Understanding the Past and Preparing for the Future: A Look at the City of Hamilton's Road Condition/Performance

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ABSTRACT

As part of their ongoing asset management initiative, the City of Hamilton has been reviewing and updating their roads "numbers" for the State of the Infrastructure Report. This paper includes a 10-year review of the City's road performance, as well as, a 10-year projection of road performance based on different funding levels.

The City of Hamilton was amalgamated in 2001. At that time, a network-level data collection survey was conducted on City roads to evaluate the condition of the road network. A network-level data collection survey was repeated again in 2006 and in 2011. These data collection surveys provided the City with 3 data points over a ten-year period.

The historical data was used to assess the pavement condition results and trends, as well as the spending results/trends since the City's amalgamation. This provided the City with a look back at the road investment and the resulting road condition. Furthermore, as a result of the 3 data collection efforts, the assumptions regarding the pavement deterioration models and decision trees were evaluated/calibrated to be used for future pavement performance.

Finally, the historical data and the new updated models were used to predict pavement performance based on various spending scenarios, including the projected funding over the next 10 years, the cost to maintain a status quo on the various classes of roads, and the spending required to reach a "B" grade level of service as recommended by City Council after the presentation of the 2009 SOTI Report.

1 Introduction

The City of Hamilton (City) has a dedicated Asset Management group, which is responsible for a city-wide condition assessment of surface and sub surface assets. The City uses information from the condition assessments to forecast and schedule appropriate rehabilitation and reconstruction activities to produce an annual capital budget program. The Asset Management group monitors current levels of service, life cycle trends, and deterioration models. These models are used to plan and develop short-term (3 to 5 years) and long-term (20 years) capital budgets to protect the city's infrastructure investments.

In 2004, the City produced a Life-Cycle State of the Infrastructure (SOTI) Report Card for Public Works. The Report Card not only includes the current status of each specific asset, but also considers future projections of these assets. In 2009, another SOTI Report on Public Works was completed.

One of the largest assets maintained by the City is their road infrastructure. As part of their ongoing asset management initiative, the City has been reviewing and updating their roads "numbers" for the SOTI Report. This paper includes a 10-year review of the City's road performance, as well as, a 10-year projection of road performance based on different funding levels.

2 Methodology

The City of Hamilton was amalgamated in 2001. At that time, a network-level data collection survey was conducted on City roads to evaluate the condition of the road network. A network-level data collection survey was repeated again in 2006 and in 2011. These data collection surveys provided the City with 3 data points over a ten-year period.

The City's maintenance management system database includes inventory and condition data for all City-maintained roads. The data contained within this database formed the basis of financial analysis completed for the road network.

The pavement condition and attribute data was extracted from the maintenance management system database, and uploaded to a pavement management system. The system was used to deteriorate the overall pavement condition to the current year, and then identify pavement rehabilitation needs and budget requirements for ten years.

Based on discussions with City staff, it was agreed that the historical performance data would be "normalized" to include sections of road that were surveyed in 2001 and 2011. Normalizing the data ensures consistency between results over the past decade, as it eliminates bias from new roads constructed/reconstructed since 2001. The performance data is generally summarized in terms of three indices:

- Roughness Index (RI) – an indication of how smooth or bumpy the road is, with 0 being extremely bumpy and 100 being very smooth.

- Surface Condition Index (SCI) – an indication of the number, extent, and severity of surface distresses, with 0 being severely distressed and 100 showing no signs of surface distress.
- Overall Condition Index (OCI) – an indication of overall pavement condition, which combines the RI and SCI.

Throughout this paper, the OCI was used as the basis for analysis.

3 Historical Pavement Performance

Upon review of historical Development and Sustainable Asset Management costs, it was determined that approximately $288 million has been invested in the City's road network, over the past 10 years. Spending has fluctuated from year to year, but has generally been increasing over time. More funds were invested in road infrastructure between 2006 and 2011 than between 2001 and 2006. The effects of these funding levels on the OCI of the network are shown in Figure 3.1.

