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CLIMATE CHANGE CONSIDERATIONS WITHIN THE ASSET MANAGEMENT OF CORE INFRASTRUCTURE FOR RURAL ONTARIO MUNICIPALITIES – AN INITIAL ASSESSMENT

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Abstract: Municipalities provide stewardship of infrastructure through asset management plans. These plans are generally focused on service-based outcomes to meet municipal strategic goals. Because uncertainty exists with the potential impact of climate change effects on infrastructure performance, it is important to understand the current state of municipal readiness to address climate change effects, as well as the broader municipal needs, challenges and gaps (e.g. technical, financial, organizational factors). If municipalities do not consider the impacts of climate change in their infrastructure planning, they could experience a greater risk of damage to their infrastructure stock, and there could be significant costs and losses in the future. A preliminary assessment of climate change considerations within asset management plans for rural Ontario municipalities is explored in this study. The general readiness landscape is synthesized and a discussion on the path forward is presented. This unique study highlights the existing capabilities of rural Ontario municipalities to utilize best practices for the asset management of core infrastructure. The integration of climate change considerations, however, presents challenges where enabling strategies are currently being developed.

1 Study Background

1.1 Project Basis

In Ontario there are 444 municipalities that can be categorized as 173 single tier, 30 upper tier and 241 lower tier. For this study, the term "rural Ontario municipality" was defined as a community with a population less than or equal to 100,000, or population density less than or equal to 100 people/km^2. Based on data from the Association of Municipalities of Ontario, of the 444 municipalities in Ontario then 409 municipalities could be classified as rural with approximately 79% (351 municipalities) having a population less than 25,000 and only 8% (36 municipalities) having a population greater than 100,000. However, the majority (~80%) of the Ontario population lives within 15 urban areas.

This research project, supported by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) through the New Directions Research Program, is primarily exploring how rural municipalities may take action in preparing infrastructure for a changing climate. If municipalities do not consider the impacts of climate change in their infrastructure planning, they could experience a greater risk of damage (e.g. more intense rainstorms resulting in flooding events) to their infrastructure stock, and there could be significant costs and losses in the future. There is a need to better understand the state of Ontario's rural municipalities in how they:

- assess risks and opportunities for their local infrastructure related to changes in climate,
- integrate climate change considerations into their asset management planning, and
- put into practice adaptive technologies/standards that may help manage climate change impacts to infrastructure into the future.

1.2 Project Objectives and Study Goal

From the perspective of climate change, this project will (1) establish the current state of rural municipalities readiness to address the impact on municipal infrastructure, and (2) develop a framework for use, adaptation and integration by municipalities within sustainable management practices.

The first objective is to provide a clear picture on state of readiness in the context of asset management enablers (e.g. technologies, resources), barriers (e.g. constraints, risks, gaps) and strategies (e.g. lifecycle, financial). This will provide an informed knowledge base with benchmarks to assess the current state of readiness, in absolute and relative terms, gauge requirements for continuous improvement and establish the path forward.

The second objective will provide municipalities with guidance and enabling resources (e.g. tools, standards, best practices) to develop a municipal-centric, comprehensive asset management framework that integrates considerations of climate change with other key attributes (e.g. risk, data needs, resources, technologies, financial plan, stakeholder engagement).

This study explores the first objective by directly engaging municipal stakeholders through a questionnaire on rural infrastructure and climate change. The survey objectives, synthesized results and assessment are presented in this paper.

2 Contextual Relationship: Infrastructure, Asset Management and Climate Change

2.1 Background: Investment and Asset Performance

Core civil infrastructure systems (e.g. water, wastewater, stormwater, roads, bridges, and culverts) are critical elements of modern society that meet our functional needs, sustain economic growth and development, and support our current standard of living. In Canada, approximately 60% of this core infrastructure is owned and maintained by local municipalities with a total asset value of $1.1 trillion (CIRC, 2016). The pan Canadian composite asset average age has fluctuated between 14 years and 18 years since the 1960s (Gagnon et al., 2008). In Ontario, the average age of core infrastructure was 15.4 years with the following breakdown for highways and roads (13.9 years), bridges and overpasses (24.1 years), water supply systems (13.1 years), wastewater facilities (16.9 years) and sewer systems (18.3 years).

