# Is the Current Level of Service of the Highway Network Financially Sustainable?

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**ABSTRACT**

**Is the Current Level of Service of the Highway Network Financially Sustainable?**

This paper discusses the challenges that were encountered by both Saskatchewan and Manitoba in developing life cycles for pavements that lead to the development of a Financial Sustainability Index for paved highway networks that is to be applied to highways in both provinces. The paper discusses the life cycle method used in the project and the sustainability index calculations. The intended use of the Financial Sustainability Index to support decision-making is also discussed.

Initially the life cycle analysis was undertaken using performance and cost information from current Ministry pavement performance models. It rapidly became evident that those models are not sufficiently accurate to enable a proper life cycle to be undertaken. This led to revisions resulting in more consistent and rational models. Those models were then slightly modified again and form the basis for all of the life cycles performed during the second half of the project.

The project uses whole of life costs that are annualized into an equivalent annual cash flow (EACF) per square metre of pavement. The annualized cost is then used to aggregate the whole of life costs for each network based on the proportion of the inventory that is within each condition state at the moment. Significant decisions about the long term levels of service underlie the life cycle costs (for the next 60 years).

As there are significant differences based on various assumptions both agencies are putting effort into identifying benchmark life cycle profiles for each network class by condition state. Both Agencies intend to annually refine the benchmark profiles based on analysis of actual performance.

Once both Agencies are able to accurately identify what the actual life cycles are then the sustainability index will be reported annually to accurately monitor funding levels for all classes of network for each year.

## INTRODUCTION

The word **sustainability** is now commonly used in society. It is often used in the context of being a goal. With the increasing use of this word in both public and private sectors the authors of this paper have tried to develop a method to determine the economic sustainability of highway networks. This paper discusses the method that was developed and has been used by both Saskatchewan and Manitoba Provinces for analysis of their primary highway networks. The method of analysis utilizes both economics and engineering. The paper discusses what we consider to be "early days" in this endeavor.

The paper covers an overview of the actual method used and what the challenges have been for both Saskatchewan and Manitoba in trying to determine the level of funding that would lead to sustainable infrastructure at a nominated level of service (*easy to say but hard to do*). The paper then goes on to talk about how the method creates an index that can be monitored over time as a trend. As this is a management measure of financial sustainability. The trend over time is more important than any individual number. Like the Dow Jones industrial average the actual value at any given time is of little interest; the trend of daily movements is closely watched.

It is envisaged that the sustainability calculations will be updated annually as new performance and condition information becomes available.

The paper covers the method in sufficient detail for the reader to see how the calculations are used and what information the calculations rely on. The paper cannot go into sufficient detail to show the reader how to do the method as that generally requires some training.

The remainder of the paper concentrates on the challenges encountered by the Provinces of Saskatchewan and Manitoba in getting sufficiently accurate information to enable the end result to be meaningful.

The paper concludes with where each province is at now and what the next steps are.

## THE METHOD USED TO DETERMINE FINANCIAL SUSTAINABILITY

Financial sustainability is calculated by using the following information:

- Performance curves for major preservation treatments which show the performance of ride, rutting, and cracking over time (called primary distresses);
- The cost of major treatments in current dollars;
- The cost of pavement maintenance per square metre of pavement under different conditions;
- Definitions that describe when conditions of a segment changes (called conditions states) due to changes in the primary distresses;
- The current percentage of the network that is in each condition state;
- The current percentage of the network that is in good condition for all three primary distresses (this equals condition state 1);
- Microsoft Excel and lifecycle costing software called LCC

Without the above information the method cannot be used. The method relies quite heavily on the accuracy of the above information. *Figure 1- The Components of the Sustainability Index* summarizes the inputs of the Sustainability Index (SI). A fairly reliable knowledge of all the parameters is required prior to undertaking the analysis.