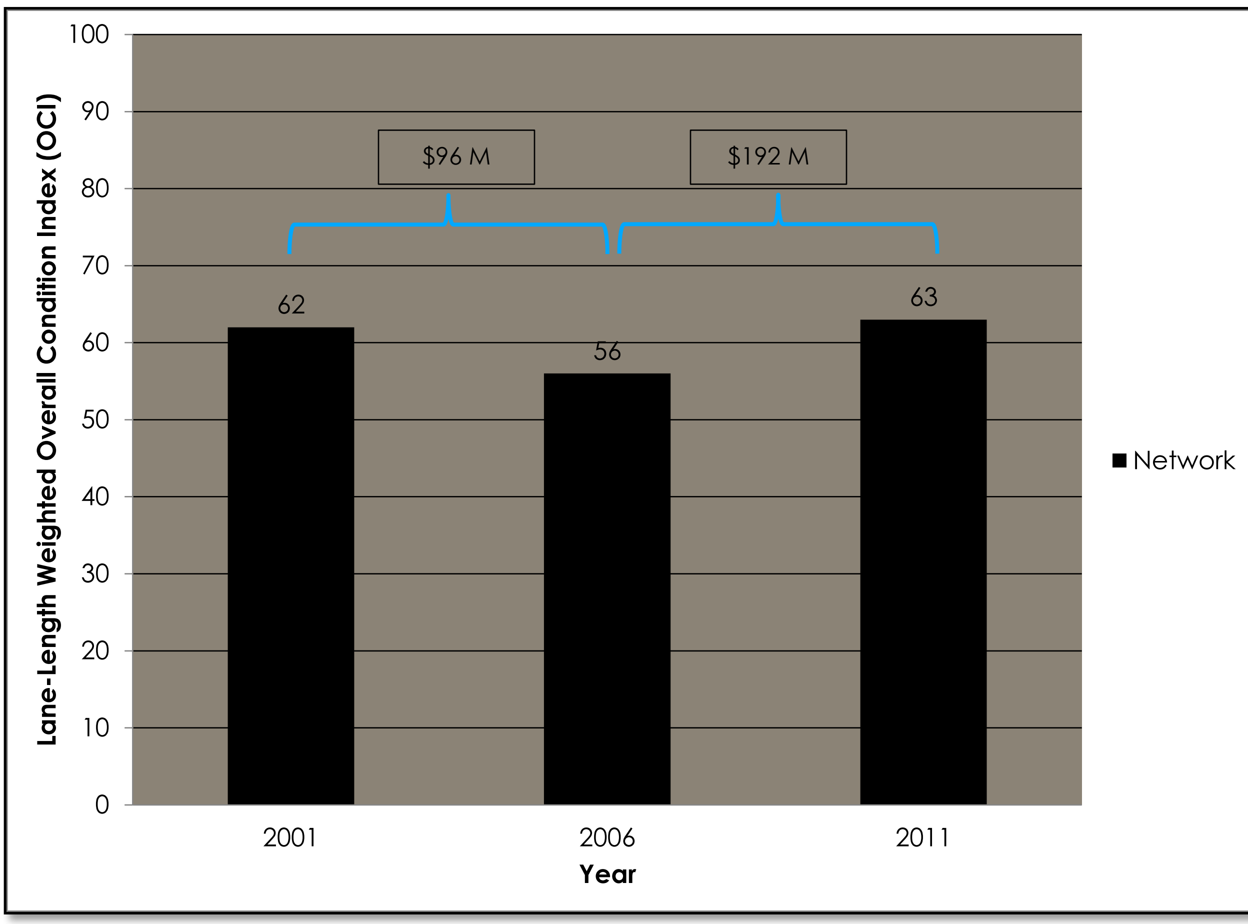

Figure 3.1: 2001-2011 Historical Performance – Citywide Results*

Note: *Data normalized to include sections of road surveyed in 2001 and 2011

The network-level performance dropped from 2001 to 2006, but then improved from 2006 to 2011. This is consistent with results from previous studies, and reflects the increase in road funding over the 2006-2011 period. In particular, the City received funding from provincial surplus that provided $25 million for neighbourhoods and $8.8 million for arterials in the downtown core. Anecdotally, the City staff indicated that the first five-year period consisted primarily of major rehabilitation or reconstruction projects. The second five-year period focused on asset preservation, with minor rehabilitation or resurfacing projects. The emphasis in the first few years was to address the roads in very poor condition. Unfortunately, major rehabilitation and/or reconstruction projects are costly and only provide minor improvement to the overall network condition, as they impact a small portion of the network. On the other hand, minor rehabilitation projects impact a larger portion of the network. They do not require the same level of effort or cost as major rehabilitation projects.

The historical average OCI values by functional class are shown in Table 3.1. Highlights are included for functional classes that are either above, at, or below the network average OCI values.

Table 3.1: Historical Average OCI Values by Functional Class*

Functional Class (FC)		2001	2006	2011
Urban	Arterial Major	63	54	61
	Arterial Minor	61	54	61
	Collector	58	**52**	**59**
	Local	59	**52**	**59**
	Urban Network	*60*	*53*	*59*
Rural	Arterial	**74**	**69**	**71**
	Collector	67	65	69
	Local	62	59	70
	Rural Network	*65*	*63*	*70*
Overall Network		62	56	63

Note: * normalized to include sections of road surveyed in 2001 and 2011

Legend
Highest FC average for a given year
FC average above network average
FC average at network average
FC average below network average
Lowest FC average for a given year

In general, the road network has improved from 2006 to 2011. Two key success factors in achieving improved performance are the federal/provincial funding program assistance and the shift towards asset preservation.

