Our Efforts to Understand Roadway Assets Conditions and Management Techniques in Small Communities of Newfoundland and Labrador, Canada

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ABSTRACT

There exists two factors to assist in deciding whether or not a municipality should expect to have a roadway management system, these being population size and road network size. A large population tends to contribute more vehicles to the roads, which leads to frequent maintenance needs and therefore requires a road management system. Municipalities with large road networks may choose to follow a road management guideline to optimize their maintenance schedules. But, in some cases, municipalities with only a few kilometers of roadway can play a vital role in the provincial road network, especially when those roads link important destinations. So, a few pertinent questions arise. Do population size and road network length determine whether a municipality or town adopts a road management system? How do municipalities with small population size and shorter road networks manage their roads? What can be the most feasible way for those municipalities to manage their roads? To answer these questions, a province-wide municipality staff survey was conducted in Newfoundland and Labrador (NL), Canada. Most of the municipalities in this province are sparsely populated, and the internal road networks are very small. The survey was conducted to determine the condition of the roadway assets in these small municipalities, the resources available, and the requirements of roadwork by transportation departments to do in order to improve their roads. This project was not a government-funded project, and there was no incentive for the participants. Therefore, participation was completely voluntary. The results provide significant information about roadway asset conditions and management systems in the municipalities.

Keywords: Pavement management system, Pavement condition data, Pavement distress, Municipality, Small communities, Low volume road, Local road, Agency.

INTRODUCTION

A pavement management system (PMS) can be defined as a combination of procedures for referencing, collecting, analyzing, and reporting pavement related data to assist authorities in deciding ideal strategies for maintaining pavements in a usable condition over a defined period of time (*1*). An effective PMS has the potential to save agencies a substantial amount of money. It is important to know the optimal timing for maintenance operations to be conducted in order to successfully manage the roadways. Failure to address maintenance needs at the proper time often results in deferral of the project, and a deferred project generally costs more due to inflation (*2*). For example, repairing a road at the 87^{th} percentile of its service life can cost five times more than it would if the road were to be repaired at the 75^{th} percentile of its service life (*3*).

PMS necessitates different kinds of data for its operation. Detail data, when available, will lead to a more sophisticated PMS. However agencies that have never had a PMS, have significant drawbacks in their maintenance operations, and have staff with little to no experience of pavement management, can institute a simple system to summarize all maintenance needs and effectively determine priorities (*2*).

It has been reported that with fewer road users, less funding is available for road maintenance, and less engineering techniques are applied (*4*). This is the main concern in NL as there are few road users in most of the municipalities. Therefore, it may prove more feasible to introduce a road users' group so that a number of neighboring municipalities can work together on their roadway issues. However, this concept absolutely depends on a number of factors such as jurisdiction, governing bodies, funding, location, and current roadway asset conditions (*5*). To understand all these factors, in the NL context, a province-wide municipality staff survey was conducted.

GOAL AND OBJECTIVE

The goal of this survey project is to understand roadway asset conditions and existing management systems in the less populated municipalities of NL, Canada. The study also aims to understand the effect of road network length and population size in adopting a road management system. The overall objective of this study is to determine the feasibility of introducing a road management system for the local municipalities of Newfoundland and Labrador which is the future scope of this research. In simple words before introducing a road management system for the local agencies this survey aims to investigate the existing practices.

The survey questionnaire has been written in a way that helps to understand the current management practices in the concerned municipalities as well as current roadway asset conditions. Considering the geographical dispersion of these municipalities, evaluating roadway asset conditions through physical survey would present high costs to the research team, even when using simple manual methods. Therefore, the idea was to understand the overall roadway asset conditions of the audience municipalities by asking questions to the municipal engineers and staff. The reliability of a physical pavement condition survey and rating from users is not all the same. However, this provides an idea about the current roadway asset conditions for developing a road management guideline, which is the future scope of this applied research project.

LITERATURE REVIEW

PMS was introduced in the 1960s as a result of numerous abrupt pavement failures on US Interstate and Canadian highways (*6*). While researching the reason for the unanticipated pavement failures, it was found that design at that time considered only traffic volume, material properties, and environmental conditions as inputs. The effects on the performance of pavement maintenance, as well as life cycle costs, were overlooked in designing pavements which have significant importance in determining pavement serviceability (*7*). PMS in Canada was introduced by Roads and Transportation Association of Canada (RTAC) in 1977 (*8*). RTAC became TAC in 1991, and a pavement management committee began to work on the up-gradation of 1977's PMS (*9*). In 1997 TAC published its updated version named "Pavement Design and Management Guide." The latest version of this PMS was released as a "Pavement Asset Design and Management Guide" in 2013 (*6*). The objective of a PMS may vary. According to Haas et al., depending on the agency (i.e., state/provincial, city, county), the focus and scope of the level of users may differ (*6*).

Pavement management decisions can be taken at three different levels; strategic level, network level, and project level (*10*). Policymakers make long term strategies, like setting performance goals, funding allocations at the strategic level. Decisions at network level deals with the present and future network conditions, and the requirements are generally within a 5-years time frame (*11*). Project level decisions are generally short-term strategies dealing with maintenance techniques, design, construction, etc. Components of a PMS can vary. Sophisticated PMS generally has many defined components, whereas a general PMS only contains the basic required components. Basic PMS components are discussed as follows:

Network defining and referencing system

A road network may consist of few to many kilometers of roads. It is important to define the network. Various parameters can be considered while defining the network, such as pavement structure (pavement materials or thickness), surface type (flexible or rigid, traffic (volume or pattern), etc.) (*10*). Agencies divide their road network into a number of manageable sections that can be referenced using a suitable referencing method. Various referencing methods are available. However, the spatial referencing system, GIS, has become very popular (*9*).

