollars.

Figure 4 - CALCULATION OF SERVICEABILITY

(Life Cycle of Composite Pavements)



G. Development of the Pavement Degradation Fee Structure

Having now established the percentage in serviceability loss over the course of a pavement's entire life cycle, it was then possible to calculate the various pavement degradation fees, which include two distinct components (loss of serviceability and associated increase in maintenance). The formula for deriving the PDF is provided below:

PDF ($\$/m^2$) = Cost of Serviceability Loss + Additional Maintenance Cost

The "Cost in Serviceability Loss", as previously discussed is calculated by multiplying the percentage of serviceability loss with the unit cost for reconstructing a pavement, which will vary for each pavement type. The formula to calculate the "Cost in Serviceability Loss" is provided below:

Cost of Serviceability Loss ($\$/m^2$) = (%Serviceability Loss x Unit Cost to Reconstruct Road)

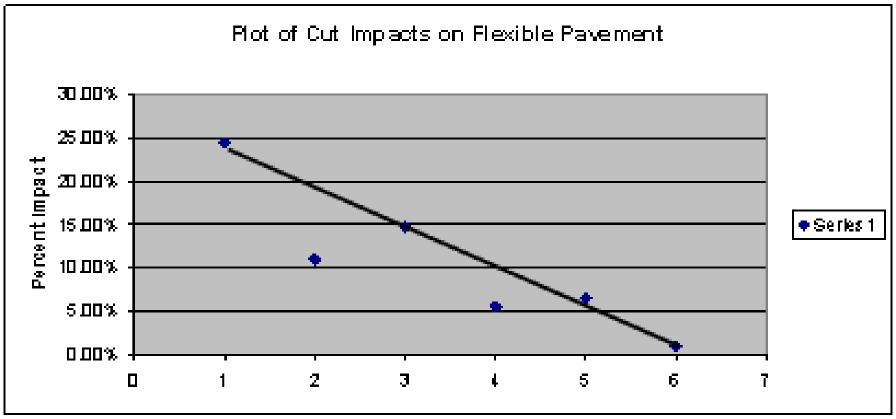
The "Additional Maintenance Cost" represents the added maintenance expenditures incurred by the City to repair pavement deficiencies resulting from road utility cuts. The types of repairs carried out include, crack sealing, patching, pothole repair and lane paving. The estimated maintenance cost attributable to utility cuts represents approximately thirty percent (30 %) of what the City of Toronto's Transportation Services typically spends in its annual Capital budget for the resurfacing and reconstruction of roads. This thirty percent component is applied to the cost in lost serviceability, previously discussed. The formula to calculate the "Additional Maintenance Cost" is provided below:

[**Additional Maintenance Cost ($\$/m^2$) = 30% x Cost of Serviceability Loss**]

In applying the above equations, an age group structure was identified (i.e., successive 15 year time periods)

1. For each of these groups, the pavement cut was introduced at the median point of the age group. The revised performance curves were then developed, and the loss of serviceability for the particular age group calculated.
2. The economic loss to the City was then calculated using loss of serviceability; calculated in step one, above, plus an additional 30% of that value to account for maintenance.
3. Finally the calculated economic loss in step 2, above, was plotted against the means of the identified age groups. A best fit curve was derived for all the points and this was then used to develop the final PDF structure (See Figure 5 below – Percent Impact vs. Age Group)

Figure 5: FLEXIBLE PAVEMENT CALCULATION



Through the analysis, it was determined that the impact of utility cuts was directly dependent on the age of the pavement at the time the utility cut was introduced. Based on these findings, a hierarchy of pavement degradation fees by pavement type, road class and pavement age was developed which are summarized in Figure 6, below. Also, the City has chosen to waive its fees when the pavement reaches a certain age or if the pavement is programmed for reconstruction within the City of Toronto's Five-Year Capital Works Program. These two conditions for waiving fees may create more incentive for utility companies to plan and coordinate their capital improvements with the City and take advantage of the waiving of these fees.

Figure 6 - Pavement Degradation Fee Schedules[1]

Flexible Pavement		
Pavement Age	Arterial Road ($/m²)	Local/Collector Road ($/m²)
0 – 15	40	34
16 – 30	32	27
31 – 45	24	20
46 – 55	18	14
56 – 70	11	9
70+	0	0
Composite Pavement		
Pavement Age	Arterial Road ($/m²)	Local/Collector Road ($/m²)
0 – 15	33	29
16 – 30	26	23
31 – 40	19	17
41 – 55	15	14
56 – 65	12	10
66 - 80	9	8
80+	0	0

1. **Pavement degradation fee is waived if pavement is scheduled for reconstruction in the five-year capital program.**

H. Concluding Remarks

The City of Toronto's pavement degradation fee structure was derived based on engineering and economic principles. The fees that have been developed may be somewhat lower than what some other jurisdictions may typically charge. However, there are a number of reasons that may account for that:

1. The performance curves used as a base are calibrated for roads with cuts. The City does not have a performance function for absolute zero-cut pavements. Therefore, the City of Toronto fees would be considered more on the conservative side.
2. Most jurisdictions allow the utilities to do their own permanent repairs, while Toronto does not. A utility company is required to reinstate a temporary patch upon completion of their work. The City then allows for one season of freeze/thaw cycles to pass before it undertakes permanent restoration work, which is then billed back to the utilities. The fact that the City does its own permanent repairs ensures better quality work, thereby reducing the amount of pavement deterioration.
3. The City requires that all utility companies maintain temporary patching in a reasonable state of repair until permanently restored. This ensures that moisture reaching the sub-base is minimized and therefore keeping the amount of damage under control.
4. While the City is charging for the cost of reduced service life through its fees; other jurisdictions may have added additional components that make up their fee, such as the cost associated interruption to their work and mobilization, to name a couple.
5. The unit costs of reconstruction for Toronto may be slightly lower than in some of other jurisdictions.

From the City's perspective, the process used in the development of its pavement degradation fees is technically sound and is legally defensible. In fact, the City's introduction of pavement degradation fees has already been challenged in both the lower court and Ontario Court of Appeal, and in both instances withstood those challenges. The process is reliable, repeatable and therefore transferrable to other jurisdictions. However, each jurisdiction should use its own data in developing its own fees. Doing so will provide some reassure to local utility companies that the fees are reasonable, and if ever challenged, easily defended in court.