Innovative approach for the condition assessment of infrastructure within right-of-ways

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Abstract

Information Management Systems and Expert Systems enable asset managers to maximize the use and value of the information available. The challenge in the asset management field is usually to combine multiple sources of information and specialized applications, such as Pavement Management Systems (PMS), into the decision making process without affecting the reliability of the analysis nor the evolution and update of information stored. When several systems and different types of assets are involved in the decision making process, the complexity of the analysis is considerably increased. That is why we need a structured and integrated approach.

This is the purpose of newly developed Decision Support Systems (DSS). These DSS further improve the use and the value of the information considered in the decision making process. In this manner, a proper assessment of a roadway section will not only consider the structural integrity and surface quality of a roadway as obtained through field testing, it should also consider riding comfort, safety and the socio-economic aspect associated with that roadway section. So, the addition of relevant parameters in the decision-making process enhances the justification and accuracy of a capital improvement plan. The addition of Geographical Information Systems (GIS) to the environment will also assist managers in the planning capital improvement works by providing a colour coded view of the results and will bring a new dimension to data querying.

On this note, the emergence of **Integrated** Decision Support Systems (IDSS) provides a new look at how public services are managed. An IDSS will assist decision makers in performing global analysis of adjacent roadway assets (pavement structures, bridges, culverts, etc.) simultaneously, while considering adjacent infrastructure and utility networks such as gas, telecom, water and sewer. This means decision-makers can, with minimal efforts, produce short and long term capital improvement plans while ensuring coordination and proper timing of rehabilitation activities on all networks, thus maximizing the effectiveness of the funds available.

The following paper provides a case study on the assessment and the analysis of the condition of municipal infrastructure assets within the public right-of-way using an **Integrated** Engineering Management System (IEMS). The paper also presents an

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overview of the range of benefits that can be achieved by using a computer software application to assist decision makers in the management of municipal assets using an integrated approach.

Introduction

A general lack of knowledge of the condition of infrastructure, how long it has been in service and combined with the limited financial resources make it sometimes very difficult to determine which improvements to make, and when to make them, in order to ensure the sustainability of infrastructure. General deterioration of infrastructure in the past few years increases the risk of catastrophic breakdowns and calls for short-term action to be taken by decision-makers.

Over the last few years, harfan technologies inc. has participated in several major projects that have increased awareness of the condition of water, sewer and road infrastructure for asset managers through the use of Integrated Decision Support System (IDSS). An example of an implementation of such a system is the City of Sainte-Foy, now part of Quebec. This project allowed the experimention and validation of a structured methodology to analyze numerous urban infrastructure networks, in a global asset management approach.

The following pages present the steps that helped building a complete condition assessment considering a PMS. The scope of the analysis is separated into three parts: Maximize available information, Condition assessment analysis and results and Integration of other networks. The first part is based on an implementation of an IDSS at the City of Montmagny[4]. The second and third parts are based on the city of Sainte-Foy (today City of Quebec) that has a road network of 350 kilometres. Furthermore, we are focusing on a condition assessment that is network-wide as opposed to a project level assessment.

Maximize available information

Efficient management of data

At the City of Montmagny, a review of the existing data helped identify all data repeated in several databases throughout the organization. This duplication of data usually results in a cost increase of maintaining the date current, as updates always need to be done in several different places at a time. In addition, all data was not easily available to all departments of the organization. There was also a risk that any given piece of data would not have the same quality or value in every database, resulting in a lack of reliability towards this information.

Validation of existing data

[4] Road network of 100 kilometers-long, 12,000 inhabitants.

In the first part of the project at the city of Montmagny, an analysis was made in order to only select the required data to obtain results with a particular level of confidence. This analysis is very important as it reduces the quantity of data to be collected and filtered from existing databases, which also reduces the quantity of data that must be updated to maintain current.

Organizations typically hold an enormous amount of information on their infrastructure, and this information may be stored electronically, on paper or simply as part of the corporate knowledge. The validation of the reliable of existing data usually allows for the recovery of large quantities of valuable data at a lower cost than field data collection.

In the process of building a reliable and precise condition assessment, we have been able to recover a large amount of date from numerous sources. Some of these sources are listed below.

