Uncertainty Communication and Consideration in EA Practice: Lessons from a Mega Transportation Project in Canada

Samia Tabarah

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By: Samia Tabarah

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Signed by the final Examination Committee:

_____Chair

Dr. Pascale Biron

_____Examiner

Dr. Jean Philippe Waaub

_____Examiner

Dr. Jill Gunn

_____Supervisor

Dr. Jochen Jaeger

Approved by _____

Dr. Monica Mulrennan

Chair of Department

_____

Dr. André Roy

Dean of Faculty of Arts and Science

Date _____

ABSTRACT

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Samia Tabarah

Environmental Assessment (EA) is a tool that informs decision making of the potential adverse impacts of proposed development projects. Since EAs deal with future events, uncertainties are unavoidable. It has been found that there are different types and sources of uncertainties in EA and decision making, however; uncertainties are not always being communicated or considered. It is understood that there is a need for more explicit disclosure of uncertainties, yet there is no consensus regarding how uncertainties are perceived, communicated, and considered by those involved in, or affected by, EA, and much less is known about the contextual dynamics of uncertainty disclosure and consideration. This study attempts to better understand the relationship between context and uncertainty practice by exploring uncertainties in a Canadian transport mega project EA, the 407 East Extension in southern Ontario.

Transport mega projects are driven by a number of contextual factors, are characterized by high uncertainty, are spatially situated, inherently displacing, and highly visible. This study investigated how elements of the context hindered, supported, or influenced the way uncertainty was communicated and considered by those involved in the EA. In particular, twenty-two (22) semi-structured interviews were performed with key project informants such as project proponents, practitioners, regulators, First Nation representatives, and affected interests. Results demonstrate that uncertainties in the EA are the result of both process and context. In the process, uncertainties were significant in the preliminary and detailed assessment stages. Elements of the environmental and socio-political context were found to contribute to uncertainty as well. In particular, results indicate that location, lack of baseline data, perception, and broader politics, organizational, and regulatory factors worked to influence the way uncertainties were either communicated or considered during the EA. In our study, information about uncertainty was not disclosed in the EA. Uncertainties were minimized or strategically avoided. In order to address these limitations and better inform decision making in EA, we offer a number of recommendations. These are: the development of an uncertainty typology; guidance for uncertainty reporting; stakeholder identification and transparency in trade-offs; uncertainty management commitments; and, more attention on the context within which EA is embedded within and attempting to interact with.

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Chapter 1: Introduction

1.1 Background

Around the world, there has been a sharp increase in the proposal and development of transportation megaprojects, such as highways, tunnels, and railways (Flyvbjerg, Bruzelius, & Rothengatter, 2003; van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008). These projects are colossal in size, extremely resource demanding, costly, and involve numerous stakeholders; megaprojects are "a different breed" (Flyvbjerg, 2014). With high stakes and irreversible commitments, megaprojects rapidly transform landscapes in profoundly visible ways, and due to their sheer size, costs, and impacts on the community and environment, they attract high degrees of public and political attention (Kardes, Ozturk, Cavusgil, & Cavusgil, 2013; van Marrewijk et al., 2008). Faced with such an important task, decision-makers should have an appropriate understanding of the potential impacts associated with a development project.

Ideally, the Environmental Assessment (EA) process should provide decision-makers and stakeholders with the best information about the potential impacts and feasible alternatives. However, EAs routinely carried out for large-scale megaprojects have been observed to be unreliable, narrow in their scope, and inconsistent (Flyvbjerg et al., 2003). Similarly the information is prone to psychological biases and political steering that seek to minimize uncertainties, overestimate benefits, and underestimate environmental impacts (Flyvbjerg, 2005). The extensive rate at which construction of megaprojects are being proposed and developed throughout the world, within highly complex and uncertain conditions (Salet, Bertolini, & Giezen, 2013), urges the need to understand the factors that contribute or impede uncertainty communication and consideration in EA and decision-making. Given the potential effect of uncertainties on megaprojects' implementation and performance, and the rate at which such projects are being proposed and developed, there is a greater urgency for EA as an effective decision-making tool.

1.2 Research Problem

Environmental Assessment (EA) is a process-oriented tool for identifying, predicting, and evaluating the potential environmental impacts of development proposals prior to a decision being made as to whether or not a proposal should be granted approval to proceed (Sadler, 1996). It is intended to provide decision-makers and stakeholders with all the necessary analysis and knowledge of a proposed project, including its potential impacts, as well as recommended strategies or alternatives to effectively manage those likely impacts (Matthew Cashmore, 2004; Sadler, 1996). However, recent empirical studies have shown that predictions in EAs are often wrong, that the information passed on to decision-makers by practitioners is incomplete, and that uncertainties are not being communicated nor addressed (Morrison-Saunders,

Annandale, & Cappelluti, 2001; Sigel, Klauer, & Pahl-Wostl, 2010; Tennøy, Kværner, & Gjerstad, 2006; Wood, Dipper, & Jones, 2000).

Since EA deals with future events, uncertainties are unavoidable (Glasson, Therivel, & Chadwick, 2005). In fact, uncertainties have been observed in all of the activities, stages, and related decisions involved during an EA process (De Jong, 1988; Lawrence, 2003). For example, post-audit studies showing that the real impacts of a project are often different from those predicted have confirmed the inherent nature of uncertainty in predictions (Buckley, 1991; Flyvbjerg et al., 2003; C. Wood, Dipper, & Jones, 2000). Complex and dynamic characteristics of the natural system, the project, and the context also contribute to uncertainty (Ascough II, Maier, Ravalico, & Strudley, 2008; Maier & Ii, 2006). It has been argued that current EA practice and its multiplicity of actors involved create 'uncertainty blindspots' that work to diminish transparent communication of uncertainty (Duncan, 2008). The appearance of certainty has also been observed in EA reports (Tennøy et al., 2006), making proposals more politically acceptable and increasing the likelihood of approval (Duncan, 2008).

Informing decision-makers of the potential uncertainties has been viewed as a means to an end (Sadler, 1996) and as a result, uncertainties can be deliberately avoided and strategically manipulated to serve a political agenda or motive (Flyvbjerg et al., 2003; Funtowicz & Ravetz, 1990; Hellström & Jacob, 1996; van der Sluijs, 2007). Empirical evidence has shown that there is a successive loss of uncertainty information being disclosed in the supporting documents as the EA process progresses (Tennøy et al., 2006). Not surprisingly, many development projects are characterized by high stakes which could reinforce uncertainty avoidance behaviours in light of economical and time constraints (Maier et al., 2008). In particular, Duncan (2008) argues that proponents, practitioners and decision-makers may have a vested interest in making EAs politically appealing and defensible, thereby systematically minimizing uncertainty disclosure. When uncertainty is not revealed to the decision-makers or others, it may not be possible to arrive at suitable decisions regarding approvals, mitigation, or follow-up measures (Wood, 2008). Therefore, there is a need to understand the context within which EA and decision-making takes place so that the reasons for communicating, or not communicating uncertainties can be revealed. This thesis explores such conditions.

The reasons for uncertainty in EA are multiple and complex (Tennøy et al. 2006). This is particularly relevant for transportation megaprojects that are embedded within the economic, social, cultural, political, and environmental fabric of many societies, and where the EAs routinely carried out have often been questioned and denounced (Vidal & Marle, 2008). The emergent nature of the projects under

consideration (Salet et al., 2013) or the influence of the dynamics of technologies, economics, politics, and other contextual factors on the EA process are uncertainties that can shape the EA processes and affect the project trajectory (Tennøy, 2008). Transportation megaprojects are spatially situated and inherently displacing (Gellert & Lynch, 2003). The growth and popularity of these projects necessitates an urgent need to address the problem of uncertainty communication and consideration (Vidal & Marle, 2008) and requires an understanding of the full range of different forms of uncertainty without attempting to reduce, ignore, or deny them (Wynne, 1992). EA cannot be a rational decision-making tool if procedural systems continue to neglect its initial objective; encouraging the view that EA is merely a perfunctory step in obtaining project implementation approval (Brown & Hill, 1995). As such, there is universal agreement that uncertainty exists in EA, particularly in impact prediction (de Jongh, 1988), that uncertainty remains a key source of decision difficulty (Retief et al., 2013) and that it needs to be managed in some way, but no consensus exists on how to do this (Leung et al. 2014).