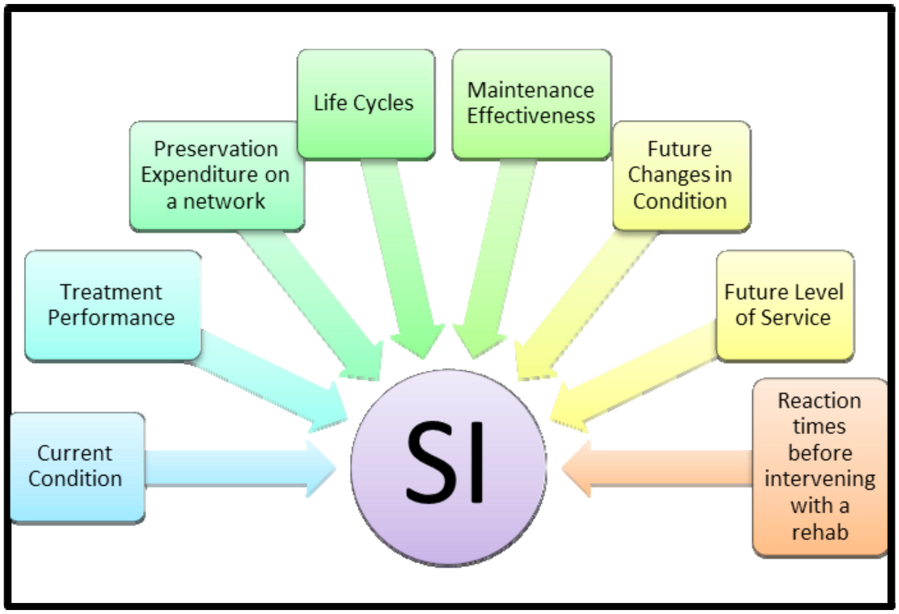
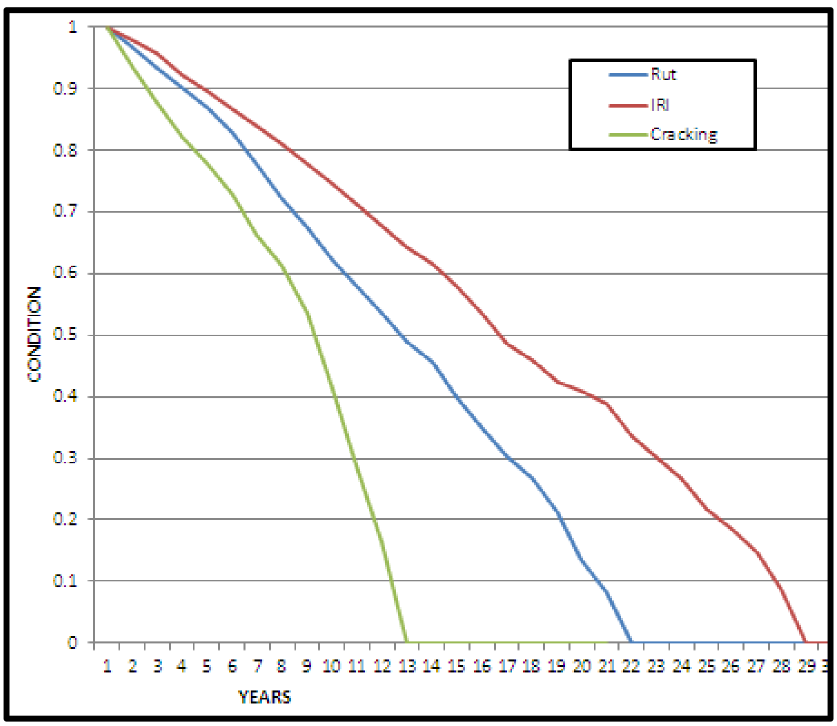



Figure 1- the components of the Sustainability index

The analysis starts with looking at the performance of individual treatments for the primary distresses (cracking, rutting, and ride). This requires an understanding of how each distress changes with time after the treatment is applied. The more evidence-based this information is the better.




For example, on the Canadian Prairies, cracking usually occurs more rapidly than rutting. Rutting usually occurs more rapidly than deterioration in ride quality. Of course it all depends upon how you measure these three parameters so that needs to be taken into account when determining how rapidly each parameter deteriorates.

If a road is initially in good condition for all three primary distresses, as illustrated in *figure 2: Deterioration of Primary Pavement Distresses*, cracking is the first distress to change from good to poor, while still rutting and ride quality are still good they have began to deteriorate. This combination of distresses would lead to a light treatment (as poor cracking is the least expensive and easiest distress to repair). As rutting and ride distresses become poor the treatments becomes more expensive and goes through a medium treatment and then later in life a heavy treatment. The combination of distresses that occur throughout the life of the highway affect the cost of maintaining that segment and the cost of a major rehabilitation or repair. The concept of treating and retreating a road and the resulting effect on condition is illustrated in *Figure 3 - simplified life cycle over 60 years.*

The lifecycle for a condition state 1 segment of highway would begin with all three primary distresses in good condition. Then gradually over time that would change as each distress deteriorates. At some stage in the future of the lifecycle a treatment would occur to address one or more of the distresses. Once that treatment has been applied the performance of each primary distress now behaves in accordance with the most recent treatment. Following the distress deterioration curves throughout the entire lifecycle period leads to a variety of treatments occurring over the 60 years.