Table I : List of sources of information related to the right-of-way condition assessment

Source	Attributes
Autocad drawings	Location information, pavement width, material
Past condition assessment	Surface Condition Index, Roughness Index, Overall Condition Index
Engineering files	Past lining projects (cost)
Bicycle lane Project	Location information, width
Culvert listings	Location information, diameter

By selecting the right information and recovering existing data that have been identified as being reliable, the organization has been able to make substantial savings. For example, the city of Montmagny has recovered data worth $250,000.

Condition Assessment Analysis and Results

Actual condition analysis

The condition assessment models used an index structure developed by harfan, validated by the École Polytechnique de Montréal. A sample of this index structure is demonstrated in the figure below.

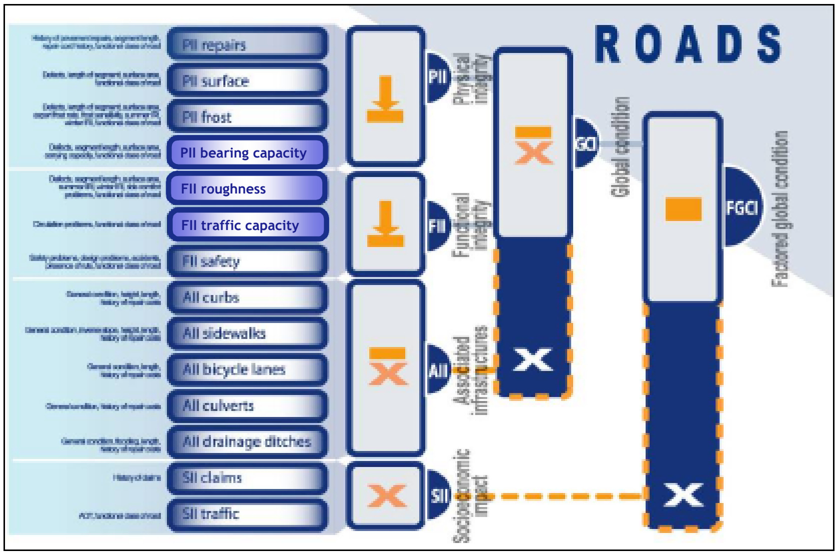

Figure 1 : Index structure of the harfan condition assessment for road system.

The main purpose of this model is to maximize the use of the information available and still get a reliable result for condition assessment. Each one of the main indices (P11, F11, A11 and S11) is explained in Appendix A.

The principal advantages of this structure are:

- Even with only a few pieces of the available information, such as the material, year of installation, and the length, the analysis can be conducted.
- For organizations with no exhaustive survey on the condition of their networks, assumptions can be made.
- The use of staff or client complaints can become a complement to the theoretical analysis (e.g. Request Management System).
- A number of parameters can be adjusted so that the system respects the level of service required by the organization.
- The use of a PMS can highly complement the results of the decision model to build a good analysis of the surface aspect, called “physical integrity” in the index structure.

It is the combination of the structural assessment and the safety analysis that makes a condition assessment extensive and complete.

Access to the condition assessment results

An IDSS must be part of an open architecture that allows it to be linked to any GIS on the market and demonstrates the results on a map with a colour coded view. An example of the results given for the study area of City of Sainte-foy is presented in the figure bellow. The organization had already in place the Autodesk GIS solution. Harfan technologies has made available an application driver to add a menu and a toolbar with features into existing and renown GIS packages. Those features provide an interaction between the two systems. The existing driver for the condition assessment DSS module was applied.