1.2.1 Purpose and Objectives

An increasing number of researchers have urged that complexity and uncertainty need to be considered as an integral part of the decision-making process (Giezen, Salet, & Bertolini, 2015; Groenleer, Jiang, de Jong, & de Bruijn, 2012; Salet et al., 2013). In particular, these researches urge megaproject planners to refrain from adopting the conventional 'closed' approach that tries to keep uncertainty and complexity out of planning and decision-making. According to Samset and Volden (2016), project proponents often are not comfortable working with uncertainty in an open manner. Yet, it has been suggested that more open and transparent EA processes that identify, expose, and disclose information about uncertainty through participatory approaches will improve EA effectiveness by bringing uncertainty information to the forefront (Wynne 2005). However, there are few studies providing empirical evidence that this will improve substantive objectives. International studies have gathered evidence to show how emergent dynamics (i.e. changes in the project, legislation, politics, etc.) can influence the treatment of uncertainties during decision-making (Dimitriou, 2014; Dimitriou, Ward, & Wright, 2013a). According to Dimitriou et al., (2013), megaproject stakeholders rarely identify contextual influences and often view projects as 'closed' systems. Therefore, it is important to understanding how contextual factors influence the treatment of uncertainty in EA and decision-making for the appraisal of mega projects.

Policy making structures and EAs are unique and embedded in context-specific dimensions of legal, administrative, and procedural circumstances (Gazzola, Jha-Thakur, Kidd, Peel, & Fischer, 2011a). Understanding the institutional and organizational structures, as well as the conventions, roles, attitudes, and values of the contextual framework and assessment process can promote the betterment of EA

effectiveness as a decision-making tool since these characteristics underline, guide, and define the development of sound practice (Hildén, Furman, & Kaljonen, 2004).

Through an investigation of the interrelated political, social, technological, environmental and physical realities surrounding a large infrastructure development project in Canada, this thesis seeks to determine how uncertainties are communicated, handled, considered and potentially influenced by the same contextual realities. More specifically, the research seeks to examine the EA process and identify key insights into the communicative practices and consideration of the uncertainties associated with a Canadian megaproject. Furthermore, the research will gather evidence of the degree to which uncertainty communication and consideration has been compromised, or influenced, by context-specific factors and emergent issues (i.e. institutional framework, regulatory systems; deadlines, budgets, etc.) surrounding the process, including requirements (i.e. public consultation). This will provide insight into how context affects the perception and treatment of uncertainty to offer an understanding of whether current EA practice is suited to manage uncertainties and integrate these in decision-making.

The findings of the research will help identify the ways in which practitioners, proponents, regulators, stakeholders, and other interests' involved in EA perceive and interpret uncertainty such that uncertainty can be better communicated throughout the process. Understanding the pathways of uncertainty communication will facilitate an investigation into disclosure practices, avoidance, and consideration of uncertainty in EA and decision-making and provide insight about how context shapes or influences the former. And the lessons formulated will provide practitioners and decision-makers with guidance on how to disclose information about uncertainty in their reports, how to communicate information about uncertainty amongst themselves and to the public, and provide the EA community with knowledge regarding the contextual dynamics that promote and/or hinder uncertainty communication and consideration.

The objectives of the research are:

I. To identify key uncertainties present during the 407 East EA as perceived by individual actors involved in the process;
II. To determine how contextual factors influenced the way uncertainties were communicated, handled, and considered throughout the EA process; and,

III. To develop recommendations and practical guidance to the EA community (i.e. practitioner, proponents, public, etc.) on uncertainty communication and consideration in EA and decision-making.

1.2.2 Case Study Context

Highway 407 is the world's first electronically operated tolled highway (Ibrahim & Gorys, 2008). Planning for Highway 407 began in the early 1950s, at the time when the metropolitan area plans called for another east-west alternative to ease traffic congestion on Highway 401, the second most congested highway in North America (Miller, 2002). Preliminary planning and route selection took place during the 1970s and 1980s (Ibrahim & Gorys, 2008). Initial construction began in 1987 and the project was completed in 1997 (Ibrahim & Gorys, 2008; Miller, 2002). The highway currently extends 108 kilometres and is composed of three main sections: Highway 407 Central (completed in June 1997), Highway 407 West Extension (completed in July 2001), and Highway 407 East Partial Extension (completed in August 2001) (Ibrahim & Gorys, 2008).

Recently, the Ministry of Transportation Ontario (MTO) has proposed a 70km easterly extension of the existing 407 highway at its current terminus at Brock Road in Pickering to Highway 35/115 in Clarington, as well as two north-south links connecting Highway 401 to the proposed 407 East extension; one in Whitby and one in Clarington. The 407 East Transportation Project is a large-scale infrastructure project that involved a variety of authorities, stakeholders, practitioners, and affected interests. The Ministry of Transport Ontario (MTO) initiated a provincial EA process in January 2005. However, a Supreme Court of Canada ruling in January 2010 required the project to undergo a federal Comprehensive Study which was commenced in July 2010 (CEAA, 2011). Also, in January 2009, the province announced that the extension would be tolled but owned by the province. Hence, the 407 East Transportation Corridor is not part of the 407 ETR's concession agreement.

The extension is considered a mega project (Holmes, 2010) and will be used as a case to critically address the research objectives. The setting of the environmental assessment process for the mega project offers valuable insight into Canada's largest sub-national region by population, and second largest by area: Ontario (Savan & Gore, 2014). The temporal and physical implications of this project, complexity, and uncertainties in terms of scale, scope, and potential for adverse impacts mean that the contextual realities (i.e. physical, social, political, ecological, technological) will provide for a rich investigation and understanding of uncertainty communication, handling, and consideration in Canadian EA practice.

1.3 Anticipated Research Contributions

Conceptually, this research aims to fill a research gap that has been identified in the international literature and specifically, in the Canadian context, on the understandings of the contextual drivers of uncertainty communication and consideration for environmental assessment practice, planning, and decision-making (Leung, Noble, Gunn, & Jaeger, 2015). Justification for this research is also pragmatic in seeking to provide practical guidance and suggestions for integrating and facilitating the uncertainty discourse for future projects. We hope that the findings can be applied, to some extent, to other contexts or encourage a discussion regarding the importance of transparent and open EA processes and decision-outcomes. Lessons and potential contributions on a regional and local scale can be expected. Results can provide valuable insight about existing and potential contributions for innovative, integrated, and transparent land use planning and infrastructure development. The contextual contribution can help EA practitioners and decision-makers gain a better understanding about the way in which they are, or could be, influenced by the context and in turn, how they may have an influence on the context.

1.4 Thesis Organization

This thesis adopts a manuscript-based thesis structure. This chapter is followed by a literature review (Chapter 2), which will explore the current state of knowledge relating to the nature, communication, and consideration of uncertainty in EA and decision-making. The review of relevant literature will also justify the present research by elucidating gaps in the knowledge. Chapter 3 will involve a secondary introduction, explain the study design, present the results of the research, and discuss the relevant findings. Lastly, concluding remarks, including recommendations for practice and suggestions for future research will be presented in Chapter 5

Chapter 2: Literature Review

2.1 Environmental Assessment Practice and Uncertainty

This section begins by explaining the purpose and rational for Environmental Assessment (EA). After framing the EA process, we discuss the inherent uncertainties in EA and decision-making and highlight major themes and classifications of uncertainty from the literature.

2.1.1 EA Practice

Environmental Assessment (EA), the earliest and most institutionalized form of Impact Assessment (IA) (Lawrence, 2013). Since the 1970s, EA has spread internationally in response to rapid development— especially over the past two decades— and it is currently being applied in over 100 countries under the auspices of various legal, action-forcing, and institutional arrangements (Matthew Cashmore, 2004; Lawrence, 2003; R. Morgan, 2012; Sadler, 1996). In Canada, the federal and provincial governments share the responsibility of conducting EAs; provinces adopt different EA regulations for projects in their own jurisdictions (i.e. Ontario Environmental Assessment Act OEAA) while the federal process applies to those projects for which the Government of Canada is a required decision-making authority under the Canadian Environmental Assessment Act administered by the Canadian Environmental Assessment Agency (CEAA) (Glasson et al., 2005; Noble, 2010).