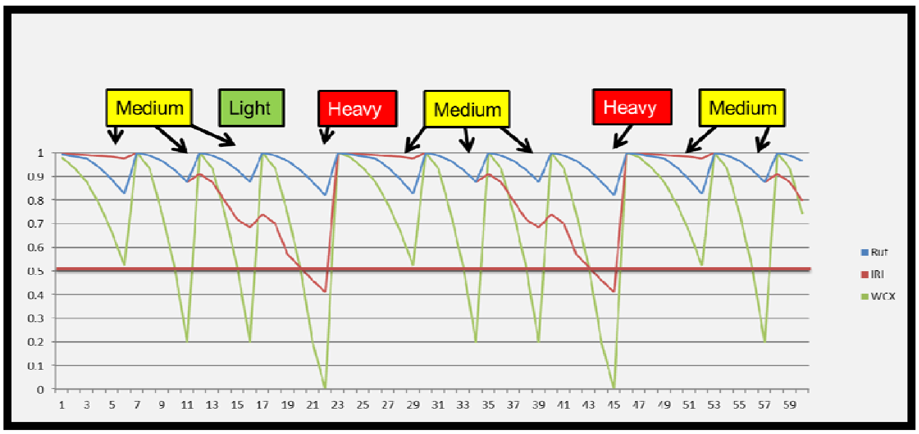



Figure 3 - simplified life cycle over 60 years

As an additional consideration if the current network has 80% good then the 60 year life cycle should have 80% of all years in good condition. This is because we are trying to **sustain the current system**. Achieving a sustainable level of good condition throughout the 60 year lifecycle influences the treatment timing by dictating how long to wait after a distress is poor before applying a treatment.

Throughout the 60 years life the segment is in various conditions states. Each condition state has a cost of maintenance included as part the lifecycle costs. Generally speaking as condition gets worse maintenance costs increase. It is important that this relationship is captured in the lifecycle of the highway.

The information about treatments, conditions states and maintenance costs are entered into a lifecycle costing (LCC) software as illustrated in *Figure 4 - Typical Life Cycle in LCC software*. The software shows diagrammatically the expenditures per year throughout the life cycle. It also allows you to set the discount rate to take into account the time value of money. Once a lifecycle is entered into the software it then computes the net present worth(NPW) and equivalent annualised cash flow (EACF) for that lifecycle. The EACF is what it would cost each year to pay off the NPW at a steady amount of money each year for the lifecycle period. Therefore, EACF is particularly useful tool to use in an economic analysis which looks at a long time period and reasonably steady annual payments.