Although periodic in nature, investments in public infrastructure have continued with these assets having experienced stressors from deterioration due to ageing and weathering effects, deferred maintenance, and increased utilization. In addition, since the late 1970's an "investment gap" (i.e. difference between the actual and needed core infrastructure investment level to meet a service level target) has emerged that has affected infrastructure performance (CIRC, 2016; McKinsey, 2016). In a recent study, it has been estimate that one-third of the existing Canadian infrastructure network ranks between "fair" and "very poor" (CIRC, 2016). This annual deficit can be an order of magnitude greater than the annual budget where the reactive costs can be up to 10 times the preventative costs (CIRC, 2016). These factors have a significant influence on decision making and asset management of infrastructure with respect to the prioritization of needs and actions, as well as the allocation of human and capital resources in order to meet defined service levels and targeted goals.

In Ontario, the infrastructure gap was estimated to be at least $60 billion in 2012, and across Canada this deficit was assessed to be $145 billion in 2013 (AMO, 2012; CCPA, 2013). In the United States, the appraised investment gap exceeds $2 trillion with a projected loss in gross domestic product of $3.9 trillion

through to 2025 (ASCE, 2016). Furthermore, from a global perspective, the infrastructure deficit is estimated to be at least $1 trillion per year with a projected $20 trillion composite deficit by 2030. Conversely, a recent study has raised questions on the validity of the "investment gap" based on an assessment of the net stock after adjusting for population and inflation (Lammam and MacIntyre, 2015). However, in that study the asset condition and performance relative to defined service level targets were not evaluated. Consequently, there may be uncertainty on whether a key hypothesis, as proposed by Lammam and MacIntyre (2015) to be "…Myth 1: Government must ramp up infrastructure spending to make up for past neglect…", can be stated with confidence.

2.2 Asset Management Planning

Stakeholders, across the spectrum (i.e. government, industry, and society) have become increasingly aware of the connections between investment, infrastructure performance and targeted service levels. In 2011, the Ontario government initiated a 10-year, $130 billion infrastructure plan "Building Together" with other strategic initiatives having been engaged over the past decade (e.g. MOI, 2015,2012,2007). As part of the strategic plan to effectively manage infrastructure, the Ontario government has tied funding with asset management plans (AMP) as a key foundational element of the partnership strategy for continued investment in municipal infrastructure.

Asset management can be defined as "…the coordinated activity of an organization to realize value from assets…". The term activity is "…the application of the elements of the asset management system…" that includes "…the approach, the planning, the plans and their implementation…". The realization "…of value will normally involve a balancing of costs, risks, opportunities and performance benefits…" (ISO 55000, 2014). Asset management plans "… allow needs to be prioritized over wants…" and "…help ensure that investments are made at the right time to minimize future repair and rehabilitation costs and maintain municipal assets…" (MOI, 2012, 2017a,b). There are four key integrated elements in this plan that include (1) the state of local infrastructure, (2) expected levels of service, (3) asset management strategy, and (4) financing strategy (MOI, 2012). The asset management framework provides an overarching methodology for the stewardship of core infrastructure by supporting effective decision making and the rational allocation (i.e. timing and delivery) of resources (i.e. human, physical, financial) in order to meet the defined service levels while optimizing costs, maximizing benefits, and mitigating risk (e.g. ISO 55001, 2014; ISO 55002, 2014).

In part, to provide a uniform benchmark for all municipalities and to reinforce the significance of AMP, the Ontario government has recently implemented the regulation (O. Reg 588/2017) Asset Management Planning for Municipal Infrastructure under the Infrastructure for Jobs and Prosperity Act, 2015. For core infrastructure, the key milestones and elements of this regulation includes:

- July 1, 2019: in-place strategic asset management policy that is reviewed every 5 years,
- July 1, 2021: in-place asset management plan (AMP) that integrates a discussion on the current level of service and cost to maintain this service for a 10-year cycle, and
- July 1, 2024: in-place asset management plan (AMP) that integrates a discussion on the proposed level of service and asset performance, over a 10-year cycle, that will be addressed by the lifecycle management and financial strategy to achieve these goals.