EA is commonly referred to as a *process* or a *tool* for identifying, predicting, evaluating and mitigating the potential effects of a development prior to major decisions or commitments being taken (Barker & Wood, 1999; Glasson et al., 2005). The process varies from country to country and may be refined by elements of the context (e.g. type of proposal, environmental conditions, types of anticipated impacts, etc.) (Glasson, Therivel, & Chadwick, 2005; Lawrence, 2013). The process establishes the approach to practice as well (e.g. formal procedures, decision-making points, or technical activities) (Lawrence, 2013). The process can be divided into three major stages that involve different and important activities (Hellström & Jacob, 1996; Noble, 2010; Sadler, 1996). The first stage is the *Preliminary Assessment* and it includes the description of the project, screening, scoping, and identification of alternatives. The second stage is the *Detailed Assessment* which covers impact prediction, determination of impact significance, mitigation, reporting, review, and decision making. Finally, the third stage is *Follow-up* and it involves monitoring, impact management, and auditing (Hellström & Jacob, 1996; Noble, 2010; Sadler, 1996).

The precise purpose of EA has been interpreted in a number of ways and has created a plurality of judgments about effectiveness (Matthew Cashmore, Gwilliam, Morgan, Cobb, & Bond, 2004). However, it is generally accepted that the intent of EA is both procedural and substantive. According to both Sadler (1996) and Lawrence (2013), procedural effectiveness addresses the extent to which EA conforms to the established standards and procedures (e.g., the extent to which opportunities for public participation was provided), and substantive effectiveness being whether the EA process achieves expected objectives (i.e., informing decision-making, the explicit consideration of environmental factors in decision-making, avoiding environmental impacts, etc.).

2.1.2 Inherent Uncertainty in EA

EAs for contemporary plans, policies, and development projects are subject to complexity and uncertainty because socio-ecological problems are characteristically dynamic and difficult to predict (Ascough II et al., 2008; Maier & Ii, 2006). Practitioners and proponents use assumptions, models, and other forecasting methods to gain a better understanding of complex systems and to predict future outcomes (Walker, Harremoës, et al., 2003). Yet, complexity, natural variability, and measurement errors are some of the reasons why predictive models contain unavoidable uncertainties (Maier et al., 2008; Walker, Harremoës, et al., 2003). Still, EA often operates under the illusion that current and future conditions can be easily and accurately measured (Lawrence, 2013). For example, a study involving 22 Norweigian EAs by Tennoy et al. (2006) confirmed that predictions in decision documents often appear much more certain than they should. It was further concluded that for the 12 transportation projects in particular, only 24% of the predictions were found to be accurate, 41% nearly accurate, and 35% inaccurate. In a politically charged arena like EA, the appearance of confident predictions and the misuse or misinterpretation of numbers can have detrimental consequences (Duncan, 2008).

The screening, impact significance evaluation, and follow-up stages have been identified as areas where practical improvements are needed (Bank, 2005; Greig & Duinker, 2011; Sadler, 1996; Tennøy et al., 2006). However, uncertainties have been found to manifest in all stages including screening (Duncan, 2008; Geneletti, Beinat, Chung, Fabbri, & Scholten, 2003), scoping (Geneletti et al., 2003), impact predictions (Hellström & Jacob, 1996; Rowe, 1994; Söderman, 2005; Tennøy et al., 2006; Wood et al., 2000), evaluation (Wood, 2008), and management and mitigation (Söderman, 2005). The literature has pushed towards the betterment of practice by providing empirical evidence about the importance of identifying, communicating, and considering uncertainties in the predictions. Prediction uncertainties

have been discussed in the works of De Jongh (1988), Geneletti et al. (2003), Tennoy et al. (2006), Wood et al. (2000), Wood (2008), and a number of others.

During the preliminary stages of the assessment, baseline studies have been identified as a source of uncertainty because they often consist of incomplete information (Sigel et al., 2010; Wood, 2008). Baseline studies establish both the current and future state of the environment in the absence of the project, and thus, require a lot of reliable data (e.g. geology, traffic flow, species abundances, landscape quality, etc.). This stage forms the basis and credibility for the next steps in the assessment—thus, is it important that the information collected and gathered for the baseline case is relatively accurate (Duncan, 2008) because unreliable baseline data can reduce the potential effectiveness of proposed mitigation measures (Geneletti, 2003). According to Wood (2008), uncertainties in predictions can arise from measurement errors in baseline data, errors in future baseline estimates, and the accuracy of predictive methods.

2.1.3 Uncertainty Classification

The concept of "uncertainty" is closely related to the concept of "risk". Many scholars refer to economist Frank Knight's (1921) distinction of risk and uncertainty suggesting that uncertainty is when we have no information about the possible event outcome and their probabilities, and risk implies a partial knowledge of the probabilities (Spiegelhalter & Riesch, 2011; van Asselt, 2000). Walker et al. (2003) define uncertainty as *any departure from the unachievable ideal of complete determinism* (p.8). According to this definition, uncertainty is more than just the absence of knowledge. For example, uncertainties can arise in situations with a lot of information available because the information may reduce uncertainty but it can also reveal the presence of uncertainties that were previously unknown (Harremoës, 2003; Walker, Harremoës, et al., 2003). On the other hand, Brugnach et al. (2008) introduce a relational definition of uncertainty from the perspective of multi-actor decision-making processes. They define uncertainty as *the situation in which there is not a unique and complete understanding of the system to be managed* (p.4), and argue that the interaction between the diverse actors and their interpretive frames is a key component to understanding knowledge and uncertainty (Brugnach et al. 2008).There are different ways of defining uncertainty but in order to encompass all the dimensions of uncertainty related to EA practice and decision-making, the definitions by Walker et al. (2003) and Brugnach et al. (2008) are most appropriate.

There exists a number of uncertainty classifications in the literature to help overcome understandings, identification, and handling of uncertainty in various fields of decision support, including EA. These

classifications are useful, but they can be confusing and insufficient (Larsen, Kørnøv, & Driscoll, 2013). They often overlap, or build upon other previously published classifications (Refsgaard, van der Sluijs, Højberg, & Vanrolleghem, 2007) (see Table 2.1). Often times, uncertainty is broken down according to their location, or source, type, and level but there is no mutually agreed upon typology or classification for handling uncertainty in EA (Kloprogge, Sluijs, & Wardekker, 2007; Walker et al., 2003; Wardekker, van der Sluijs, & Janssen, 2008a). Due to the nature of our study, purely statistical uncertainties will not be looked at and are not always covered in the following existing topologies.