Detailed database

A PMS needs to have a detailed database. This database contains different types of data, for instance, inventory data, pavement condition data, traffic data, historical data, policy data, environmental data, cost data, etc. (*12*). Pavement inventory data vary at the network level and project level of the pavement management system (*13*). Network-level inventory data may include the general information of the network while project level inventory data comprise of data specified for a particular project. Pavement condition data vary at different levels. For example, international roughness index (IRI) and surface distress are collected at the network level by many agencies, but structural capacity is obtained primarily at the project-level (*14*). **Table 1** summarizes different kinds of pavement condition data collected at the network and project level (*13*).

Collecting traffic data such as average annual daily traffic (AADT), average annual daily truck traffic (AADTT), traffic growth, annual Equivalent Single Axle Loads (ESALs) are the requirements of a PMS. To determine the load equivalency factors, extensive research has been done, and as an approach, the AASHTO Road Test suggests using weight-in-motion (WIM) devices to estimate the number of ESALs (*15*).

Historical data is necessary for predicting future performance of pavement (*16*). Historical data can be divided into three categories, construction history, maintenance history, and traffic history.

Environmental factors have a huge impact on pavement performance. For environmental data, the focus is given on climatic issues like precipitation rate, temperature, freeze-thaw cycle and subgrade drainage condition, etc.

Policy data deals with the budgetary plan, maintenance, and rehabilitation alternatives, and provincial or territorial regulations. Policy data is a piece of backup information that is necessary for deciding issues in policymaking. Policies regarding the hiring of full-time staff can be tied to the population size rather than the network size since the biggest need for tax funds may be directly related to wages paid to the employees (*17*).

Cost data may include initial construction cost, maintenance cost, data collection and processing cost, employee cost, user cost, etc. It has been estimated that pavement condition data collection and analysis may cost an agency from $2.23 to $10.00 per mile (*18*).

Table 1 Types of data collected at network and project-level for PMS

Feature	Network level	Project level
Distress data collected	• IRI • Rut depth • Faulting • Cracking • Punchouts • Patching • Joint condition • Raveling • Bleeding • Surface texture	• Detailed crack mapping and other distresses • Structural capacity (e.g., falling weight deflectometer [FWD]) • Joint load transfer • Base/soils characterization (e.g., ground-penetrating radar, cores, trenches)
Other data collected	• GPS coordinates • Geometrics (e.g., curve, grade, elevation, cross slope) • Road assets such as bridges, culverts, signals • Events (e.g., construction zones, railroad crossings)	• Detailed crack mapping and other distresses • Structural adequacy measures (e.g., Falling weight deflectometer, FWD) • Base/soils characterization (e.g., ground-penetrating radar, cores, trenches)

Uses	• Planning • Programming • Budgeting • PMS treatment triggers • Identification of candidate projects • Life cycle cost analysis • Condition reporting at the network level • Mechanistic-Empirical Pavement Design Guide (MEPDG) calibration	• Detailed crack mapping and other distresses • Structural capacity (e.g., falling weight deflectometer) • Joint load transfer • Base/soils characterization (e.g., penetrating radar, cores, trenches)
Speed characteristics	Highway speeds	Slower speed or walking

Pavement condition evaluation system

An agency needs to have a condition evaluation system. Pavement condition détermines pavement performance. Agencies collect individual distress data and express the magnitude of the distress in terms of density and a severity scale. Density defines the frequency of the distress; severity defines the extent of the distress (MTO 1989). Evaluation of density and severity levels depend on the protocol or the manual the agency follows.

Different distresses may be transformed into one single expression to describe the overall condition of the pavement. According to the NCHRP report of 2004 on pavement management, around 80% of the agencies combine their distress rating or index with other ratings or indices such as roughness. **Table 2** shows combined distress expressions by some agencies (*19*).

Table 2 Pavement condition indicators used by the US and Canadian agencies

Agency	Rating name	Agency	Rating name
British Columbia	Pavement Condition Ratio (PCR)	Hawaii	Pavement Condition Index (PCI)
Newfoundland & Labrador	Pavement condition Index (PCI)	Illinois	Pavement Condition Survey (PCS)
Ontario	Pavement Condition Index (PCI)	Maine	Pavement Condition Rating (PCR)
Arizona	Present Serviceability Rating (PSR)	Minnesota	Ride Quality Index (RQI)
California	Pavement Condition Survey (PCS)	Missouri	Present Serviceability Rating (PSR)
Colorado	Remaining Service Life (RSL)	New York	Pavement Condition Index (PCI)
Delaware	Overall Pavement Condition (OPC)	Ohio	Pavement Condition Rating (PCR)

Florida	Pavement Condition Rating (PCR)	Wyoming	Present Serviceability Rating (PSR)

There are established protocols and manuals for evaluating pavement conditions. However, an agency may develop its own based on needs.

Maintenance and rehabilitation priority program

For carrying out maintenance and rehabilitation tasks at the appropriate time with limited funds, a priority program is a requirement. Integration of information, identification of possible needs, priority assessment, and output reports are four necessary steps to develop a priority program (*9*). Different transportation agencies follow different priority models. Parametric ranking, subjective ranking, economic ranking are some of the common priority models employed by transportation agencies. However, big agencies adopt mathematical program-based optimization or comprehensive optimization for more appropriate decision making.