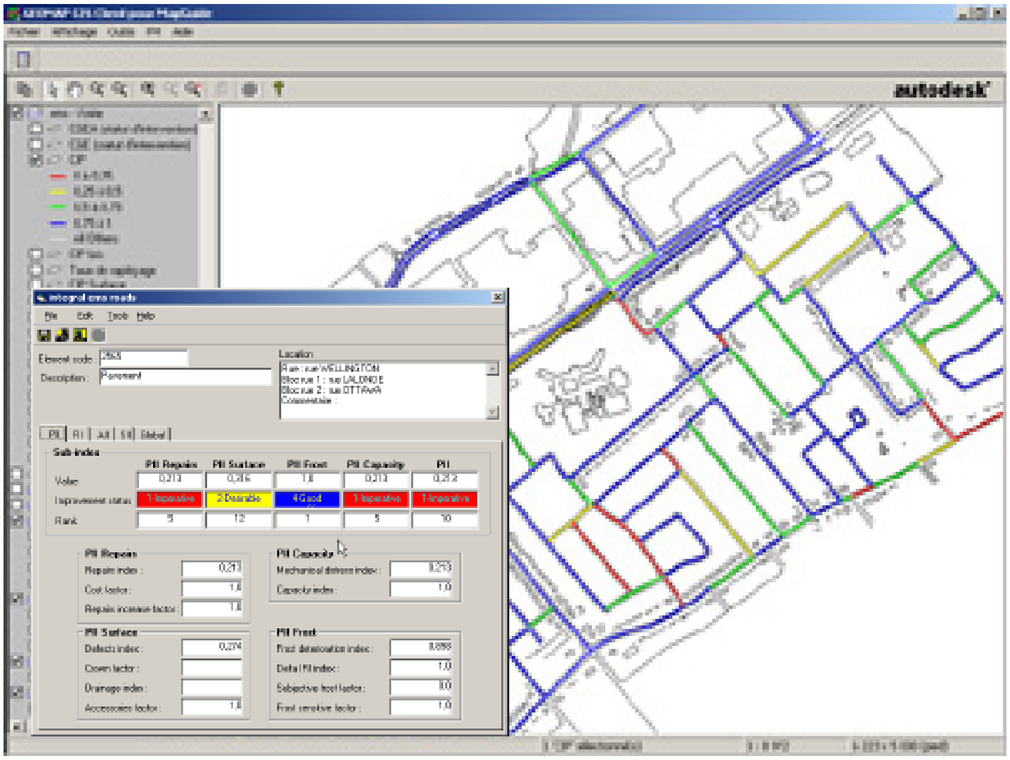

Figure 2 : Viewing of results with GIS driver and harfan ems

Future condition using deterioration curves

To determine which type of improvement to do, we need to get a broader range of possibilities that cannot be given by the actual condition alone. It is now time to include deterioration curves in the analysis. This will help to determine the right time to improve the network segment.

Based on a theory coming from MM. Kleiner and Rajani from the National Research Council of Canada (NRC)(Kleiner and Rajani 2002), we have built deterioration curves for road sections. The process of building deterioration curves encompasses three steps:

- First, group road sections having the same pavement material, traffic, year of construction, past rehabilitation projects, soil conditions.
- Second, identify the defects that occurred in the past, for each group of conduits.
- Finally, draw curves of cumulative defects for each year of age of the road segments.

Since we have good history of defects on some of the segments, we will always prefer the actual condition to the condition given by the curve as a starting point for the forecast of the condition. In the example below, we will take the actual condition instead of the condition dictated by the age of the conduit.

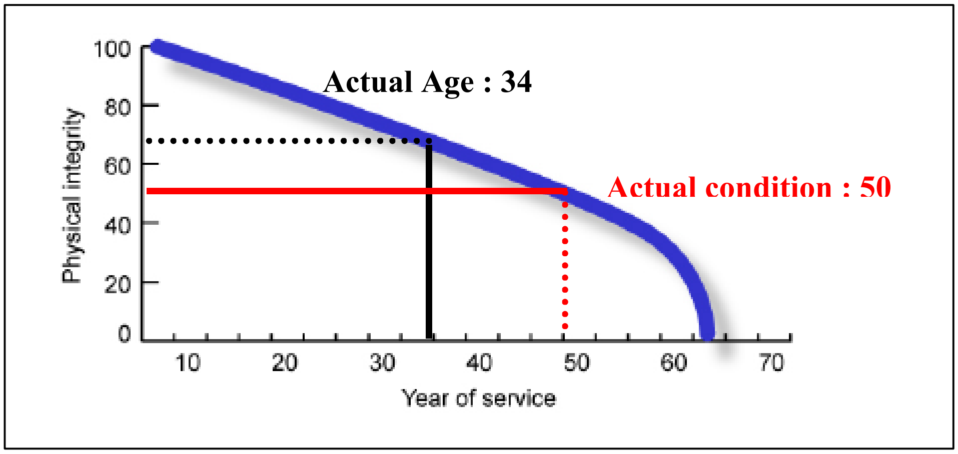

Figure 3 : Use of deterioration curves

Integration of other networks

Integration of other network and economic analysis

To complete a capital plan, we did not need to only take into account one network but the actual and future condition of nearby networks.