The regulation has different requirements for municipal governments based on population (i.e. above or below 25,000) and geographic region (i.e. within Greater Golden Horseshoe growth plan area). The regulation was developed in consultation with all stakeholders (e.g. municipalities, municipal sector organizations, public). To address concerns with technical capabilities and capacity, the Ontario government is providing $25 million over the next 5 years (2018-2023) to provide training and development (i.e. AM tools and practices) and planning activities (e.g. condition assessments) for small communities. Inline with this approach, the 2016 Canadian Federal Government budget allocated $50 million over 5 years, through the Municipal Asset Management Program, to help Canadian municipalities strengthen infrastructure investment decisions based on sound asset management practices, which is delivered by the Federation of Canadian Municipalities (FCM).

2.3 Climate Change Considerations

Climate change effects (e.g. erratic or cyclic variation in temperature, precipitation) add another layer of complexity that shape and impact how we think about infrastructure performance (e.g. increased level of damage such as rutting or potholes). This has impacted Canada's northern regions with accelerated infrastructure deterioration, landscape transformations and disturbed ecosystems due to adverse climate change effects on permafrost (Burn et al., 2015; Calmels et al., 2015; O'Neil et al., 2015; PTP, 2014,2011) and has affected infrastructure in more southern locations (Bolivar-Phillips, 2013; GCC, 2017; Félio, 2015; 2013; Palko and Lemmen, 2017). The frequency, scale and intensity of climate change related hazards (e.g. flooding, geohazards) are expected to increase with more adverse outcomes where current load events may exceed the original design basis (IPCC, 2014; Palko and Lemmen, 2017; Warren and Lemmen, 2014). Reliance on the historical climate record and current engineering framework will most likely lead to increased exposure and vulnerability of the infrastructure that may affect the asset performance, resilience and integrity. This has resulted in measured economic loss due to property damage, personal injury and loss of life.

Historical data and recent events are supporting this hypothesis. Severe weather events have been affecting governments, at all levels, with more than $3.3 billion provided, under the national Disaster Financial Assistance Arrangements program, since the 2009-10 fiscal year, which exceeds the total funds provided ($2.4 billion) for the previous 39 years (AGC, 2016). This trend of increasing cost associated with climate change effects is also highlighted by data from the Insurance Bureau of Canada (Figure 1) for estimates of increasing catastrophic disaster payout (i.e. greater than $25 million for property and casualty insurance). The natural events included floods, forest fires, tornadoes, hurricanes, and wind, hail, snow and ice storms. Since 1983, the total catastrophic loss has been $22.4 billion (2017$) with an exponential trend line for catastrophic losses through to 2015. For the period of 1983-1988, the total catastrophic loss (in 2017$) was $1.1 billion ($180 million per year average) that has increased by an order of magnitude to $10.6 billion ($1.77 billion per year) for the period 2010-2015 (IBC, 2016). Recent flooding events in Ontario and Quebec are present indicators of the current and future challenges that lie ahead where in excess of $225 million in insured damages was incurred and several municipalities, including Montréal, declared a local state of emergency. These events suggest climate change events and outcomes will continue to have a significant negative impact on the economy, infrastructure, environment and society if left unabated or inadequately addressed. In the future, the estimated costs due to climate change effects, across multiple sectors (e.g. health, transportation, energy, natural resources, ecosystems) across Canada will be $5 billion per year in 2020 and may reach $43 billion per year by 2050 (NRT, 2011).