Performance prediction model

Pavement deteriorates with time due to multiple factors, including traffic load, poor maintenance, harsh environmental condition, etc. Performance prediction models have been categorized into two types, deterministic and probabilistic (*20*). Deterministic models consider the primary response, functional performance, structural performance, and damage models. Probabilistic models may include Markov chain (MC) models and survivor curves (*20*). The main advantage of the probabilistic prediction model lies in its ability to identify and aid uncertainties in design analysis leading to reliability-based pavement designs. Yang et al. (*21*) find pavement performance gradually decreases with the increase of construction age and the traffic load times; its changing phenomenon is related to the pavement structure in the past. The approach for developing a performance prediction model mostly depends on the parameters taken into consideration.

Life-cycle cost analysis tool

A life cycle cost analysis tool determines the cost-efficiency of alternatives in terms of Net Present Value (NPV) (*22*). The concept of LCCA in terms of life-cycle cost-benefit analysis was first introduced by the American Association of State Highway Officials (AASHO) in its Red book version in 1960. There are different LCCA models adopted by different agencies. Some well established LCCA models are Whole Life Costing System by the USA, COMPARE by Great Britain, QUEWZ by Australia, Highway Design, and Management (HDM I to IV) by the World Bank (*22*).

SURVEY DESIGN

The survey questionnaire was developed after an extensive literature review on pavement management systems and low volume road maintenance techniques. Suggestions were taken from a municipality engineer as well as from some local citizens of Newfoundland, to ensure the efficacy of the questionnaire. Basic pavement management components were covered in the questionnaire.

The design of the questionnaire considered that participating municipalities might not have an asset management guideline. Therefore, it was developed in a way that non-technical staff could understand the technical questions. A total of 36 questions were asked though this number might vary for each participant based on their responses. The questionnaire was divided into two parts. In the first part, general questions were asked, and, in the second part, linked questions were asked.

In the general question section, participants were asked to prioritize the components of the roadway assets they wanted to be improved, based on their current condition. They were also asked to provide their opinion on budget allocation and to report any resources available that could be used in roadway asset management.

In the linked part, for example, participants were asked to choose the classes of roads maintained under the jurisdiction of their municipalities. Based on their response, they were taken to a pavement condition evaluation questionnaire. Pavement distresses, with pictorial references were shown and participants were asked to rate those distresses. Another linked question was to choose the types of resources available in their municipalities. For each type of resource selected, the participants were given a set of options to select what tools/equipment were available under the selected category.

The survey aimed to understand the components of a pavement management system available in the municipalities. Therefore, questions were asked with respect to the components described in the literature review section. The survey was anonymous, and participants had the freedom to skip any question.

The scope of this survey study is focused on low traffic volume roads. Newfoundland and Labrador have around 13,500 lane kilometers of roads. Local roads contribute 7,664 kilometers, making them 56.8% of the total road network of the province. There are 276 municipalities in this province, of which 262 have a population size smaller than 5,000. These 262 municipalities were considered as small municipalities and therefore addressed as the audiences of the survey.

The objective of this survey is to understand how small communities manage their roadways, while considering that they may not have a management system. Consequently, this work aims to understand the overall condition of their roadway assets and what management practices can feasibly be introduced to these small communities.

EFFORTS FOR SURVEY RESPONSE

Email addresses of the audience municipalities were collected from the association of municipalities of Newfoundland also known as MNL's municipality directory. Seven municipalities did not have an official email address and therefore were unable to be contacted, shrinking the size of potential participants from 262 to 255. The survey questionnaire was sent through email, and a reminder was sent after a week to the nonresponding audiences. Response collection was active from June 9th to July 28th of 2020. Many municipalities did not have designated staff for road management or for taking this survey, and in some cases, mayor or councillor was found to be voluntarily working as a municipal staff. For other municipality staff, it was difficult to invest time to take the survey as the number of staff in those municipalities was limited, and there were other local issues to deal with. Therefore, these people were contacted individually over the phone to encourage them to take part in the survey. Thanks to the Canadian Broadcasting Corporation (CBC) "St. John's Morning Show", which conducted a live interview on this survey and featured this project, which helped in increasing the number of responses.

FINDINGS

As indicated, the survey was sent to 255 municipalities with a population size smaller than 5,000, cognisant that smaller communities have fewer vehicles on the road. **Table 3** represents the population range of the municipalities and the number of responses received from each population range.

Municipality staff were asked a total of 36 questions. As the survey was anonymous, the first question was whether the responding municipality staff was an engineer or not. Of the 53 responses received, only 5 of them were by an engineer.

Table 3: Population range and the number of responses received from the target municipalities.

Population range	Number of municipalities	Number of responses
Less than 100	17	5
100 to 499	136	23
500 to 999	65	10
1000 to 1999	23	7
2000 to 2999	16	6
3000 to 5000	5	2
Total	**262**	**53**

Figure 1 represents the location of participating or audience municipalities in green and responding municipalities in red. Most of the responded municipalities are in Newfoundland, the island portion of the province, which is home to almost 500,000 people. In this figure, base map shapefile and municipality coordinate data were collected from the "Open data" and "Latitude" websites.

Road network

Figure 2 is drawn with the data obtained from the survey. The response showed that the network length within these municipalities varies from a minimum of 2 kilometers to a maximum of 50 kilometers. As the survey offered the option of skipping any question, almost 15% of respondents chose not to answer, and 5% of respondents were not sure about the network length. This figure also shows that seventeen municipalities own less than 10 kilometers of road networks. Thirteen municipalities have 10 to 20 kilometers of roads under their jurisdiction. Cumulatively, almost 80% of the responding municipalities own a network size under 20 kilometers. Only three municipality staff confirmed that their municipalities own more than 30 kilometers of network.

Figure 3 represents the classes of roads municipalities own. It shows that 13 municipalities have minor arterial roads under their jurisdiction, and seven municipalities have collector roads alongside the local roads. 86% of the responding municipalities have their local roads paved, while six municipalities have only gravel roads.