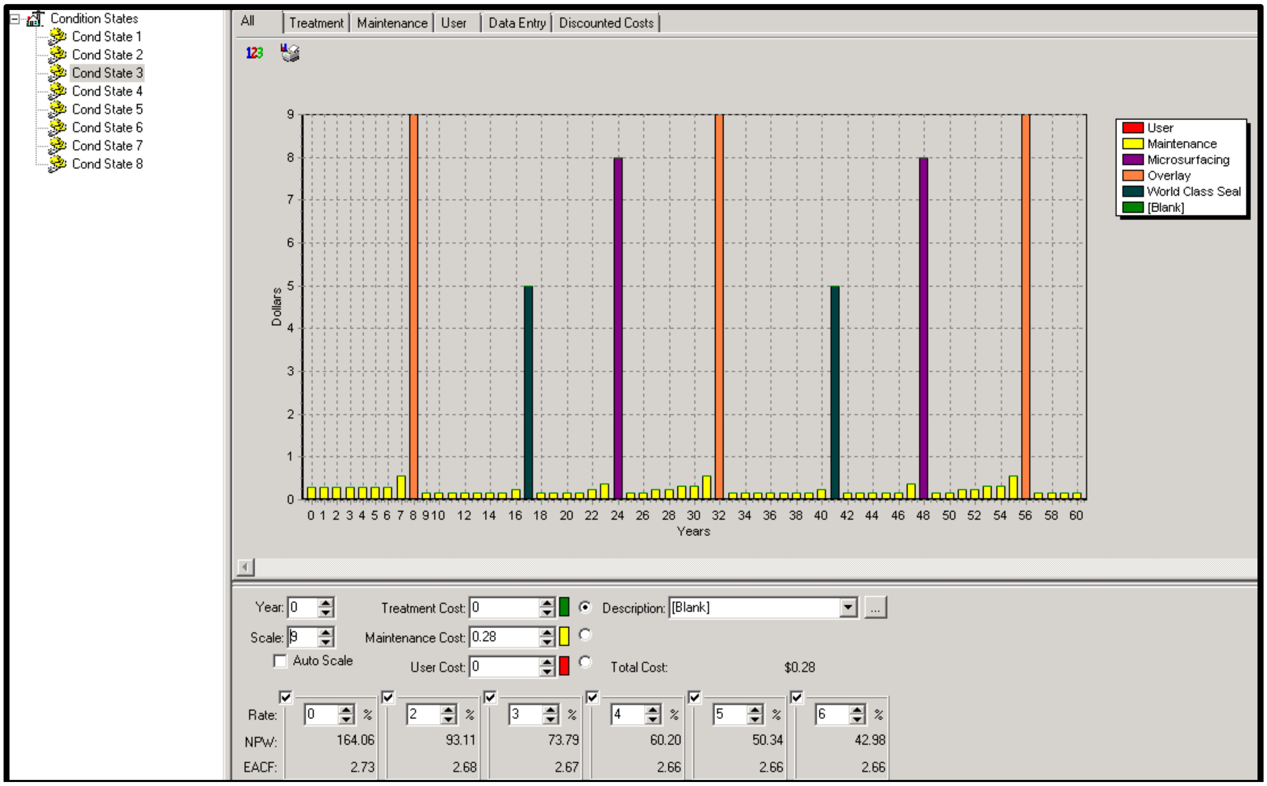



**Figure 4: Typical Lifecycle in LCC Software**

In the case of Saskatchewan and Manitoba both Agencies have eight possible conditions states so the lifecycle analysis of the network is done for each of the eight conditions states.

| Region | Network | CS | EACF | TARA | Total Cost |
|---|---|---|---|---|---|
| 7 | EG | 1 | $ 1.91 | 8,849,091 | $ 16,901,764 |
| 7 | EG | 2 | $ 2.42 | 5,429,622 | $ 13,139,685 |
| 7 | EG | 3 | $ 3.24 | 476,394 | $ 1,543,515 |
| 7 | EG | 4 | $ 2.69 | 368,422 | $ 991,055 |
| 7 | EG | 5 | $ 2.98 | 474,914 | $ 1,415,244 |
| 7 | EG | 6 | $ 2.98 | 772,921 | $ 2,303,305 |
| 7 | EG | 7 | $ 3.19 | 207,821 | $ 662,949 |
| 7 | EG | 8 | $ 3.20 | 32,025 | $ 102,480 |
| | | | | | |
| | | | | | $ 37,059,996 |

**Figure 5 - Sample Results of the Life Cycle Calculations for a Network**

*Figure 5 - sample results of the life cycle calculations for a network* shows some actual results from a network in Saskatchewan (Note TARA is the area of pavement inventory in square meters). As can be seen from figure 4 the calculated Equivalent Annualized Cash Flow (EACF) is different for each condition state. As you would expect the best condition states have the lowest EACF and the worst conditions state has the highest EACF. EACF is reported in dollars per square metre. So once you know that value for a condition state and you know the total area of the conditions state in the network you can simply multiply the EACF by the total area of that condition state on the network to determine the total dollars needed per annum for that state. The dollars per condition state is summed producing the dollars per annum for the entire network. In figure 5 the EACF for the network is shown in the lower right hand corner.