Table 1.1: Uncertainty typologies found in the literature

Reference	Theme	Location of uncertainty	Nature of uncertainty	Type of uncertainty	Level of uncertainty
Funtowicz and Ravetz (1990)	Science for policy			Inexactness Unreliability Border with ignorance	
Wynne (1992)	Science for policy			Risk Uncertainty Ignorance Indeterminacy	
Brugnach et al. (2008)	Science for policy	Technical system Natural system Social system		Ontological Epistemic Ambiguity	Unpredictability Incomplete knowledge Multiple frames
Koppenjan and Klijn (2004)	Network theory for decision-making		Variability Epistemic Ambiguity	Substantive uncertainty Strategic uncertainty Institutional uncertainty	
Maxim and Van der Sluijs (2011)	Science for policy	Substantive Contextual Procedural Problem framing Knowledge creation Knowledge use	Variability Epistemic Linguistic Legitimacy		Statistical uncertainty Scenario uncertainty Recognized ignorance
Rotmans and Van Asselt (2001)	Integrated Asses.	Model quantities Model completeness Model form Inherent uncertainty Model operation	Variability Knowledge	Methodological Technical Epistemological	
Refsgaard et al. (2013)	Climate change	Input data Model Context Multiple knowledge frames	Epistemic Aleatory Ambiguity		Statistical uncertainty Scenario uncertainty Qualitative uncertainty Recognized ignorance Total ignorance
Walker et al. (2003)	Model	Context Model structure Parameters Input Model outcome	Epistemic Variability		Statistical uncertainty Scenario uncertainty Recognized ignorance Total ignorance
Janssen et al. (2005)	Science for policy	Context Data Expert judgment Output	Epistemic Variability		Statistical uncertainty Scenario uncertainty Ignorance
Sigel et. al (2010)	Science for policy		Epistemic Variability	Fact-related knowledge Norm-related knowledge	Certainty Uncertainty Lack of knowledge
Van der Keur et al. (2008)	Integrated Ass.	Natural context Social context Technical context	Epistemic Variability	Statistical uncertainty Scenario uncertainty Qualitative uncertainty Recognized ignorance Total ignoranc	

The *location* of uncertainty reflects where the uncertainty manifests itself (Walker et al., 2003). In Walker et al. (2003) and others (see Table 2), they characterize the location of uncertainty within the system. The classification by Brugnach et al. (2008) and Van der Keur et al. (2008) enables a wider applicability as it reformulates location to reflect the context and activities of policy development independent of models.

The *level* of uncertainty characterizes uncertainty on a gradual spectrum of imperfect knowledge. According to Walker et al. (2003) the level of uncertainty ranges from determinism via scenario uncertainty, statistical uncertainty, scenario uncertainty, recognized ignorance, and total ignorance. Determinism is the situation in which we know everything with absolute certainty. Statistical uncertainty is when the uncertainty can be defined in statistical terms, and when it cannot then it is referred to as scenario uncertainty. And when there is simply an awareness of a lack of knowledge it falls into recognized ignorance while total ignorance is a state of complete lack of awareness of even having a lack of knowledge (Walker et al., 2003). Refsgaard et al. (2007) and Van der Sluijs (2006) argue that such deterministic distinctions of uncertainty do not consider the qualitative dimensions. The authors include qualitative uncertainty in their classifications for situations when uncertainty cannot be characterized probabilistically and that not all outcomes are known.

Epistemic and variability uncertainty are well recognized in the literature and reflect the origin or the *nature* of uncertainty (see van Asselt, 2000; Walker et al., 2003): Epistemic uncertainty is due to incomplete knowledge of the system, and variability uncertainty is due to inherent randomness and unpredictability of the system. Epistemic uncertainty is concerned with what we do not know but might know eventually and in some cases, it can be reduced (Walker et al., 2003). On the other hand, variability uncertainty is caused by the random or chaotic system behaviour, such as natural processes, or social dynamics and thus, it cannot be reduced by more research because this uncertainty involves things that we cannot know (Walker et al., 2003). Interestingly, recent changes in the conception of uncertainty have incorporated ambiguity as another *nature* dimension of uncertainty (Brugnach et al., 2008; Maxim & van der Sluijs, 2011; Raadgever, Dieperink, Driessen, Smit, & van Rijswick, 2011). Ambiguity is another type of uncertainty that is due to the different and multiple interpretations or framing of the system and we find ambiguity uncertainty in situations where there may be more than one valid way of framing knowledge. This type of uncertainty is likely to emerge when decision making processes involves multiple actors with diverse background, judgements, and values (Brugnach et al., 2008). EA processes are likely to encounter several instances where ambiguity type uncertainties are present.

The *source* of uncertainty, according to Sigel et al. (2008), refers to the point of reference or knowledge or specific issue that the uncertainty is related to (also called 'location' or 'causes' by other authors). Sources are context-specific and relate to the system or project characteristics. For example, sources include commercial and competitive pressures, technological surprises, financial constraints, institutional reform, value diversity, or other dynamics in the system (van Asselt & Rotmans, 2001). For the integrated water resource management process of the Rhine river basin in Germany, Van der Keur et al. (2008) classified the following sources of uncertainty: data uncertainty; model uncertainty (incomplete understanding or description of the system); multiple frames uncertainty; and, system conditions uncertainty (uncertainty about future conditions and external factors). Similarly, Koppenjan and Klijn (2004) examined the strategic behaviours of actors in situations of uncertainty based on network theory and identified the following types of uncertainty: strategic uncertainty, institutional uncertainty, and substantive uncertainty. Each type has different sources, for example strategic uncertainty can arise from unexpected and conflicting strategic actions of stakeholders, institutional uncertainty can come about from the dynamics of policy development and, substantive uncertainty is due to knowledge and variations in the interpretations and handling of knowledge.

According to Brugnach et al. (2008) all sources of uncertainty can be considered in the context of natural, technical, or social systems (Table 2.2). The natural system includes ecological and biological system components (i.e., climate impacts, water quality, wildlife, etc.), the technical system includes artifacts/elements that are utilized during the development of the infrastructure (i.e. highways, stormwater management, fencing, etc.), and the social system includes the economic, legal, political, administrative, and internal dynamics of the project development. Variability, epistemic, and ambiguity can exist in each of these context systems and are indicated in Table 2.2.

Table 2.2: Brugnach et al.'s (2008) uncertainty classification

	Variability	Epistemic	Ambiguity
Natural System	Unpredictable behaviour of the natural system	Incomplete knowledge about the natural system	Multiple knowledge frames about the natural system
Technical System	Unpredictable behavior of the technical system	Incomplete knowledge about the technical system	Multiple knowledge frames about the technical system
Social System	Unpredictable behaviour of the social system	Incomplete knowledge about the social system	Multiple knowledge frames about the social system

Recognizing the various ways in which uncertainty pervades EA can be helpful. Attempts to manage uncertainty in this way are often based on the assumption that uncertainties are identifiable, quantifiable, as well as easily communicable (Duncan, 2012) and that the disclosure of uncertainty will lead to better, more informed decisions and uncertainties will be better integrated and considered in decision-making (Tennøy, Kværner, & Gjerstad, 2006). The following section will go over some of the key arguments and findings in the literature about uncertainty communication and consideration.

2.2 Uncertainty Communication and Consideration in EA and Decision-Making

There is much criticism in terms of how uncertainties are communicated and considered in EA (Bond, Morrison-Saunders, Gunn, Pope, & Retief, 2015; Duncan, 2008; Larsen, Kørnøv, & Driscoll, 2013; Tennøy et al., 2006). Communication and interaction among the actors engaged in EA can facilitate new knowledge generation (Zhang, Kornov, & Christensen, 2013) as well as contribute to the effectiveness of the EA (Morrison-Saunders & Bailey, 2000). Therefore, it is important that practitioners translate their findings into non-technical language that is meaningful to the public and decision-makers—including uncertainties (van Asselt, 2000). However, much of the control rests with the project proponents who decide what information will or will not be passed on to the decision-makers (Wood, 2008), and disclosing information about uncertainties has been viewed as a means to an end for proponents who may have a vested interest in making their projects politically palatable (Cashmore, Bond, & Cobb, 2007).

It is understood that there is a need to improve uncertainty communication (Budescu, Por, & Broomell, 2011; Wardekker, van der Sluijs, & Janssen, 2008b); however, there is also a need to understand how

uncertainty is understood and information about uncertainty is treated before this can happen. In this section, the relationship between uncertainty communication and perception will be outlined. This will be followed by a discussion of applicable theoretical perspectives and current treatments of uncertainty.

2.2.1 Perception

When evaluating uncertainty communication and consideration in EA, it is important to identify how different actors perceive uncertainty. There will often be differences in the way problems are framed, uncertainties understood, and addressed between the scientific and non-scientific communities involved (Frewer, Scholderer, & Bredahl, 2003; Funtowicz & Ravetz, 1990; Hellström & Jacob, 1996; Walker, Harremoës, et al., 2003; Wardekker, van der Sluijs, & Janssen, 2008). According to Leung et al. (2016) the relationship between uncertainty information and communication of uncertainties is where perceptions play an important role in shaping the flow of information. The authors argue that there is a need to better understand how uncertainties are viewed in order to improve uncertainty consideration.