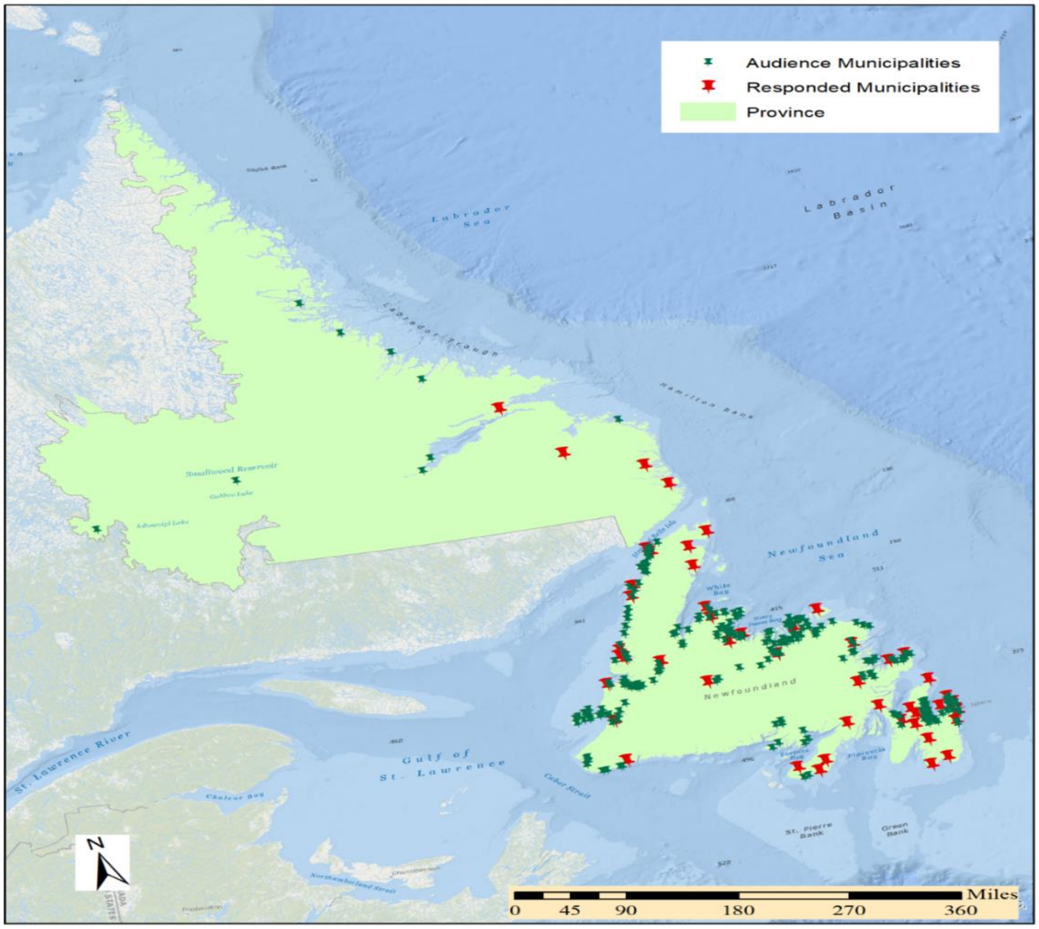

Figure 1: Audience and responded municipalities of the survey.