The rural wards tend to have higher performance scores relative to the urban wards. It's important to note that the vast majority of the rural roads are surface treated. Surface treatment has a shorter life span than traditional asphalt, and generally needs to be resurfaced every six to eight years. Asphalt roads generally need to be resurfaced every 15 to 20 years.

Growth is a factor that is often ignored when managing an asset. The City's Transportation Master Plan has identified committed/planned road widenings to accommodate planned growth. The plan also identifies upgrades/expansion of road links serving employment areas and growth areas. As a result of growth, the operating costs for roads increase every year. The City estimates that the operating cost for new development projects is approximately $11,400 per lane-kilometre.

4 Deterioration Models

Deterioration models are used to project expected performance condition over time. The rate of deterioration for roads can depend on many factors, including environment (weather/climate), traffic, existing pavement structure, and subgrade conditions. Deterioration models for roads were developed as part of a previous. In this study, those deterioration models were validated against the data collected from the three road condition assessments.

Initially, deterioration models were developed based on input from City staff regarding expected service lives for different functional classes (see Table 4.1).

Table 4.1: Expected Service Lives

Class	Type of Work	*Service Life (Years)*
Urban Collectors/Locals	Reconstruction	35
Rural Collectors/Locals	Reconstruction	30
Urban/Rural Arterials	Reconstruction	28

The service life is an estimate, in years, of how long a given road will last until it reaches a given trigger or service level. The service life shown above is based on the reconstruction trigger.

The deterioration models were compiled from a review of deterioration of roads in several cities, in southern Ontario. Figure 4.1 illustrates the deterioration models that were developed as part of the previous study. The rehabilitation trigger identifies when a pavement should be considered for rehabilitation or resurfacing. A reconstruction trigger indicates when a pavement may qualify for major rehabilitation or reconstruction.