By definition, perceptual relativity denotes the situation when actors or stakeholders have different perceptions of reality based on their unique frames of reference, backgrounds, and world-views (Walker et al. 2003). In many stages of EA, subjective and value-laden assumptions are made (e.g. choice of parameters, impact significance, methods, etc.) (van der Sluijs 2004), and in the political arena, the experts, scientists, and consultants involved are pulled together and required to transform the information, the predictions, the assumptions, the complexities, and the uncertainties in a simplified, policy-relevant manner (van der Sluijis 1997; Wardekker et al. 2008). Similarly, the progressive transfer of knowledge about uncertainties throughout the stages of the EA will reflect the individual knowledge producers' perception about the information. In other words, the perspectives present among the diversity of actors involved suggests that each actor might treat uncertainty differently (Rowe, 1994) creating a gap between the authors' intentions and readers' understanding (Budescu et al., 2011). According to Brugnach et al. (2011), collective decision-making can give rise to ambiguity which is an indication that there may be more than one valid way of framing the knowledge.

Effective communication of uncertainty information is necessary, but it is equally important that decision-makers readily consider the uncertainty for responsible decision-making. Wardekker et al. (2008) looked at uncertainty perception, presentation, and communication in the Dutch science-policy interface and showed that policymakers and scientists held mismatching perceptions of uncertainty. From an economic perspective, proponents and developers of major or controversial projects may view uncertainty as an

imminent threat for project approval and choose to strategically avoid communicating uncertainties (Bond & Pope 2012; Wood 2008). This was documented in the Norwegian study by Tennøy et al. (2006) who found that, while uncertainty was identified in most prediction documents, uncertainty was indicated in only 59% of the Environmental Impact Statements (EISs), and 58% for decision-documents suggesting that decision makers are only given limited information. However, studies have shown that communicating uncertainty can impair negotiations, weaken policy proposals, delay action, and even cause confusion (Wardekker et al., 2008b). Van der Sluijs et al. (2008) argue that managing and communicating uncertainties involves more than just reporting, stating that "scientific uncertainty should be jointly established in a dialogue with all stakeholders" (p7). Government agencies are increasingly recognizing that uncertainties can no longer be suppressed or minimized (Van der Sluijs et al., 2008) and recommend better, more systematic treatment of uncertainties, improved communication and transparency, and better consideration.

Uncertainty cannot be eliminated in science, but better uncertainty disclosure can improve its integration into decision outcomes. According to Tennøy et al. (2006), when decision-makers were made aware of the uncertainties in the Grualia-Bruvolle road tunnel project, responsible mitigation and monitoring programs made it possible to detect several problems and improve the ability to deal with the uncertainties. Similarly, a study evaluating the quality of EISs and performance of EA, in terms of its effect and influence on project modifications, in 8 European countries, Barker and Wood (1999) reported that the EA process brought about modifications to several projects that were being assessed. This would suggest that decision-makers are making use of the knowledge in the EA reports provided to them. However, the following factors have been identified as having an influence on the quality of the information: legal and regulatory requirements; the experience of the proponent, consultants, and competent authority; the nature and size of the project; scoping; the length of the report; and, time needed to collect, analyze, and disseminate the information (Barker & Wood, 1999; Caldwell, 1991; Wood et al., 2000); in other words, the contextual elements of the EA.

2.2.2 Theoretical Perspectives

There is germane research on uncertainty outside the EA literature that attempts to explain human behaviors in regards to uncertainty, uncertainty communication, uncertainty avoidance, and decision-making in the face of uncertainty (see for e.g.: Leung et al., 2015). Several theories and ideas have been tested, including *actor-network theory* (Groenleer et al., 2012; Klijn & Koppenjan, 2002; Koppenjan & Klijn, 2004; Latour, 1987)*, prospect theory* (Kahneman & Tversky, 1979)*,* and *the certainty trough* (Duncan, 2008; Mackenzie, 1990).

Mega projects can be characterized as networks of people and agencies that work together to address a complex problem. The recent concept known as *actor-network theory* can be used for exploring uncertainty perception, the pathways of uncertainty information, and trajectory of communication in the EA context. Developed by French sociologists, Bruno Latour and Michel Callon, actor-network theory provides a theoretical and normative concept for analyzing and mapping dynamic processes of decision-making in network settings (Latour, 1987), making it easier to evaluate how perceptions, interactions, and institutions play a role in decision-making (Koppenjan & Klijn, 2004).

First, actor-network theory argues that society is made up of human and non-human components (i.e. legislation, economics, scale, etc.)(Latour, 1987). Actors are entities that are mutually dependent on one another, and the interaction patterns and processes that emerge establish the context for which actors articulate, evaluate, and address complex issues (Koppenjan & Klijn, 2004). Actor-network theory considered uncertainty as an inherent characteristic of actor interactions, resulting from the diverse interests, roles, and preferences underlying the behaviours of actors involved (Klijn & Koppenjan, 2012; Koppenjan & Klijn, 2004). At the same time power can be used to influence problem framing to the advantage of some actors. For example, Latour (1987) relates actor-network theory to the way in which scientist create facts by closeting controversies, and 'black-boxing' uncertainties and assumptions to avoid scrutiny—similar to the criticisms found in the EA literature where it is widely recognized that decision-making processes do not occur in a vacuum, but are actually influenced by context and power (Cashmore & Richardson, 2013; Lee & George, 2000; Wynne, 1992). Inspired by actor-network theory, Koppenjan and Klijn (2004) developed an uncertainty classification on the basis of actor networks where they describe substantive uncertainty (the absence of or interpretations of knowledge), strategic uncertainty (the unpredictable actions of actors relative to perception, motive, or behaviour), and institutional uncertainty (the complexity as a result of actors' different organizations and policy arenas interacting) (Klijn & Koppenjan, 2012). Because uncertainty in EA is broadly understood as encompassing both the absence of knowledge and shared understanding of the knowledge, introducing a network can expose strategic and institutional uncertainties in the process.

Furthermore, there is a vast body of literature in cognitive sciences and behavioural decision theory that is dedicated to research concerned with the inconsistencies underlying choices and judgments. Among the most prevalent theories in the literature is *prospect theory,* first formulated by Tversky and Kahneman (1979). This theory is designed to explain a common pattern of choice for when individuals choose among alternatives with probabilistic or uncertain outcomes by exploring the framing and evaluation

stages of decision-making. For example, Tversky and Kahneman (1979) argue that individuals tend to be risk-averse when stakes of losses are high, and risk-seeking if the stakes of losses are low. The theory attempts to show how individuals may make choices irrationally due to the psychological effects and heuristics (Kahneman, Slovic, & Tversky, 1982). First, prospect theory introduced a phenomenon called the certainty effect which describes the tendency to overweigh certain outcomes relative to outcomes that are merely 'possible'. If we extend the bias to EA for example, it suggests that decision-makers prefer a situation with less uncertainty. Alternatively, in prospect theory framing refers to a decision-maker's conception of acts, outcomes, and implications associated with a particular choice. The frame adopted by a decision maker is controlled by past experiences, by availability of information, and partly by the norms, values, and personal characteristics of the decision-maker (Kørnøv & Thissen, 2000; Tversky & Kahneman, 1981). Empirical research shows that the perception of a situation is affected by the way it has been framed, such as the order of the information or presentation of consequences (Kahneman & Tversky, 1979). With regard to EA, a framing effect can occur when different, but equally logical words or phrases can alter an individual's preference. For example, decision-makers might reject a proposal that focuses on the negative consequences of a proposal but give approval consent to one where impacts are framed positively. Kahneman and Tversky (1979) suggest that decisions which are more uncertain are more risky, and introduce an heuristic called 'loss aversion' which stipulates that losses are experienced more intensely than gains. This effect can contribute to discrepancies between how individuals value what they currently possess more than comparable things that they do not have. Alternatively, actors may accept risks in order to avoid receiving a reputation for inaction. Tversky and Kahneman (1973) also introduce the 'availability effect' for when decisions are based on information that is most readily accessible. For example, individuals will likely perceive air travel as being more dangerous than car travel because of the dramatic nature of aircraft calamities and the lasting impression that these incidents have.