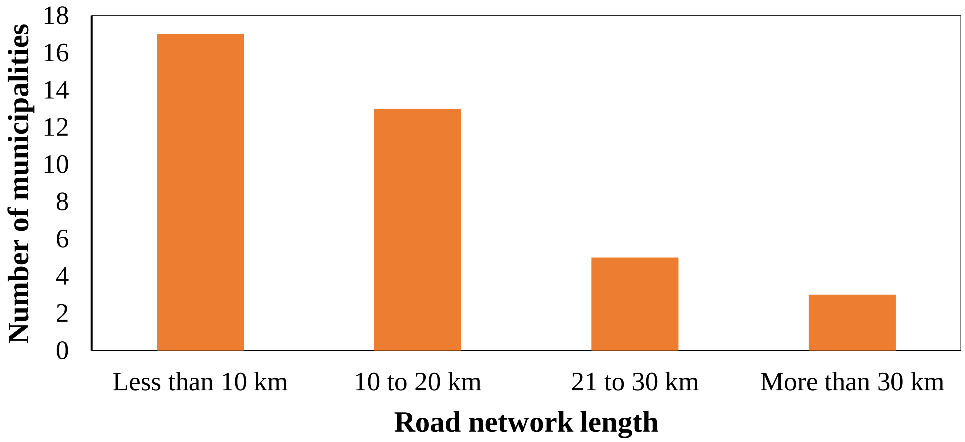

Figure 2: Network length range and number of corresponding municipalities

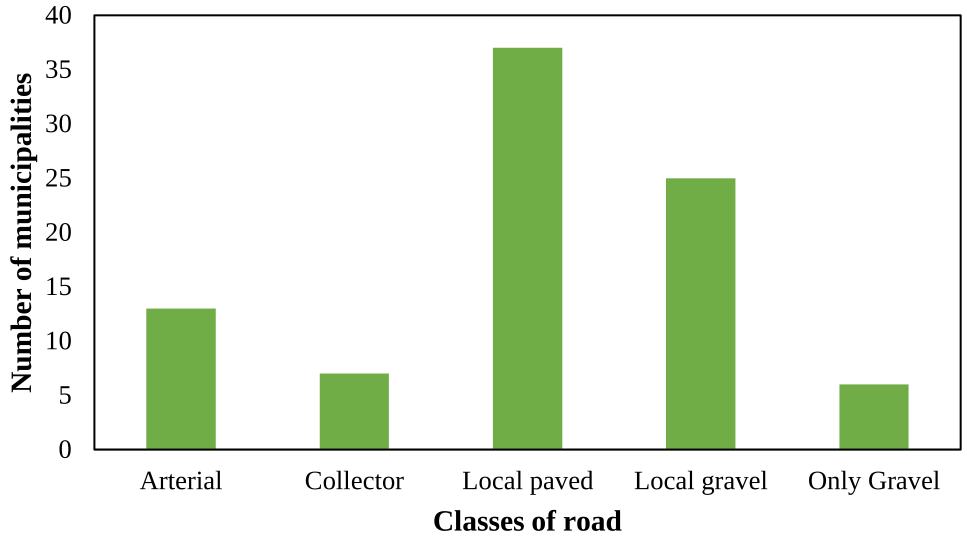

Figure 3: Different classes of roads and the corresponding number of municipalities

Pavement condition

From the municipality staff's perspective, the overall conditions of different classes of roads are presented in **Figure 4.** There was no existence of an "Excellent" gravel road according to respondents. However, 32% of participants rated the gravel roads "Good," while 48% rated them "Average". "Poor" and "Very poor" were rated by 20% of the respondents.

For local paved roads, "Excellent" was rated by 15% of participants. "Good" and "Average" were rated by 30% and 35% participants, respectively. 20% of the respondents rated them "Poor" and "Very poor."

The collector road was rated as "Excellent" by only 14% of the raters. 43% of participants said that the overall condition was "Average," while almost an equal percentage described their collector road conditions as "Poor" and "Very poor."

Condition of arterial roads was given "Excellent" and "Good" ratings by a cumulative 63% of the respondents. 8% of participants rated them "Average," while the rest other rated them "Poor" and "Very poor."

While interpreting these data, please note that the municipal staff rated their respective road networks except for major arterial ones within their municipalities, which were assumed to be managed by the provincial Department of Transportation and Works (DTW).

Participants were also asked to rate the density of common distresses on different classes of roads. They were asked how frequently they saw particular distresses on their roads. There were four density scales, namely, very frequently, frequently, intermittently, and not exist.

Pothole, alligator cracking, longitudinal cracking, transverse cracking, and rutting are the distresses presented for rating by the municipalities. The questionnaire had pictorial references for each distress to facilitate the understanding of the audiences while rating. Information on individual distress density on each class of roads is presented in **Figure 5.**

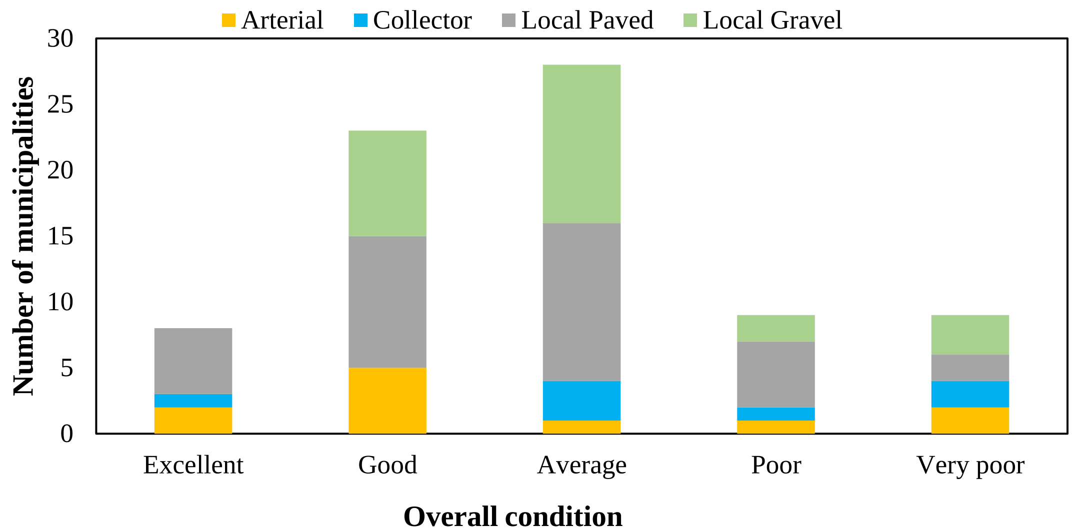

Figure 4: Overall condition of the roads of different classes

Figure 5 illustrates that in the arterial roads, alligator cracks are very frequently seen rated by almost 38% of the raters, while an equal percentage said that this distress did not exist. Only 23% of participants reported frequent or intermittent alligator cracking. This information is not surprising as there is not much traffic in communities with fewer than 5000 people. Therefore, load-related cracking, such as alligator cracking, was not expected to be a severe problem.

For longitudinal cracks in arterial roads, the respondents mostly rated "Intermittently" followed by "Not exist" and "Frequently". The comparative score for the arterial roads was better for longitudinal cracks than for alligator cracks. Rutting was rated "Intermittently" by almost 47% of the respondents and “Not Exist” by 15% of respondents, which suggests that the arterial roads are not very rutted. The rest of the respondents said the distress was very frequently to frequently observed. Meanwhile, almost 30% of raters responded that transverse cracking either did not exist or was intermittently seen on the arterial roads while the rest either rated very frequently or frequently.

As it can be seen in **Figure 5,** overall, the collector roads have the highest number of distresses from the participant's point of view. In the collector roads, all types of distress were very frequently observed. More than 40% of the ratings were given to this option. It represents the deplorable condition of the collector roads in the municipalities.