Leadership is required across all stakeholders (i.e. levels of government, public, staff, consultants, academia) to advance the strategic vision, across disciplines (i.e. financial, engineering, social, policy), to address climate change considerations within the effective management of infrastructure assets. For example, to understand the long term impact and benefit, it is estimated the $63 million ($525 million in 2017$) invested for building the Red River Floodway in 1960, with expansion costs of $627 million in 2014, has resulted in $40 billion ($43.2 billion in 2017$) savings in recovery costs by 2011 (AGC, 2016; ECC, 2016). A national, and arguably global, incentive exists to mitigate risk and reduce infrastructure vulnerability due to climate change effects by advancing mitigation strategies and adaptation practices. There is a need to integrate climate change considerations through evolution and continuous improvement of management systems (i.e. financial, engineering), organizational structures (e.g. green organizations) and strategic directions (e.g. policy, regulations) to provide incentive for mobilizing action, afford positive return on investments, and improve infrastructure resilience and safety (e.g. ECC, 2017,2016).

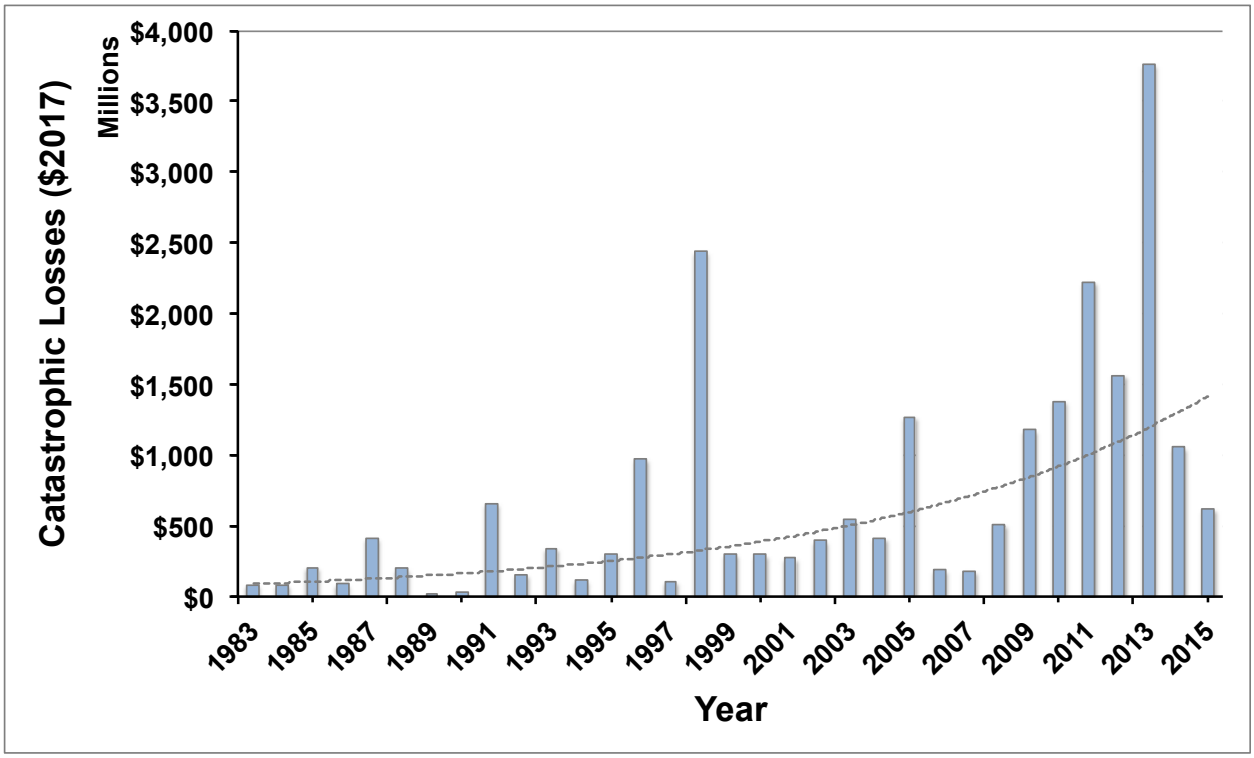

Figure 1: Catastrophic losses due to natural events (after, IBC, 2016)