Other relevant heuristics are found in the uncertainty guidance developed by Kloprogge et al. (2007) such as 'confirmation bias', and the 'overconfidence effect'. The former is when initial impressions structure the way subsequent information is made to fit within the decision and interpreted for the purpose of action. Confirmation bias can have implications for decision-making because contrary information that is not consistent with the initial understanding can be viewed as unreliable and disregarded entirely (Kloprogge et al., 2007). The overconfidence effect occurs when individuals place unwarranted certainty on their own personal work or judgments (Kloprogge et al., 2007).

Finally, the 'certainty trough' introduced by MacKenzie (1990), takes a social constructivist position in understanding how social distance shapes the perception of scientific knowledge. The concept suggests

that those directly involved in the production of knowledge and those further alienated from it will have relatively high levels of uncertainty, while those who are knowledge users, at medium distance, will attribute lower levels of uncertainty to the knowledge. The idea has been specifically discussed and applied in the context of environmental decision-making (Duncan, 2008; Shackley & Wynne, 1995). Shackley and Wynne (1995) confirmed that climate change practitioners attributed higher certainty to knowledge from another speciality than practitioners in the first speciality would attribute to it themselves. And Duncan (2008) reports how distance from the location of knowledge production can actually make knowledge claims appear more reliable than warranted. According to Duncan (2008), the assessment isolated actors in the process and created distances between knowledge producers and knowledge users, and this served to diminish uncertainty disclosure.

2.2.3 Responding to Uncertainty

There is improved theoretical understanding of the need to incorporate and manage uncertainties for decision-making, but the practitioner community continues to face criticisms in terms of not properly communicating uncertainties (Tennøy et al., 2006) because incomplete uncertainty communication can result in inadequate EA performance and questions regarding the legitimacy of appraisal outcomes (Duncan, 2008). In many cases, EA has little influence on the authorization decisions for development proposals (Wood, 2008) and others have argued that even if the uncertainties are explicitly disclosed in the reports, that the information will not necessarily reach decision-makers (Tennøy et al., 2006; Wood, 2008). Decision-makers should be given information about uncertainties that are present throughout the assessment to determine the best decision outcome (Geneletti et al., 2003). The lack of communication and consideration is generally associated with limited access to information (data and assumptions), errors in baseline data, model errors, uncertainties in impacts predictions, and uncertainties in impact significance and many others identified in the literature (Buckley, 1991; Duncan, 2008; Walker et al., 2003; Wardekker et al., 2008b; Wood et al., 2000). The responsibility for providing appropriate environmental information used in the process rests with the project proponents, who take control over the information and quality of the EA passed on to the decision-makers (Wood, 2008).

EA approaches are difficult to define as a result of the diversity of policies, practitioners, and professional cultures that exist in practice (Morgan et al., 2012). Because of this, the sections in an EA report (i.e. different impact areas) use different language, different criteria, and adopt a number of methodologies which can be difficult and even confusing for the reader (Wood et al., 2000). The challenges in EA can be remedied by adopting consistent and systematic communication approaches that better identify and manage uncertainties. In a review of the current literature, Leung et al. (2015) argue that practitioners

have limited guidance on uncertainty communication, disclosure and consideration for decision-makers and as a result, should not be criticized. They propose further research necessary to develop practical guidance about how practitioners should identify, interpret, and communicate uncertainty information. Typologies can also help practitioners and decision-makers understand the types of uncertainties that they are faced with and can prevent miscommunication or interpretational problems (Morgan et al., 2012; Walker et al., 2003; Wardekker et al., 2008).

Uncertainty cannot be detached from environmental decision-making and tools to better identify and manage uncertainties have been reported in the literature. At the same time, new developments in integrated management frameworks for EA have emerged which embrace the notion that complex environmental problems are inherently uncertain (Harremoës, 2003). Harremoës (2003) argues that post-modernism encourages new directions in terms of uncertainty handling which necessitates better participatory approaches, the adoption of the precautionary principle, and adaptive management.

Post-normal science

Post-normal science is a reflective approach introduced by Funtowicz and Ravetz (1990) which implies that normal science, aiming to consolidate policy with measurable, valid, and reliable information, has been impractical for issues driven by environmental risks (e.g. GMOs, anthropogenic climate change) (van der Sluijs 2007). Post-normal science seeks to establish a methodology of inquiry appropriate for issues with political pressures, disputes, high decision-making stakes, and uncertainty (van der Sluijs 2007). EA exhibits many conditions requiring a post-normal approach. Harremoës (2003) argues that deterministic science can be used to strategically hide uncertainty while Funtowics and Ravetz (1992) acknowledge the limits of scientific research and state that "..in the face of such uncertainties, they [experts] too are amateurs". According to Harremoës (2003), in cases where predictive scientific approaches fail or suffer from uncertainties, the precautionary principle is an approach to avoid and minimize the effects of scientific surprises (p. 24).

Precautionary Principle

Sustainability and precaution are key characteristics of post-normal science (van der Sluijs 2012). In the absence of scientific certainty, the precautionary principle is a strategy that incites anticipatory action to better cope with uncertainty. The Wingspread definition of the precautionary principle states: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof" (Wingspread Conference

on the Precautionary Principle, 1998). Alternatively, the precautionary principle is an appeal to prudence which encourages proactive decision-making under situations characterized by high risk or uncertainty (van der Sluijs, 2012). In Canada, the precautionary principle is embedded in federal environmental laws, including the Canadian Environmental Assessment Act (CEAA). The Canadian government's approach to the precautionary principle asserts: "The absence of full scientific certainty shall not be used as a reason for postponing decisions where there is a risk or serious irreversible harm" (Privy Council Office of Canada, 2003). However, although the recent changes in the Canadian Environmental Assessment Act 2012 reiterates the commitment to the precautionary principle, no mention is made regarding the means or adaptive capacity needed to effectively respond to a possible risk (Gibson 2012).

Adopting post-normal scientific approaches, or increasing reliance on the precautionary principle does not guarantee uncertainty communication in EA, yet, it may improve the inclusion of uncertainty in decision-making and provide for better accountability, credibility, and impact mitigation (van der Sluijs 2012). However, in the case of great uncertainties, it has been suggested that adaptive management measures should take precedence (Harremoës, 2003).

Adaptive Management

Adaptive management (AM) is an approach that presses for management strategies that are flexible, allowing adjustments to dynamic contextual factors, decision, events, or circumstances. AM encourages EA practitioners, planners, and decision-makers to conceptualize and design management plans that respond to change and are modified with increasing knowledge (Noble, 2000). Noble (2000) reports that traditional EA reflects a *blueprint* planning approach that seeks to eliminate uncertainty rather than manage it. AM is a more suitable approach to EA and inherent uncertainties because it also incorporates participatory approaches and stakeholder engagement to determine robust solutions. The isolation of the actors engaged in EA processes has been identified as a factor diminishing EA effectiveness by reducing disclosure of uncertainty information (Duncan 2008) and AM approaches could provide suitable grounds for more open and flexible decision-making.

2.3 The Importance of Context

The structure of an EA process has been understood as being dictated largely by the issues it is attempting to address, by the regulatory and legislative requirements within which it operates, by the socio-political and geographical context, and by the dynamic relationships and configurations of the projects actors and stakeholders (Leung et al., 2015; Tennøy et al., 2006; Wardekker et al., 2008a; Wood, 2008). The

literature has suggested that the substantive effectiveness of EA is context specific (Cashmore, Richardson, Hilding-Ryedvik, & Emmelin, 2010; Gazzola, Jha-Thakur, Kidd, Peel, & Fischer, 2011b; Hilding-Rydevik & Bjarnadóttir, 2007).

The following section begins by describing the important relationship between context and EA effectiveness. Since the current research involves a transportation mega-project in Ontario, Canada, a brief discussion about the related environmental impacts, uncertainties, and current practical limitations will conclude this section of the literature review.