Municipalities with gravel roads reported that potholes were the most common distress on the roads, and almost 65% aligned responses (very frequently and frequently) justified that. In answer to rutting, more than 40% of the respondents said that distress did not exist.

For local paved roads, all distresses, except rutting and transverse cracking, were found to be common. Almost 45% of the respondents reported that rutting did not exist, followed by a 33% rating on intermittently available. More than 30% of respondents described that potholes were frequently observed, and the same percentage of the respondents said that potholes were found intermittently visible. Almost 20 % of raters described potholes were very frequently available while the rest rated “Not exist.” Alligator and longitudinal cracking got a mixed rating for local paved roads. However, comparing both of these distresses, longitudinal cracks are less visible than the alligator cracks.

Figure 5: Distress density in different municipality-owned roads

Roadway components condition

For municipality roads, five features are commonly observed alongside the pavement: pavement shoulders, sidewalks, road signs, pavement markings, and streetlights. Participants were asked to rate the overall condition of those features from excellent to very poor. "Not available" option was also there in case any feature was missing. The condition rating of different roadways is summarized in **Table 4.**

Table 4: Different roadway assets condition

Condition	Number of responses recorded				
	Pavement shoulder	Sidewalks	Road signs	Pavement marking	Streetlights
Excellent	0	0	2	2	10
Good	4	1	17	4	15
Average	11	3	17	10	10

Poor	5	3	2	11	0
Very poor	5	2	1	2	0
Not available	14	30	0	10	4

Management organizations

After determining the overall condition of the roads, it was important to understand which organization(s) manages the municipality-owned roads. **Figure 6** shows that most of the roads are managed jointly by the municipalities and Department of Transportation and Works (DTW). Six responding municipalities manage their own roadways while two municipalities are managed by the DTW. One respondent said that roads are managed by a contractor.

Since NL is in a wet-freeze region with rain and snow precipitation year-round, winter road maintenance has always been an important consideration for road management. The respondents were asked after a 10 cm and a 10 to 25 cm snowfall event, how long they expected to wait until their roads are plowed. **Table 5** represents the responses.

Most respondents, 73% for 10 cm and 51% for 10 to 25 cm, indicated that their roads would be plowed within a reasonable time frame following a large snowfall event. The few who reported longer wait times for snow plowing were a combination of smaller and larger municipalities, some who relied on the DTW for maintenance and some who did not. Winter maintenance times correlate mostly to remoteness of the municipality and network size, not road ownership or types of roads available within the municipality.

Municipality staff were also asked to rate their satisfaction level on the maintenance of different classes of roads. Most of the respondents determined that they are somewhat satisfied with the maintenance of most of the roads. For arterial roads, the majority of the rating given were extremely dissatisfied, which mostly represent the roads managed by the DTW.

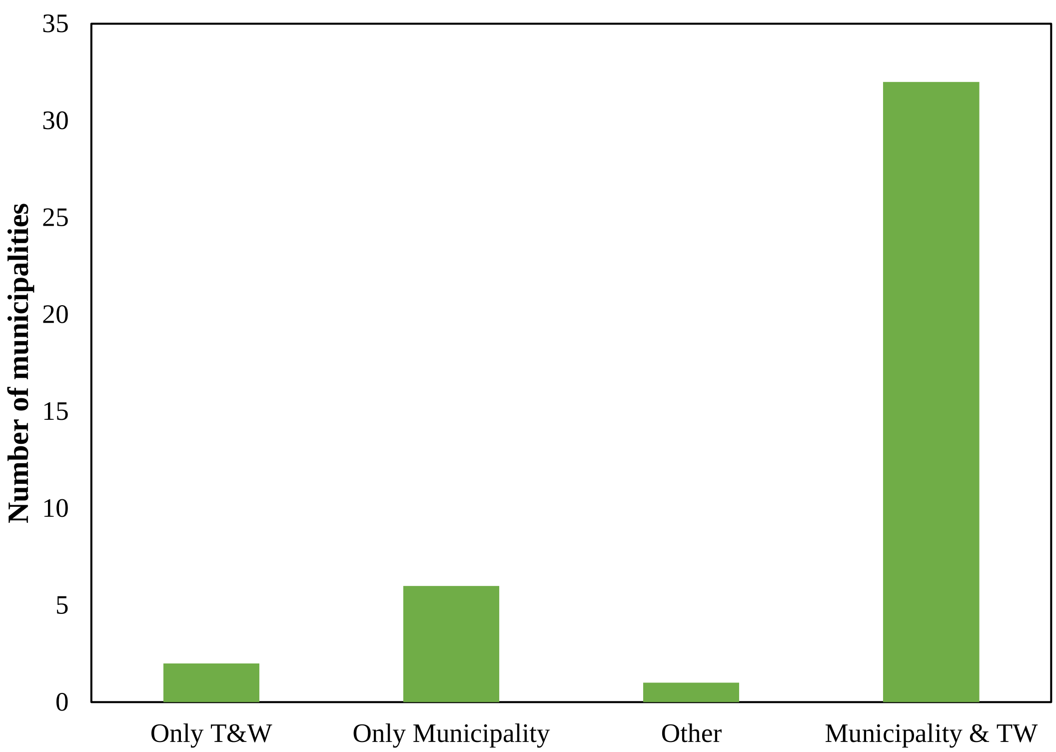

Figure 6: Management agencies and the corresponding number of municipalities.