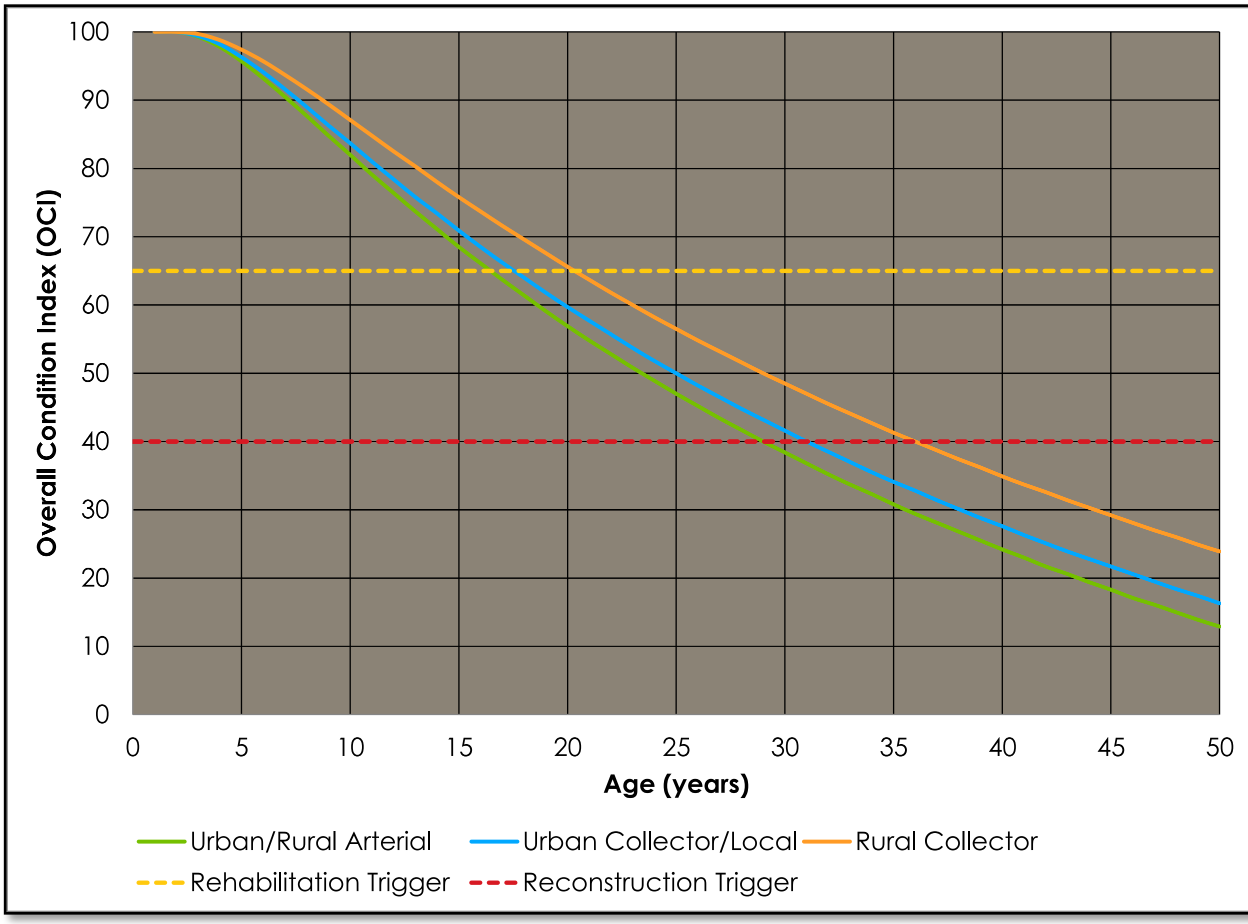

Figure 4.1: Initial Deterioration Models

4.1 Deterioration Model Results

To evaluate the existing deterioration models, the measured OCI values from 2001 and 2006 were aged using the deterioration models. The predicted OCI values from 2006 and 2011 were compared to the measured OCI condition data in 2006 and 2011. Comparisons were made between the OCI data for 2001 to 2006, 2006 to 2011, and 2001 to 2011. The relative difference between the predicted and measured OCI values is shown in Figure 4.2. The difference was measured as a percentage. A negative value indicates that the predicted OCI value was less than the measured OCI. A positive value indicates that the predicted OCI was greater than the measured OCI.