2.3.1 Contextual Considerations in EA

Projects are unique and reflect a context-specific socio-political arrangement, or sets of legal, administrative, economical, and political circumstances, or even environmental settings (Jones et al., 2005). Moreover, it is widely recognized that decision-making processes, including EA, do not occur in a vacuum but are significantly influenced by context (Lee & George, 2000; Wynne, 1992). For example, the decision-making context according to Lee and George (2000) is influenced by two broad contextual factors: (1) who is involved in taking the decisions and their motivations, and (2) the social, political and economic circumstances as well as the regulatory, procedural and institutional constraints within which the decisions are taken. In particular, an EA process is directed by institutional arrangements which involve various interconnections among decision making authorities (i.e. proponents, governments, departments, regions, etc) wherein the information, or the connection, is filtered through an intricate set of legal, political, administrative, formal, and informal arrangements (Lawrence, 2013). Similarly, Arts et al. (2012) suggest that the effectiveness of EA will be influenced by context in the form of the procedures, the decision-making context, the involvement of actors, and the interests of the actors involved in the decision-making process.

According to Ascough et al. (2008), decision-making can be influenced by uncertainties from variability in the EA that stems from human behaviour or contextual dynamics (i.e. social, economic, institutional, etc.). Therefore, the context can introduce a number of factors shaping EA processes and performance as well. For example, Wood (2003) suggests that the more committed a particular institution is to addressing environmental concerns and incorporating them into decision-making, the more influence the information may have on decision outcomes. Similarly, a study by Lorenz et al. (2013) found that the extent to which uncertainty was disclosed in the reporting documents was dependant on the policy style and national context.

Contextual factors surrounding EA processes can be socio-economic, political, environmental, cultural, or other. Institutional and organizational arrangements can also pose a major structural challenge to the effectiveness of EA practice (Kolhoff, Runhaar, & Driessen, 2009) and includes both formal institutions, like administrative units, and informal institutions, such as cultural and social norms. At any given time, these institutions reflect the values of a society (Gazzola et al., 2011a). However, the political system is one of the most influential factors (Kolhoff, Driessen, & Runhaar, 2013). Authors like Kornov and Thissen (2000) have placed emphasis on the complexity in decision-making contexts and the relative significance of political powers. Hilden et al. (2004) point to the significance of legal and administrative factors for procedural aspects of environmental decision-making and argue that effectiveness is a product of the degree to which the assessment is tailored to the decision-making context. Further, Gazzola et al. (2011) argue that understanding the elements within an organization's context may improve the effectiveness of environmental appraisals. However, there is limited guidance currently available that would address the uncertainties arising as a result of a particular socio-political, environmental, or broader development context (Leung et al., 2015).

Kolhoff et al. (2009) studied the contextual factors constraining the effectiveness of EA in developing countries and developed a conceptual model (see Figure 1) to determine the contextual factors that influence the performance of an EA process. The EA system consists of the regulatory framework, informal rules in practice, and the capacities of the actors involved in the process. The context includes such factors that influence the components in the EA system, that thereby shape the overall performance output. These are the political system, the socio-economic situation, the institutional and legal framework, and the environmental situation. According to the authors, each contextual factor can influence the development and performance of the regulatory framework and the development and performance of capacities differently.

In a more recent article, Kolhoff et al. (2013) attempt to characterize and explain the development of EA legislation and provide a framework to better understand constraining contextual factors. They apply the framework to three developing countries on the basis that each country has unique contextual dynamics that can constrain or better EA performance. They found that there are two dominant actors influencing EA ambitions: the environmental authority, defending the environment and supporting EA, and the sector ministries, strongly defending the interests of their project development. For example, in Yemen sector ministries with strong political influences attempted to delay and avoid mandatory EA requirements. Kohloff et al. (2013) maintain that heightened environmental awareness can work to reduce such political

influences. Furthermore, results from their study showed that decision-making is influenced by the capacity (i.e. knowledge, experience) of the EA authority and also by the level of democracy of the political system.

2.3.2 The Transport "Megaproject" Context

Transportation infrastructure projects are among the biggest drivers of biodiversity loss globally (Trombulak & Frissell, 2000; van der Ree, Jaeger, van der Grift, & Clevenger, 2011). Some of the most cited ecological effects of roads include habitat loss, wildlife-mortality due to collisions with vehicles, edge effects, population subdivision and isolation, reduced population viability, barrier effects, resource inaccessibility, and increased human access (Forman & Alexander, 1998; Jaeger et al., 2005; Lenore Fahrig, 2009; Spellerberg, 1998; Trombulak & Frissell, 2000; van der Ree, Jaeger, van der Grift, & Clevenger, 2011). There are many direct (i.e. wildlife and vehicle collisions), indirect (i.e. isolation), as well as cumulative impacts associated with transportation infrastructure. Cumulative effects arise from the combination of many, varied projects, or from repetitive impacts of a single source (Treweek, 1999). A project can, by itself, have few impacts but collectively, with other disturbances or projects nearby, can result in detrimental consequences on both species and ecosystems at the local and landscape-scale (Byron, Treweek, Sheate, & Thompson, 2000; Geneletti, 2003; Jaeger, 2015; Treweek, 1996; 1999). However, landscape-scale effects of roads and road networks are difficult to quantify, and also poorly addressed in EAs (Jaeger, 2015). In a review of road-related EAs, Treweek et al. (1993) identified the following shortcomings: failure to identify the actual size of the proposed development (e.g. land take), lack of data, failure to commit in ecological surveys or reports, lack of quantifiable predictions and a reliance on ambiguous or vague descriptions, lack of baseline data, failure to commit to follow-up monitoring, evaluations of impacts limited in scale (e.g. local, regional, national), inadequate mitigation measures, and ill-supported mitigation prescriptions. Similarly, Byron et al. (2010) reviewed 40 UK ecological assessments of road development Environmental Impact Statements (EIS) and found that despite some improvements from their earlier reviews, the EISs still failed to address and predict the full range of ecological impacts: "the EISs gave the impression that some form of impact was likely, but were extremely vague about what type of impact might occur". Moreover, the study showed that predictions were hardly quantified, and cumulative effects were mentioned in only one EIS. This demonstrates that road-related EAs are facing a number of shortcomings and currently do not provide reliable predictions because the spatial scale is often inadequate, the resources and methods for predictions are seemingly flawed, investments in the provision of early, reliable ecological information is lacking, and cumulative effects are not sufficiently considered (Jaeger, 2015).

On the other hand, transportation projects are increasingly being built as mega projects (Gellert & Lynch, 2003). Mega-projects are characterized in the literature as having the following qualities (Flyvbjerg et al., 2003; Vidal & Marle, 2008): high degree of complexity; large-scale; embedded in a dynamic social and political context; widespread impacts; novel and innovative technologies and legislation; involvement of many diverse actors; many uncertainties; politically desirable; subject to resistance and opposition; lengthy planning and implementation time frames; and, are composed of a mixture of joint organizations and legally separate organizations.

Research over the last decade has shown that mega projects exhibit numerous environmental uncertainties which have profound lasting implications (Decision-Making on Mega-Projects: Cost-Benefit Analysis, Planning and Innovation, 2008). Citing their tendency to bring about landscape, aesthetic, and social change, Gellert and Lynch (2003) describe megaprojects as "creative destruction" by landscape transformation that is rapid, intentional, and profound (p.15). Besides their functional purpose, transportation megaprojects are physically extraordinary engineering feats that can instill national pride and gain international prestige. However, mega project EAs have also been criticized for being too narrow in their scope and inconsistent in their approach (Flyvbjerg et al., 2003). The impacts associated with transportation mega-projects are not temporally confined, implying that the decisions being made in the initial project formulation stages, and EA process, are very important (van Wee et al., 2005). The management of mega-projects and the determination of alternatives are critical because of the high stakes and resources needed. Therefore, careful assessments and considerations for the social, economic, and environmental impacts are needed to inform policy (Flyvbjerg, 2014).