Aligned with this strategic direction, the advancement of requisite skills, tools and resources is needed to build critical mass and sustain capacity is gaining momentum and strength. In 2009, a study highlighted that climate change adaptation planning within Canadian municipalities was in the infancy for consideration and development (Peel, 2009). Albeit marginally, the landscape has improved since that time where 19% of the reporting municipalities have integrated climate change considerations within internal mechanisms (e.g. policies, adaptation practices) in support of decision-making processes, (CIRC, 2016). Over the past decade, screening level support tools have been developed to assess the risk and vulnerability of infrastructure within a changing climate that can be used to support asset management and guide decision making processes (e.g. AMEC, 2017; Chiarelli et al., 2017; Engineers Canada, 2016,2014; Félio, 2015; IISD, 2013; Warren and Lemmen, 2014; Palko and Lemmen, 2017). Case studies have been conducted that highlight the utility of these assessment tools, which can be used to support decision making with the asset management of infrastructure and consideration of adaptation plans (e.g. CBCL, 2012; Engineers Canada, 2016,2014; ICLEI, 2010; ICLR, 2012; IISD, 2013). Furthermore, there has been some advancement of recommended practices and engineering standards that address climate change effects on infrastructure and risk control measures (e.g. APEGBC, 2017; CSA S502, 2014).

The recent CIRC (2016) report card observed only 19% of the 120 reporting municipalities have integrated climate change considerations within internal mechanisms (e.g. policies, adaptation practices) in support of decision-making processes. Based on the CIRC (2016) data, integrating climate change strategies was less prevalent for smaller (10%) municipalities (< 30,000 population) in comparison with the medium and large size municipalities (27%). This outcome is consistent with the results observed in this study. The CIRC (2016) report did not address or provide direction on how municipalities could better integrate climate change considerations or adaptation practice within asset management plans.

Consideration of climate change effects on infrastructure performance is now generally accepted and recognized as an important and integral component of a comprehensive asset management plan. Experience from practical application of case studies and protocols, as well as implementation of mitigation practices and adaptation strategies will guide the development and integration of climate change considerations within AMP for smaller, rural Ontario municipalities.

3 Municipal Questionnaire on "Rural Infrastructure & Climate Change"

3.1 Objectives

A questionnaire was distributed to municipal staff members (e.g. Chief Administrative Officer, Engineering Manager, Treasurer, etc) of rural Ontario communities with an electronic link provided to respond to the questions. The survey was anonymous and was approved by the Carleton University Research Ethics Board. The questionnaire objectives were to develop insight on (1) in-place asset management plans, (2) integration of climate change considerations, (3) nature and extent of climate change considerations, and (4) characterization of infrastructure vulnerability.

3.2 Results

A total of 160 rural municipal representatives responded to the survey, which is a 0.39 participation ratio. For some of the survey questions, there was missing data where the total number of responses was less than the total number of survey participants (160). Also, some questions had possible multiple response selections where the total number of responses can be greater than the number of respondents (160).

In Section 1 (Integrating Climate Change Considerations) of the questionnaire, the survey explored how (if) considerations of climate change impacts have become integrated within the infrastructure planning, policies and programs that help shape municipality asset management plans. The major overarching outcomes can be summarized as

- climate change effects are generally not considered in the development of asset management plans (77% of 120 responses stated No),
- the primary limiting factor was attributed to insufficient human resources (e.g. time, people, budget) to address the potential impact of climate change effects (49% for 172 responses, Figure 2). The legend entry "N = #" indicates the total number of responses to the question, and
- the lack of in-place sustainability plans (74% stated either No or Future Study for the 120 responses) and public engagement (66% stated No for 145 responses) may have also been contributing factors.

In Section 2 (Nature and Extent of Climate Change Considerations) of the questionnaire, municipalities were queried on how (if) elements of an adaptive management strategy are used to support the asset management plan with respect to potential climate change impacts. This strategy provides an improved understanding, when dealing with uncertainty such as climate change effects, through system monitoring and learning outcomes to adapt and shape policies, practices and decisions. Key elements of this strategy include (1) planning, (2) improving knowledge, (3) assessing potential impacts, (4) assessing risks and infrastructure vulnerabilities and (5) establishing adaptation controls. Consistent with previous responses, most municipalities have not developed an adaptive management strategy (79% stated No for the 120 responses). Only 5% of the 120 respondents had some form of adaptive management strategy (e.g. PIEVC protocol, ICLEI) with 16% having partially developed a plan.