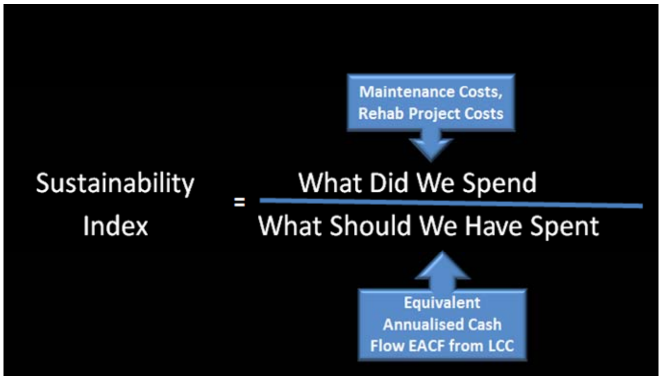



Figure 6 - the Sustainability Index Calculation

With good information it typically takes about a day for an experienced person to do a sustainability calculation on an entire network.

Figure 6 shows how the dollar amount of what is needed is compared to the dollar amount of what we have been spending to come up with an index. The index is called the Sustainability Index (SI). From figure 6 it is evident that if we are spending more than what's needed the SI will be greater than one and if we are spending less than what is needed the index will be less than one. Both Saskatchewan an Manitoba have done this calculation quite a few times now and have some confidence in the method delivering what they feel are realistic results. It should be noted that the "what did we spend" portion of the index is usually based on the last three years average to smooth out any annual irregularities in funding.

**THE INTENDED USE OF THE SUSTAINABILITY INDEX**

As the sustainability index uses most of the condition information about the highway network it is seen as being a key performance measure for decision-making over a longer period of time. As it is made up of the ratio of the actual expenditure to the needed expenditure any variation in either value will lead to a change in the index (*see Figure 7*).

For example, if the expenditure remains static but the condition gets better the sustainability index would improve because the sustainable cost would be getting lower. Assuming the information that went into the calculation was accurate this would most likely occur where the funding level is above what is needed to sustain the network and therefore it will actually improve the network under constant expenditure. The green line in the chart illustrates this. Conversely should a network be underfunded and its condition is getting worse over time then with constant funding the SI curve could look like the red one in the chart. The purple line would occur if both condition is getting worse and funding dropped further.

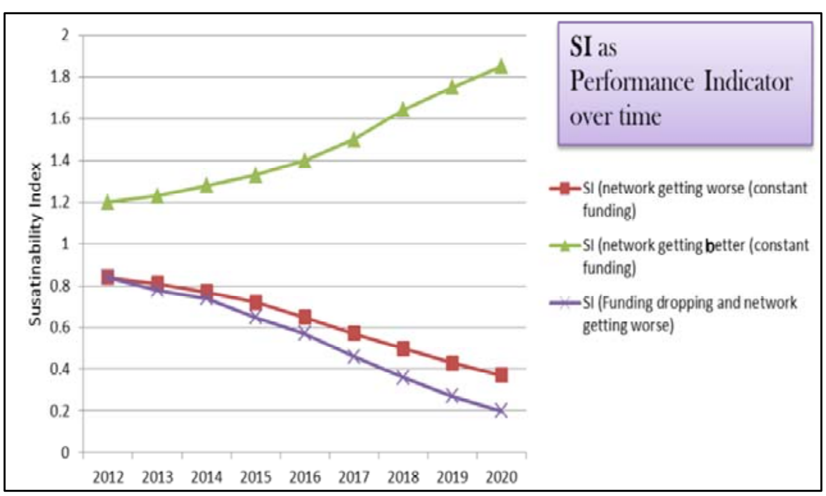



Figure 7 - How the SI could change over time

As can be seen from the above discussion the sustainability index is potentially a valuable performance measure for assessing the for evaluating the level of investment into a variety of networks. It is particularly valuable when comparing a network investment to another network investment over a period of time. We believe the index will support goal setting within both Manitoba and Saskatchewan.

## THE CHALLENGES IN APPLYING THE METHOD

Both Saskatchewan and Manitoba have come across similar challenges in applying the method described earlier in this paper.

### Treatment Performance

The biggest challenge in both agencies has been to accurately identify the actual performance of treatments over a long period of time. Both agencies are putting significant effort now in to updating and maintaining a treatment history database that will enable the condition to be accurately correlated with the treatment that was most recently applied.

The actual shape of the distress curves probably has the biggest impact on the result of the lifecycle calculations. As mentioned above, not knowing how each distress typically behaves after applying the treatment is a huge limiting factor in doing the lifecycle. Performance curves that are typically used in a pavement management system are usually not applied for subsequent treatments. However what has been discovered is that the mere act of doing the life cycle has also refined the estimated performance curves. Doing the 60 year life cycle analysis will quickly highlight deficiencies or inconsistencies in performance curves which can then be modified to give more realistic life cycles. The reality check is that if the lifecycle is constantly suggesting a certain treatment is needed which rarely would be applied in reality then that would indicate there is some anomaly in the performance curves.