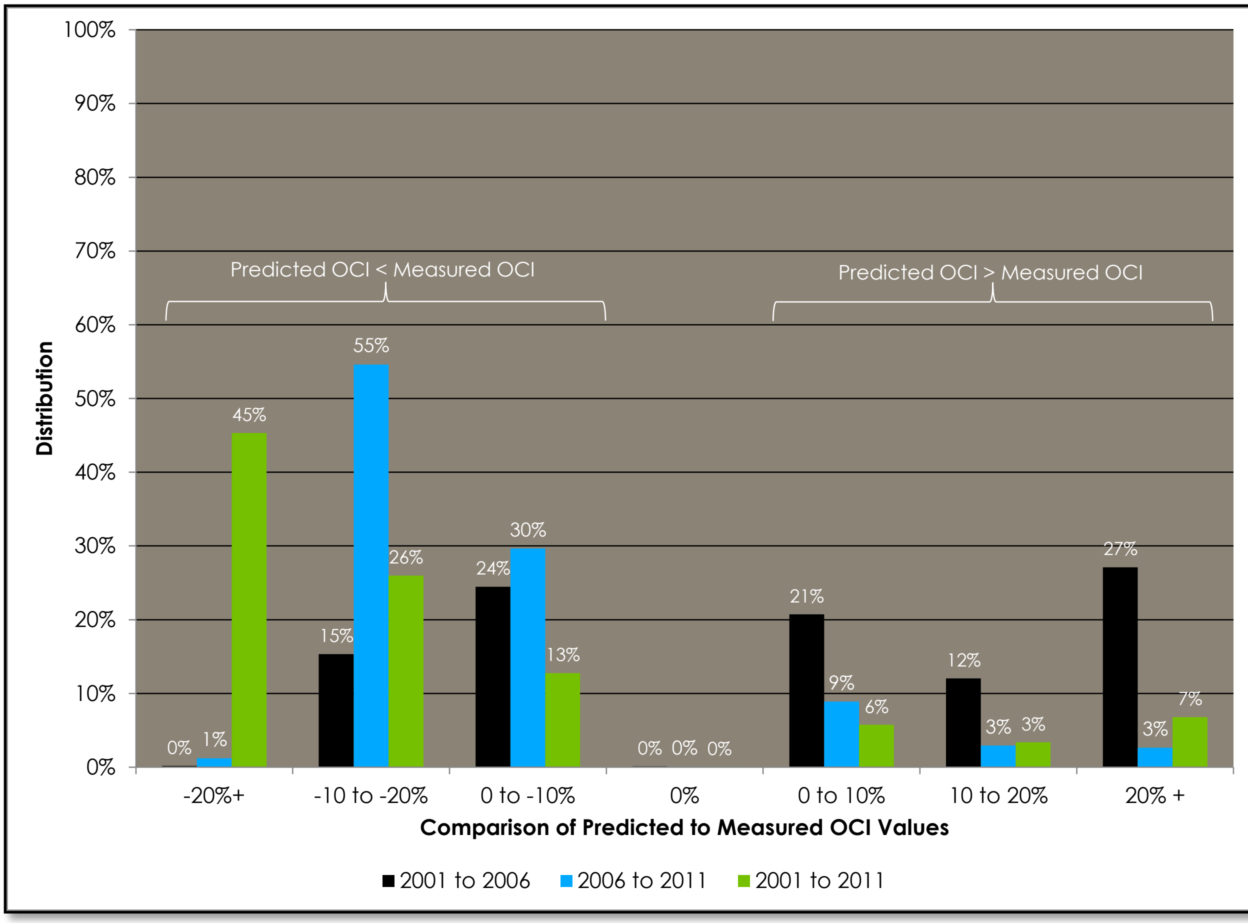

Figure 4.2: Deterioration Model Measure of Error

The results are mixed, depending on the years used for comparison. Between 2001 and 2006, many of the predicted OCI values were greater than the measured OCI value. Between 2006 and 2011, many of the predicted OCI values were lower than the measured OCI values.

It is important to reiterate that the City was employing different pavement management strategies between 2001 and 2006 compared to 2006 and 2011. It is suspected that the shift from “worst-first” to pavement preservation will gradually slow the rate of deterioration for the road network. For the purposes of this study, it was agreed that the original deterioration models would continue to be used. However, it would be a worthwhile exercise to validate these models again after the next condition assessment.