Table 5: Snowplowing expectation after two different snowfall events

10 cm snowfall event		**10 to 25 cm snowfall event**	
Expected hours of plowing snow	Number of municipalities responded	Expected hours of plowing snow	Number of municipalities responded
4 to 6	27	5 to 8	19
6 to 8	5	8 to 12	11
8 to 10	3	12 to 16	2
10 to 12	2	16 to 20	5

Current Priorities

Based on the current condition of roadway assets, participants were asked to make a priority list of the components that they think should be improved in their municipalities. **Table 6** presents a priority rating on different roadway components.

Pavement was prioritized as first by almost 74% of the raters, while drainage system improvement was suggested by 21% as their first priority. Considering the first two priorities, it is clear that the respondents want their pavements and drainage system to be improved. Pavement shoulder comes into the next combined priority, followed by pavement marking. The streetlight was given less priority as the condition of them was already good (Please refer to table 4). Sidewalks were not given much importance by most of the raters as they were prioritized as last by 47% of respondents, likely due to the rural nature of these municipalities and their roads.

Table 6: Maintenance priority of roadway components

Priority	**Roadway asset features**					
	Pavement	Sidewalks	Streetlights	Shoulder	Pavement marking	Drainage
Priority as 1	28	0	0	1	1	8
Priority as 2	7	3	3	9	3	13
Priority as 3	1	4	8	15	7	3
Priority as 4	1	5	5	7	13	7
Priority as 5	1	8	13	5	9	2
Priority as 6	0	18	9	1	5	5

Available resources

The respondents who indicated that their roads are managed by their own municipalities were asked if they own any roadway maintenance equipment. Some of them answered that they own asphalt recyclers and compactors, while a few of them said they own mastic patchers, rammer, calcium spreader, and a few other general tools. However, overall, the municipalities did not have any sophisticated maintenance equipment to report and 20% of respondents had no maintenance equipment at all. This does pose a challenge with regards to the implementation of any pavement management systems.

Table 7 represents the human resources available in the responding municipalities.

Table 7: Human resources in the municipalities

Population range	Number of municipalities	Number of municipalities responding	Number of part-time staff	Number of full-time staff	Number of total staff
Smaller than 100	17	3	0 to 2	1 to 2	1 to 3
100 to 499	136	19	0 to 3	0 to 7	1 to 10
500 to 999	65	8	0 to 3	0 to 2	1 to 4
1000 to 1999	23	5	0 to 5	3 to 10	3 to 15
2000 to 2999	16	5	0 to 5	5 to 12	4 to 17
3000 to 3999	5	1	22	8	30

A commonality observed among all the responding municipalities was their limitations in not only their equipment, but also their employees. The number of staff employed by each municipality is more strongly correlated to the population size than the total road network length, meaning that some municipalities lacked the people to manage their larger road networks. **Figure 7** shows the correlation between staff size and network size, while **Figure 8** shows the correlation between staff size and population. In general, municipalities with more available resources reported better conditions in their roads, regardless of their population sizes. In terms of the implementation of a PMS, the small staff sizes may initially present a challenge to willing municipalities.