In Section 3 (Infrastructure Vulnerability) of the questionnaire, roads and bridges (38% of 378 responses) were identified as the major core infrastructure affected by climate change, which is consistent with the general asset mix for rural Ontario communities. The primary climate effect identified was rainfall (29% of 299 responses) with approximately 35% of the 105 respondents attributing the effects to coupled interactions including rainfall and snowfall, or rainfall and erratic temperatures. The most significant climate change hazard was flooding (31% of the 239 responses) with 40% of the 105 respondents selecting both Flooding and Freeze/Thaw climate change hazards. For the 93 respondents, the most common adverse

effect was damage or deterioration on the infrastructure (39% of 176 responses, Figure 3) with 25% of the respondents indicating multiple linked adverse effects (e.g. temporary loss of function, damage/deterioration, and failure/permanent loss of function).

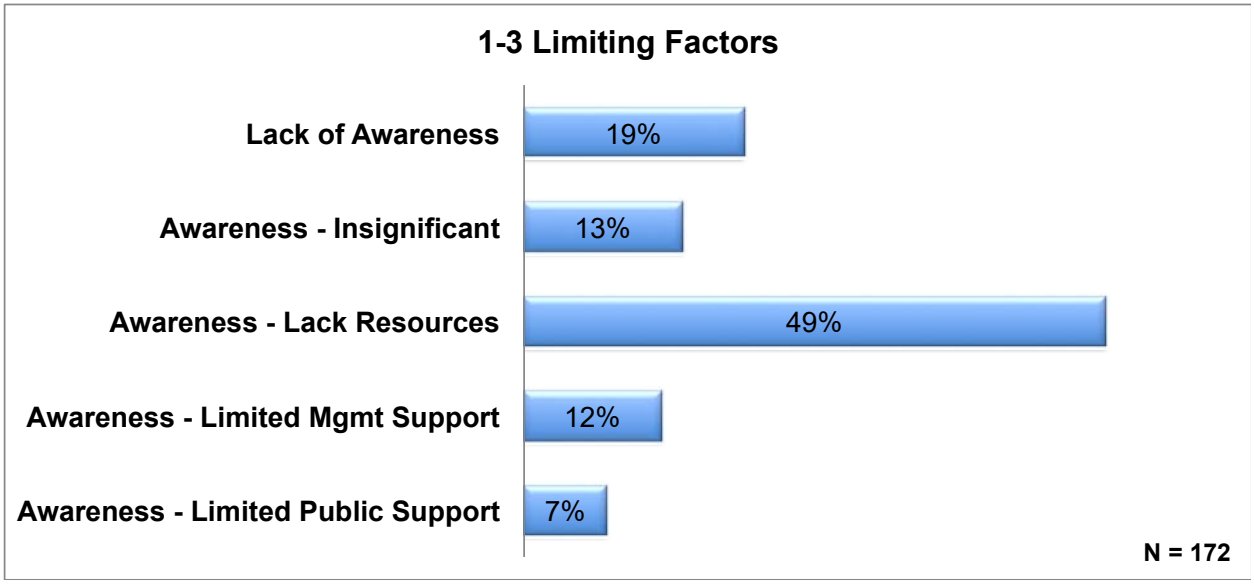

Figure 2: Questionnaire response to factors limiting the integration of climate change considerations