5 Decision Trees/Matrix for Roads

Decision trees were developed to generate maintenance and rehabilitation strategies for the network. Decision trees combined with budget or performance constraints, and deterioration models were used to develop long-term work programs. This was also used to evaluate the impact of budget scenarios on the network. A sample decision tree is provided in Figure 5.1.

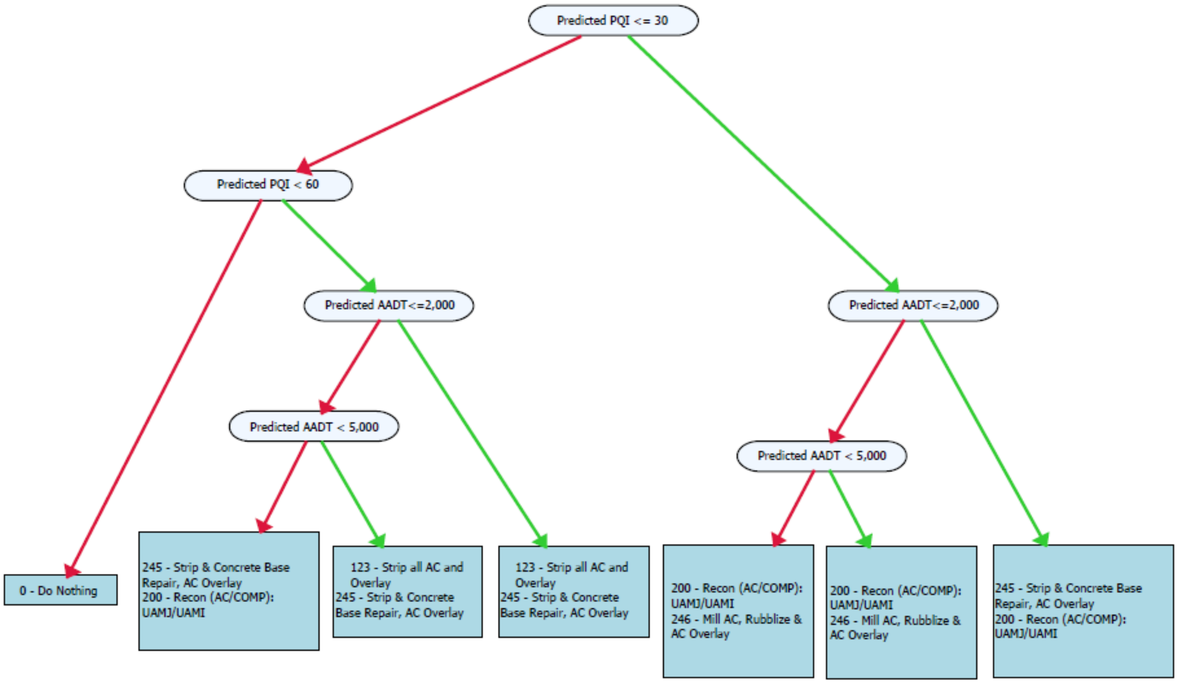

Figure 5.1: Sample Decision Tree for Roads

6 Future Funding Evaluation

The predicted OCI values for 2012 were calculated using historical survey data and the deterioration models presented above. The predicted 2012 OCI values by functional class are presented in Table 6.1.