### Treatment Intervention Timing

Another issue is quantifying how long a distress would exist in a poor state before it would be treated. The delay in treating in normal circumstances is due to the need to identify the problem in the first place then allow it to get sufficiently bad to be treated and then get that treatment into a program with a budget. Simulating all of this in the lifecycle for each treatment has been a challenge.

### Identifying the Actual Expenditure

The actual expenditure in the calculation is the average of the last three years. The expenditure covers maintenance and rehabilitation. It does not cover maintenance that does not affect the pavement and it does not cover capital projects that were enhancements to existing infrastructure or new infrastructure. Getting this number accurately for the previous three years has not been easy for either organization.

### How to Update the Index Annually

Another issue that has been discussed is the need to update the sustainability index annually in a reliable and consistent way. The annual updating process needs to be efficient but take into account new condition and new costs without disrupting the valuable trend analysis of the index. Discussions so far have centered around the need for some new information to be applied backwards to update the history while some information should only be applied from this year going forward. Which parameters should be updated for the past analysis is the subject of discussions and the design of a process at the moment.

**CURRENT SITUATION**

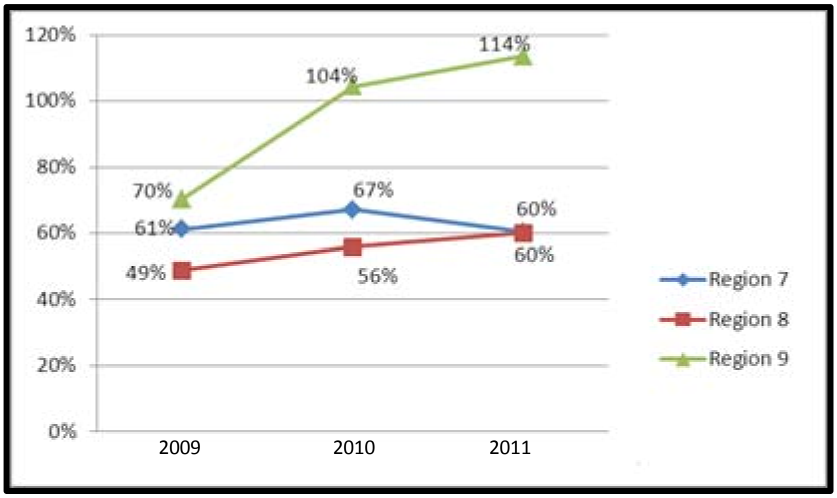



Figure 8 - Example of Early Results of a Multiyear Comparison

Saskatchewan is currently building a business process for decision-making on networks that includes the use of the sustainability index to determine funding levels and to set goals for networks. The sustainability index will be one of a few performance measures that will aid senior decision-making.

*Figure 8 - example of early results of a multi-year comparison* shows a comparison that was done early in the project by Saskatchewan. This type of use of the SI is driving the need to ensure the information is accurate so the comparisons are valid.

This past year is the first that Manitoba Infrastructure and Transportation has engaged in the process of determining a sustainability index for its three primary networks. Manitoba is working towards further refining the sustainability index with the goal of moving it into part of the annual reporting process to support senior decision makers. At present, two-thirds of Manitoba's Networks are providing meaningful sustainability indices.

**THE NEXT STEPS**

One of the main challenges to be addressed in the near future is the annual updating process. The sustainability index is only useful if it does have an annual update based on new condition, and new costs. To maintain the ability to trend the index over time when the costs are updated we need to be careful to ensure that does not affect the relevance of the history to date.

There have also been discussions about creating a benchmark lifecycle which all segments' performance can be compared against to rapidly identify whether or not the lifecycle is typically representing the network or not. Another issue is how to take into account new treatments (innovations) when updating the life cycle. Saskatchewan has already used the life cycle approach to identify the benefits of new treatments compared to existing ones. *Figure 9 - sustainability index annual updating business process* shows some of the early thinking in the development of this annual updating process.