The integrated analysis of adjacent networks – in our case water, sewer and road – has brought an entirely new vision for the prioritization of works to be done. The consideration of the condition of each infrastructure as part of an "integrated segment" – a right-of-way segment – has helped decision-makers understand a street's overall condition, rather than the condition of each separate infrastructure. The establishment of selection criteria for determining the types of improvements to be done also helped identify the segments where new rehabilitation techniques would be more appropriate than a complete reconstruction of infrastructure, therefore reducing overall costs of improvement.(Lalonde and Prince 2001)

The use of an IDSS has greatly improved the quality of information available on infrastructure by establishing the condition of each segment according to various criteria. For example, the ability to create different improvement scenarios and compare results between scenarios helps refine proposed solutions and flesh out the planning of public works. Even though the level of knowledge in infrastructure has notably increased for technical personnel and decision-makers, the implementation of an IDSS has nevertheless raised new questions requiring even more precise, complete answers on different elements. One example might be the condition assessment of infrastructure if no improvements were made over a determined number of years.

In other words, decision-makers want to manage the risk of major breaks occurring over several years and to plan improvements before the level of risk becomes too high. In the same vein, the evaluation of life-cycle cost will also provide valuable information to technical personnel and decision-makers.

Conclusion

This paper has demonstrated the steps to build a relevant and complete condition assessment, considering all infrastructures within the right of way. By using only a PMS, you would put aside some precious elements of the decision making process for state-of-the-art right of way management.

First, at an economic level, the analysis of data, in order to identify exactly which information is needed for achieving results of a certain precision, significantly reduces the costs of initial data collection as well as the cost of later updating.

Secondly, the condition assessment can be conducted according to an index structure which has been presented in part two. The aspects that have to be taken into consideration are the physical integrity, the functional integrity (serviceability), the condition of relate assets and the socio-economic impacts. The future condition has also to be put in perspective to give a good idea of what should be done as an improvement for the network segment.

Thirdly, every capital improvement plan should include the other networks in the decision making process. Having a global view of the condition of nearby assets, forecasting the right moment for doing an improvement becomes easier for technicians.

Finally, the experience in each of the city mentioned in the article was very enriching for asset-managers. Since we used cutting-edge technology in the decision-making process, the project presented an interesting technical challenge that was very motivating for asset managers. At an organizational level, the interaction between decision-makers and technical personnel is greater than before. At the beginning of the process, decision-makers are involved in determining the service level a City wishes to provide its citizens. Afterwards, the presentation of the integrated capital improvement plan is very interactive as technical personnel are able to answer decision-makers' questions very precisely as well as being able to compare the condition of different segments.

References

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Appendix A Definition of the main indices

Physical integrity index (PII): The Physical Integrity Index (PII) is evaluated with parameters translating the degree of importance of the anticipated degradations which justifies improvements because it can affect the future capacity of an infrastructure to fulfil its function. Robert Klusman states the rules to follow in the implementation of a Maintenance Management System for a water network and mentions: “Systems or areas of high priority should include *those with high failure rates* or recurring problems and those that have a high safety environmental or cost impact”. He adds: “[…] mechanical integrity is a priority in all situations where potential safety and environmental impacts are significant” (Klusman 1995) .

The Functional Integrity Index (FII) is evaluated with parameters translating the capacity of an infrastructure to fulfil its function. For the water and sewer networks, an evaluation of the networks’ hydraulic capacity (Modeling System) is needed and for the road network, we need the ride comfort and traffic fluidity.

The Associated Infrastrucre Index (AII) is a measure used by the system to consider all associated infrastructure in order to prioritize two segments which are in similar conditions.

The Socioeconomic Impact Index (SII) measures the impact that a negligence on the physical and functional integrity of infrastructure can have on the clientele when doing emergency improvements.