Table 6.1: Projected 2012 OCI Values*

Functional Class	2012 OCI
Urban Arterial Major	61
Urban Arterial Minor	60
Urban Collector	57
Urban Local	57
Rural Arterial	68
Rural Collector	68
Rural Local	68
Overall Network	**61**

Note: *Data normalized to include sections of road surveyed in 2001 and 2011

The results show that urban arterial major roads are at the network OCI average of 61, based on 2012 projections. The average OCI of the urban arterial minor, urban collector, and urban local road networks are all slightly below the network average. All rural networks have average OCI values greater than the current network average.

Averages can be misleading, as the highs/lows (excellent and poor condition) are hidden. Therefore, the predicted OCI condition ranges by functional class, based on five performance categories, are presented in Figure 6.1.

Performance Categories:

- Failed OCI 0 – 20
- Poor OCI 21 – 40
- Fair OCI 41 – 60
- Good OCI 61 – 80
- Excellent OCI 81 – 100

As presented in the figure below, approximately three-quarters of the rural road network is in good or excellent condition (OCI greater than 60). The majority of the urban network is in fair condition (OCI 41-60), with approximately 10% requiring major rehabilitation or reconstruction (OCI less than 40).

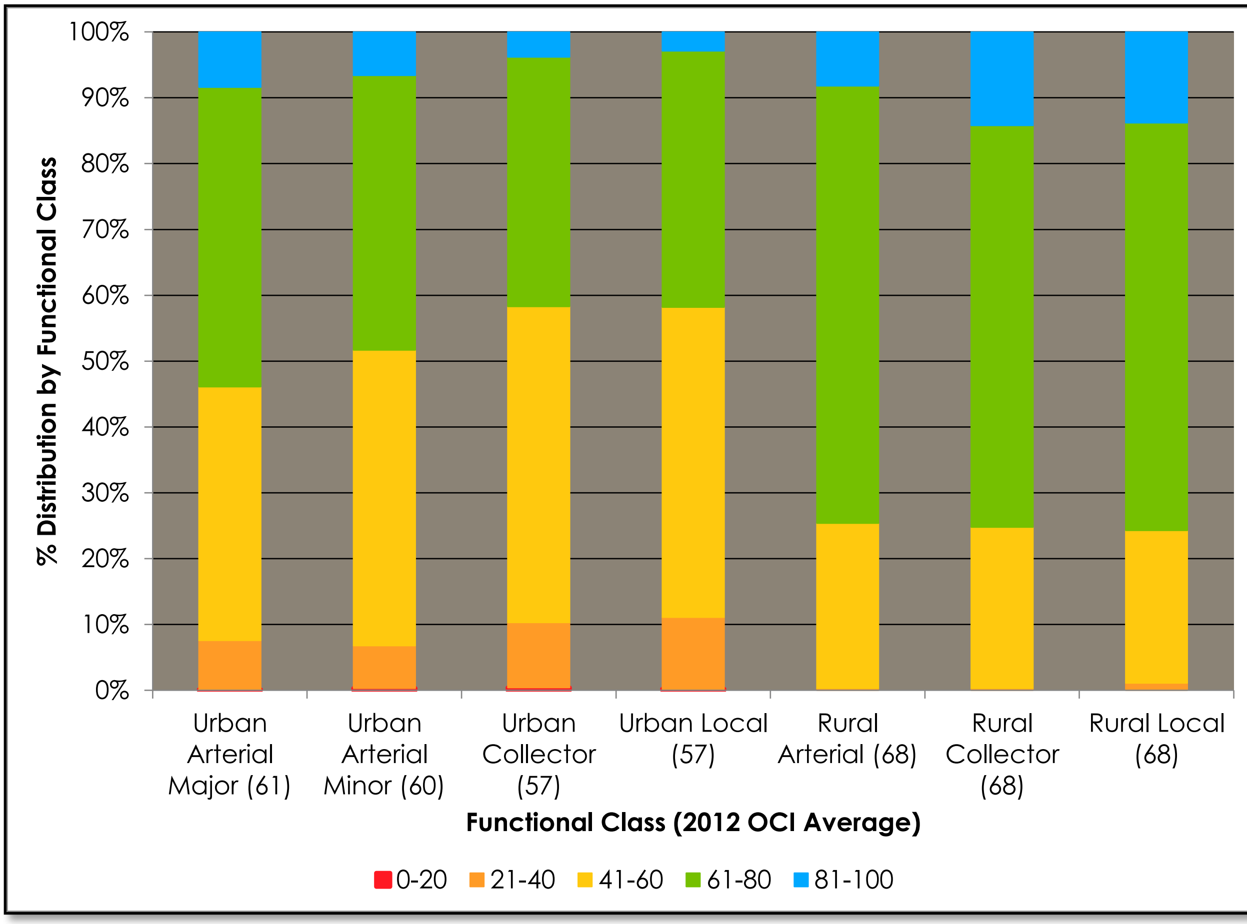

Figure 6.1: Predicted 2012 Condition Ranges by Functional Class*

Note: *Data normalized to include sections of road surveyed in 2001 and 2011

6.1 Projected Funding

To evaluate the impact of future funding on the network, a set of budget-driven and performance-driven budget scenarios were created. A ***budget-driven*** scenario indicates a maximum dollar value that can be spent. A pavement management system is then used to determine the resulting network performance based on that budget scenario. In a ***performance-driven*** budget scenario, a performance target is set, such as an average OCI. A pavement management system is then used to determine a funding level to achieve that target. The following budgets were considered in this analysis:

Budget-driven scenarios:

- Dedicated block funding for arterials in all Wards (Art Block)
- Dedicated $1.6 million for collector and local Council priorities ($1.6 M UC/UL) – 100% of Council priority funding
- Dedicated $800,000 for collector and local Council priorities ($800 K UC/UL) – 50% of Council priority funding

- Dedicated $2.0 million for rural collector and locals in rural network ($2 M RC/RL)

Performance-driven scenarios:

- Maintain 2012 OCI by Functional Class in each ward
- Achieve OCI 60 by Functional Class in each ward
- Maintain 2012 OCI in each ward
- Achieve OCI 60 in each ward

To evaluate the impact of budget-driven scenarios and the cost required to achieve performance-driven scenarios, a pavement management system was used. The survey data was exported from the City's maintenance database and loaded into the pavement management system. The deterioration models and decision trees previously presented were used in the pavement management system.

6.2 Future Funding Results

The results of the various funding scenarios on the network, and the functional class are subsequently presented.

The impacts of the funding scenarios on the network are shown in Figure 6.2.