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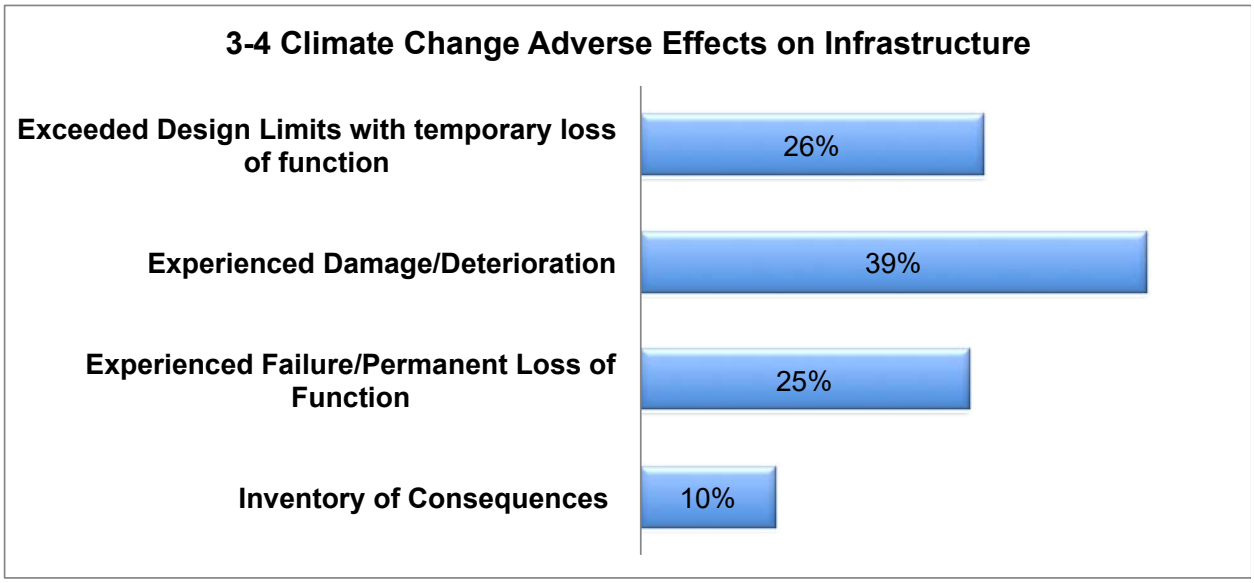

Figure 3: Questionnaire response to climate change adverse effects on infrastructure

4 Closure and Path Forward

This paper has presented preliminary results from a recent study exploring the current state of readiness for rural Ontario municipalities to address climate change considerations within asset management plans. Through a questionnaire with municipal representatives, an improved understanding on the state of readiness landscape with respect to enablers (e.g. technologies, resources), barriers (e.g. constraints, risks, gaps) and strategies (e.g. lifecycle, financial) was established. The nature and extent of these considerations, as well as the exposure and vulnerability of infrastructure to climate change impacts was assessed. The significance of moderating factors (e.g. technical, financial, organizational, public perception) and advancement of best practices for integrating climate change considerations within the asset management framework, which will improve decision-making under uncertainty, was examined but not presented.

At present, for even urban municipalities, the formal integration of global climate change considerations through the knowledge base and specific tools, within the asset management framework is in the process of development (e.g. Black et al., 2014; CIRC, 2016; CCME, 2015; Deloitte, 2010; Langford, 2013). Furthermore, in the face of climate change considerations, current practice used to evaluate hazard effects on the performance and integrity of core civil infrastructure systems have inherent deficiencies and uncertainties in the underlying engineering models. Limitations in these tools create barriers for informed decision making that impact the effective development and assessment of engineering design options, and adaptation practices across the range of practical design and operational envelopes (AGO, 2015). There is a need to further promote tools and practices for the effective integration of climate change considerations within the asset management framework.

Although a weathervane direction has been identified, the path to be taken is somewhat amorphous and will require development. For rural Ontario municipalities, the challenge is how to integrate asset management practices and climate change effects assessment in the face of practical realities for smaller communities that include finite municipal capacity (i.e. human, physical and financial resources) to address the scale of challenges faced (e.g. investment gap, past or current practices, community growth patterns, asset condition assessment programs) that may also be limited by local constraints (e.g. physical environment, remote location). As discussed in this paper (Section 1.1), these aspects and goals will be explored in future work, as part of this project, and will be will be the subject of a future publications.

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