In conclusion both agencies have used the SI as part of becoming familiar with how to look further into the future and identify funding needs and any shortfalls. Both agencies have personnel who are very familiar with the treatment costs and performance models. Both agencies have also tracked maintenance to condition segments for many years so they have a fairly good understanding of the relationships between maintenance and condition. There is much work still to be done to refine the precision of the analysis and the inputs to the process but both agencies are treating that as a priority at the time of writing this paper.

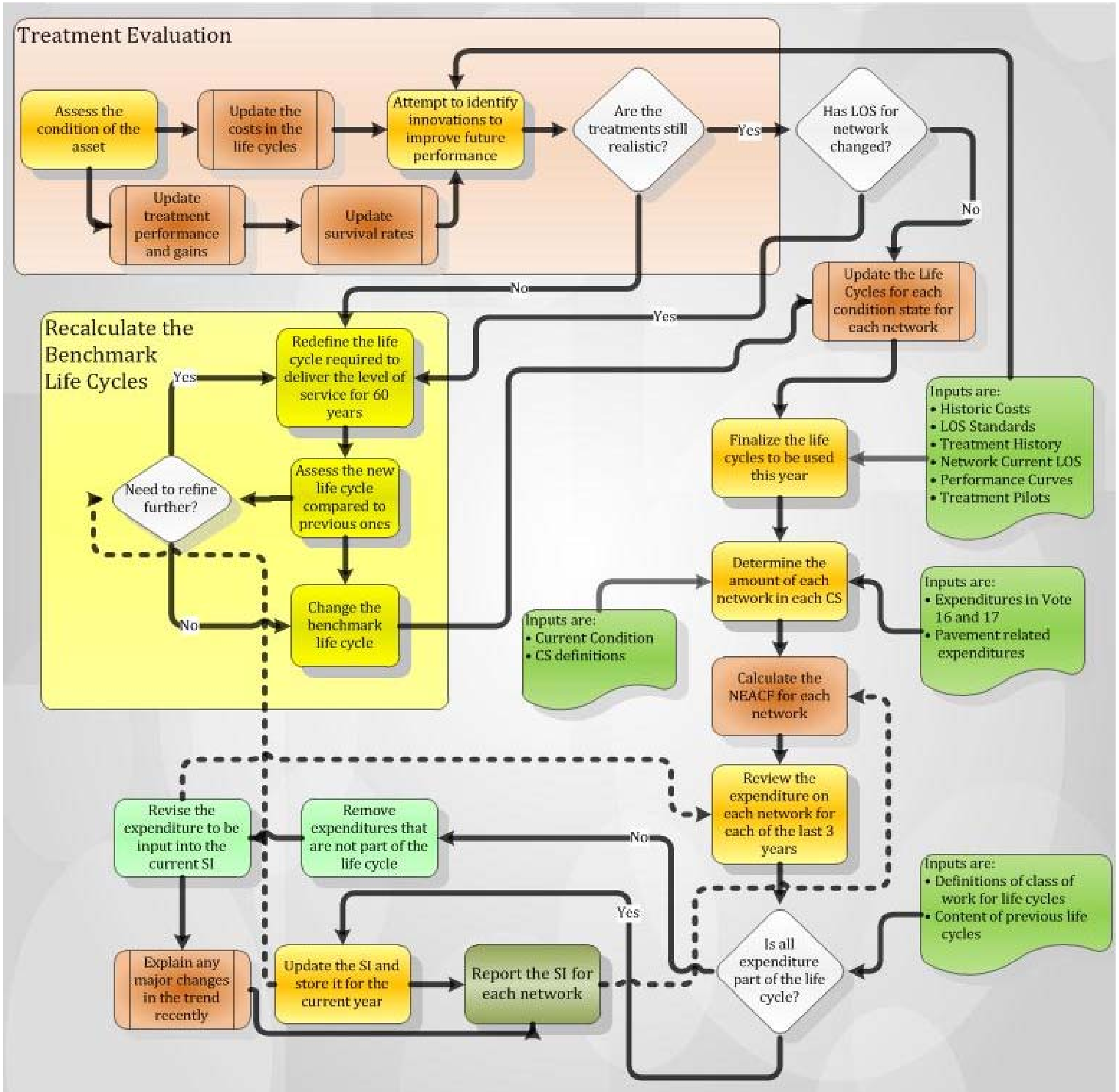



**Figure 9 - Sustainability Index Annual Updating Business Process**