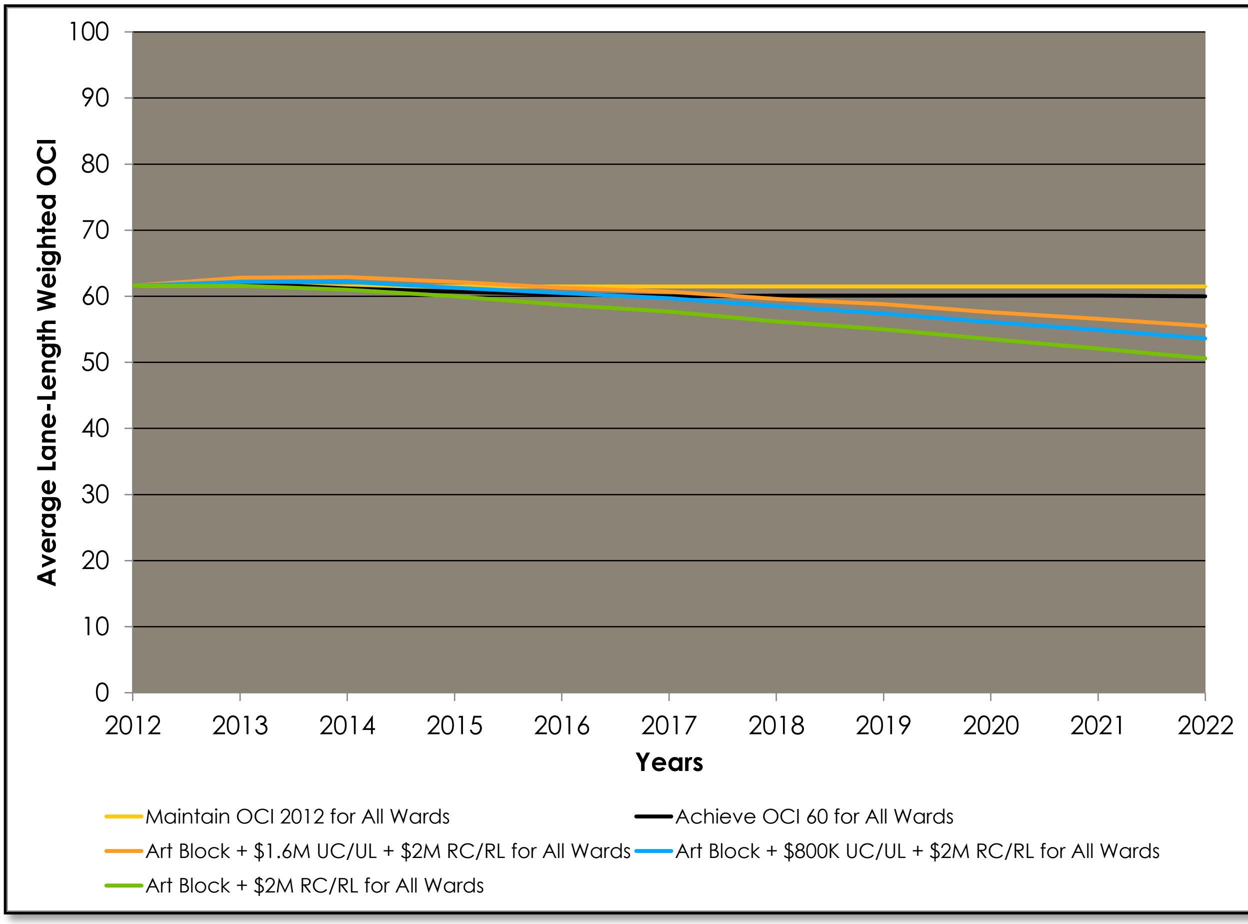

Figure 6.2: Future Spending Results – Citywide Results

For the three budget-based scenarios, the analysis indicates the network average either remains the same or improves slightly for the first two to three years. The network average then drops beyond 2015. If the urban collector and local roads are ignored, the overall network condition will decrease to 50. The urban collector and local roads account for more than 40% of the urban/local road network. As a result, their performance has a significant impact on the overall network.

The total spending and resulting OCI at the end of the 10-year analysis period (in 2022) are presented in Table 6.2, by functional class, for each budget scenario. It should be noted that the Maintain OCI and Achieve OCI budget scenarios are based on the OCI averages by ward.

Table 6.2: 10-Year Total Spending and Resulting 2022 OCI by Functional Class, for each Budget Scenario* ($ millions)

		Functional Class (F/C)			
		Arterial	UC/UL	RC/RL	All/FC
2012 OCI	**OCI**	62	57	68	**62**
Maintain 2012 OCI	**$**	$169	$80	$195	**$444**
	OCI	70	51	69	**62**
Achieve OCI 60	**$**	$174	$116	$90	**$380**
	OCI	70	54	61	**60**
Arterial Block Funding	**$**	$156	n/a	n/a	**$156**
	OCI	68	n/a	n/a	**50**
$1.6 M UC/UL Funding	**$**	n/a	$128	n/a	**$128**
	OCI	n/a	51	n/a	**49**
$2 M Distributed Rural Funding	**$**	n/a	n/a	$20	**$20**
	OCI	n/a	n/a	53	**44**
Combined Art Block + UC/UL + Rural	**$**	$156	$128	$20	**$304**
	OCI	68	51	53	**56**

Note: *Data normalized to include sections of road surveyed in 2001 and 2011

7 Summary

This paper presents a look back at historical spending-associated performance for the City's road network. Historical spending on the City's road network between 2001 and 2006 was less than $25 million per year. Between 2007 and 2011 (with the exception of 2008), the City invested between $35 million and $50 million per year on roads. During this period, the City also shifted from reconstruction projects to resurfacing projects.

The additional funding between 2007 and 2011 was from the provincial surplus. The shift towards more pavement preservation since 2006 has also helped the City improve their overall road network. Resurfacing typically costs one-third to one-half of reconstruction. This means resurfacing projects cover two to three times more roads than reconstruction projects for the same price.

A set of budget-driven and performance-driven budget scenarios were created.

This paper presents the results in terms of the impact on the functional class. The results show that approximately $40 to $45 million per year is required over the next 10 years, to attain a network average OCI of 60 or more. Even if all available funding is allocated to the road network, the current funding level is below the level required to maintain the road network at its current level of service.

At the current funding level, the overall network average OCI decreases to approximately 56, from 62 by the end of 2022. With the Block Funding dedicated to arterial roads, there is improvement in arterials over the next 10 years. Using a $2 million distributed funding for the rural collectors and locals, the network average for these roads drops to an approximate OCI of 50.

For urban collectors and urban locals in some wards, the additional $1.6 million will help to improve the roads. In other wards, a dedicated $1.6 million for the urban collector and local roads will not be sufficient to maintain the current level of service.