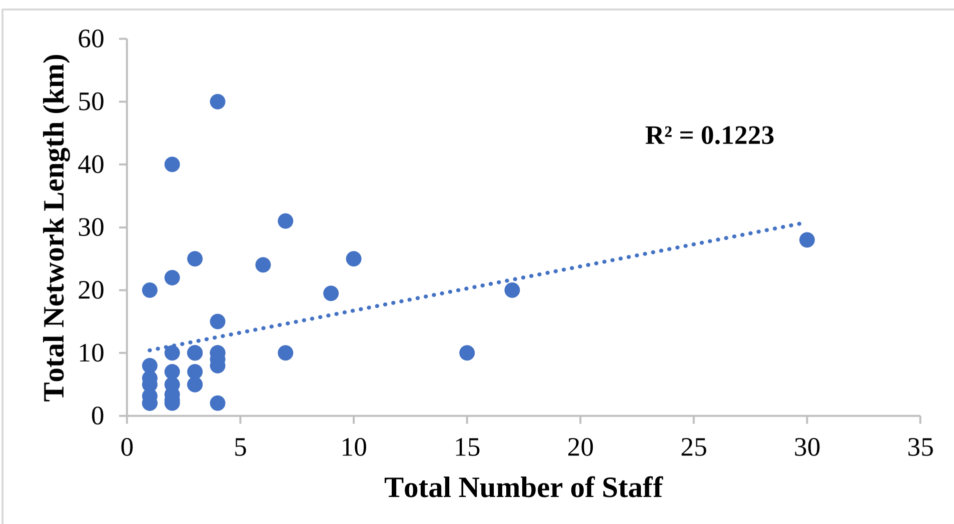

Figure 7: Total number of staff based on municipality road network length

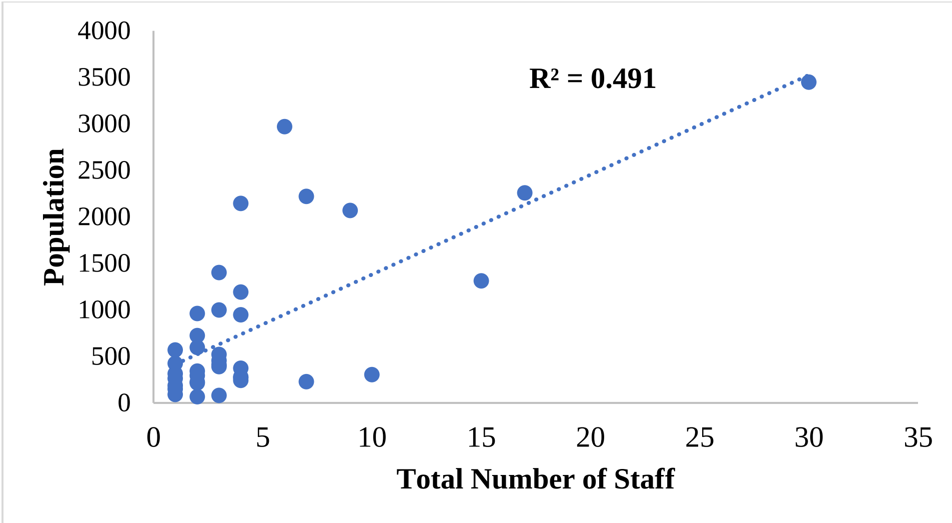

Figure 8: Total number of staff based on municipality population size

To conclude the survey, the participants were asked to provide their suggestions regarding the improvement of their roads. Some respondents described that road conditions within their municipality as deplorable and expressed their desire for DTW to approve projects at a faster pace. A few respondents explained that it is difficult for some municipalities to share 50% of the cost for the necessary road maintenance. Winter maintenance has been an issue in some municipalities, and some of the respondents reported that snow plowing does not occur in their jurisdictions. A few respondents doubted that any monitoring is taking place on DTW collector roads, and they suggested that a proper monitoring program be implemented. Some municipalities want to invest in road maintenance equipment, but due to a lack of knowledge in this field, they cannot do so. Some of them also suggested improving drainage conditions. When considering all of the above listed suggestions, the need for specialized management guidelines for municipality roads is apparent. Once implemented, guidelines should be followed by both the municipalities and DTW to avoid the lack of communication reported by so many of the respondents to this survey.

In larger provinces, pavement management practices are introduced and made available to all municipalities through pavement management groups. An effective example of such a group is the Ontario Good Roads Association (OGRA). Through the OGRA, education regarding pavement management is made accessible to all municipalities who desire it. The founding of a similar group in Newfoundland may help municipalities to implement the management techniques that they require. Through the survey conducted, some participants expressed their interest in learning of the management techniques mentioned, which may indicate that a group similar to OGRA would have a receptive audience in NL. There will however be some challenges in accomplishing this, namely gathering resources for municipalities, and finding suitable funding.

SUMMARY AND CONCLUSIONS

The survey was approved by the "The Interdisciplinary Committee on Ethics in Human Research (ICEHR)" at Memorial University after submitting all necessary documents needed for conducting research with human participants. It was an anonymous survey, and the participation required a complete understanding of the consent, which was provided as a prelude to the questionnaire. The following conclusions can be drawn from the survey results.

- This survey evaluates two issues. One is the current condition of the municipality-owned roadway assets, and another is current management practices.
- Municipality roads are in varied conditions. However, conditions of collector roads in the responding municipalities are deplorable. 86% of respondents rated the overall condition of collector roads as "Average" to "Very poor."
- Arterial roads were rated by 44% as "Good" to "Excellent," while "Average" was rated by a little above 23% of the respondents. The rest other rated them either "Poor" or "Very poor."
- 35% of respondents found local paved roads are in average overall condition. Good and excellent were rated by 44% of the raters.
- The overall condition of the gravel roads was rated as "Average" by 50% of the participants. Around 31% of respondents rated the condition as "Good." There was no "Excellent" rating from the participants for gravel roads.
- Among all the distresses, potholes were found to be the most common in each class of roads. However, they were more common on the collector and gravel roads, as around 71% and 65% of respondents, respectively, rated that potholes were visible "Frequently" to "Very frequently."
- Alligator cracking was commonly found on the collector roads, followed by being present on arterial roads.
- Longitudinal cracking was also found to be very common on the collector roads as almost 43% rated that this distress was "Very frequently" observed. Longitudinal cracks were less common on the local paved roads.
- Transverse cracking was less common, according to 60% of the respondents.
- Rutting was rated "Intermittently" or "Does Not exist" by most of the raters. However, respondents found this distress common on the collector roads followed by the arterial roads.
- For road components condition, almost 72% of respondents said that they did not have a sidewalk while another 40% described that the pavement shoulder was missing. The condition of streetlights was rated "Good" to "Excellent" by 64% of respondents. Other components were mostly rated between "Average" to "Good."
- Around 8% of respondents to the survey were an engineer or technical staff.
- Almost 22% of respondents described that they had arterial roads under the jurisdiction of their municipalities alongside the local roads. Around 12% of respondents said that they had collector roads.
- Roads are managed jointly by the municipalities and DTW for 78% of the responding municipalities. Almost 7% of the municipalities manage roadway assets on their own, 3% by contractors and the rest of the respondents reported that DTW was the only responsible organization for managing their roads.
- The number of municipality staff was found to be dependent on the municipality's population in most cases.
- Among roadway components, the priority of improvement was given to the pavement, followed by the drainage system and pavement shoulder by the survey participants.
- For a 10 cm snowfall event or less, 73% of the respondents expected that snow should be removed from the pavement in 4 to 6 hours. For an event with 10 to 25 cm snowfall, 52% of respondents expected that snow to be plowed in 5 to 8 hours, while around 30% of the respondents said that 8 to 12 hours would be an adequate time for the task.
- For improving pavement conditions, on average, participants want to spend 41.2% in resurfacing 22.3% in pothole patching and 36.5% in reconstruction.

- More than 47% of respondents believe that maintenance decisions should be taken based on collected data rather than subjective judgment. 37% responded "maybe," while 16% relied on subjective judgment.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design by Kamal Hossain and Shajib Guha; survey conducting and data collection by Shajib Guha; analysis and interpretation of results: Shajib Guha and Kamal Hossain; manuscript preparation: Shajib Guha, Kamal Hossain and Alyssa Bernier. All authors reviewed the results and approved the final version of the manuscript.

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