The stress of a mega transportation project on the environment can be detrimental and uncertainties arising from the nature of the development are unique and ever more challenging (Vidal & Marle, 2008). Many transport projects have been linked to the underestimation of environmental impacts and lack of uncertainty disclosure (Thorne et al., 2014; Lobos & Partidario, 2014; Wood et al., 2000). However, urban development has become an important component of economic growth in major Canadian cities (Boudreau et al. 2009) and mega projects are seen as the solution (Priemus & van Wee, 2013). According to Dimitriou et al. (2013), mega projects are key drivers of change and have the potential to transform the context of the places, economies, and societies within which they operate. Findings from Dimitriou et al. (2013) study revealed that mega projects are often treated as 'closed' systems and do underestimate the influence of context on project development. The contextual factors influencing uncertainty communication and consideration could potentially correspond to mega-project components, comprising issues surrounding scale, social values, ecological sensitivity, economic situations, institutional

arrangements, political systems, capacity, and others (Vidal & Marle, 2008; Wood, 2008). Understanding the potential contextual influences of uncertainty on the communication and consideration could be beneficial and relevant on a national scale as it can, perhaps hopefully, lead to better decision making in the face of unavoidable uncertainties.

Chapter 3: Uncertainty Communication and Consideration in a Canadian Transport Mega-Project

3.1 Uncertainties in Transport Mega-Projects

Mega-projects are large-scale, multibillion-dollar infrastructure projects, usually commissioned by governments, and delivered through public-private partnerships (Flyvbjerg et al., 2003). These project tend to attract high levels of public attention and political interest as a result of their high costs, technological novelty, and substantial direct and indirect impacts on the environment and society (van Marrewijk et al., 2008). Cost-benefit analyses and environmental assessments (EA) are typically at the core of documentation and decision making processes for mega projects (Flyvbjerg, 2009). However, their one-of-a-kind nature, complex causal interdependencies, and heightened degree of political, scientific, and institutional uncertainties make transport mega-projects particularly difficult to manage (Flyvbjerg, 2007). Moreover, complexities increase because of the long-term nature and geographic extent of transportation mega projects; the long timespan between EA and implementation, the more jurisdictions, players, and interests involved, the more social, political, environmental, and economical hurdles there are (Priemus, 2010). As such, the success of any given mega-project depends not just on the quality of design and construction, but also on the quality of information provided to the decision makers, stakeholder, and the public—including information about uncertainties (Fischhendler, Cohen-Blankshtain, Shuali, & Boykoff, 2013).

EA has been successfully established worldwide and has been considered an important decision-making tool (Cashmore, 2004), but there is growing criticism related to the treatment of uncertainties in current practice (Duncan, 2008). Uncertainties occur throughout the process (Wood et al., 2000), stemming from various sources (i.e. models, input data, assumptions, values, methods, etc.) (Maier & Ii, 2006; Sigel et al., 2010; Tennøy et al., 2006; Walker et al., 2003; Wardekker et al., 2008b), and yet despite the growing recognition of uncertainty, empirical evidence has shown that there is a lack of transparency in the EA prediction process and uncertainties are not adequately disclosed (Tennøy et al., 2006; G. Wood, 2008). To be effective, EA should support and inform decisions, but information passed on to decision-makers by practitioners is often fragmented and poorly systemized (Sigel, Klauer, & Pahl-Wostl, 2010), and decision-makers and stakeholders are often provided with partial or incomplete information about the potential impacts of a proposed project (De Jong, 1988; Duncan, 2008; Tennøy et al., 2006; C. Wood et al., 2000). Also, it has been suggested that EA has been reduced to a perfunctory formality that results in a cumbersome report, read by few and with little effect on decision-making (Tennøy et al., 2006). For

example, Vaessen (2003; p. 124) concludes: “by far not all information in a report is read, and also important information on uncertainties that is needed to assess the strength of the conclusions is often not read”. Although the potential implications of non-disclosure are well documented (see Duncan, 2012; Tennøy et al., 2006; Wardekker et al., 2008), communicating uncertainties does not mean that such knowledge is used to inform decisions. Therefore, it is beneficial to reflect upon EA as a dynamic process wherein uncertainties are perceived, identified, and communicated by a range of actors which are themselves influenced by personal judgments, beliefs, and also by the broader social, cultural, and political context.

Transportation mega-projects are unique in that they are embedded within the context of past and future institutional pressures as well as the current political, social, and economic setting that is driven by local, regional, and national forces; essentially pulling together a diverse and competing group of interests, values, and resulting in considerable uncertainty (van Marrewijk et al., 2008). This situation can result in ambiguity; a type of uncertainty that arises from the presence of multiple valid, and sometimes conflicting ways of framing an issue (Brugnach, Dewulf, Henriksen, & van der Keur, 2011). On the other hand, the process remains vulnerable and malleable; that is, powerful players can shape how the project is assessed and defined in order to achieve personal goals (e.g., approval consent). Practitioners hired by project proponents have been observed to exhibit a tendency that positively reinforces a particular alternative, or project outcome that is most favorable to their clients (Mostert, 1996); or as Wachs (1989) put it ‘lying with numbers’. Project proponents delegate much of the EA process as well as oversee the information that goes into the final EA report before it is passed on to authorities, decision-makers, and the public (G. Wood, 2008). Thus, the substance of an EA is prone to intentional bias because proponents may selectively or strategically include findings while downplaying, or even excluding (Owens, 2005; Tennøy, Hansson, Lissandrello, & Næss, 2015) other results or uncertainties. Problems may also be framed in ways that simplify or reduce uncertainties, and this can mislead decision-makers or others by making predictions appear more certain than they actually are (Tennøy et al., 2006). In order to improve the quality and effectiveness of EA, several scholars have expressed the need for more explicit uncertainty disclosure and transparency (Bond, Morrison-Saunders, Gunn, Pope, & Retief, 2015; Kloprogge, van der Sluijs, Wardekker, & Department of Science, 2007; Tennøy et al., 2006; van der Sluijs, Petersen, Janssen, Risbey, & Ravetz, 2008; G. Wood, 2008).

Every EA system operates within a political, legal, administrative, and cultural context, and there is much literature discussing how context influences EA effectiveness (Bina, Jing, Brown, & Partidario, 2011; Bina, 2008; Hilding-Rydevik & Bjarnadóttir, 2007; Runhaar & Driessen, 2007; Wang, Bai, Liu, & Xu,

2012). The idea is that the dynamic interactions between elements of the context influences the entire EA activity including; the participants involved; the approach adopted; the process; the outcomes, and; the decisions (Bina, 2008; Wang et al., 2012). Therefor, given the possible importance of context, (Matthew Cashmore, Richardson, Hilding-Rydevik, & Emmelin, 2010; Hilding-Rydevik & Bjarnadóttir, 2007; Wang et al., 2012) this study questions the extent to which context constrains or promotes the communication and consideration of uncertainties in EA. In particular, transport mega projects have a tendency to evolve and react to the dynamics of the social, political, and environmental context (Salet, Bertolini, & Giezen, 2013), are marred with uncertainties and, in the words of Silvio Funtowicz and Jerome Ravetz, where facts are uncertain, decision stakes are high and values are in dispute (1994), uncertainty and knowledge quality require explicit attention. Thus, we aim to identify the contextual factors that shape the way in which uncertainties are communicated, handled, and considered in EA and decision-making of a Canadian Transport Mega Project.

Research Objectives

This research requires extensive knowledge about the contextual factors surrounding the project and development of the EA. To answer our research question we need to determine the relative influence of context on the communication, handling, and consideration of uncertainties. The study is delimited to a specific case study, and only a specific subset of decision-making will be investigated, the Environmental Assessment (EA) process. The scope is further reduced to a specific set of variables, i.e. uncertainties, perception, communication practices, and the context specific factors of the project (political, social, economical, environmental). Context issues relevant to EA include, for example, legislative requirements in place, formal and informal institutional arrangements, prior decisions or plans, and the ecological, cultural, social, political, and economics aspects that define and shape how an assessment functions (Pope & Grace, 2006).

The following three research objectives guide the study:

I. To identify key uncertainties present during the 407 East EA as perceived by individual actors involved in the process;
II. To determine how contextual factors influenced the way uncertainties were communicated, handled, and considered throughout the EA process; and,
III. To develop recommendations and practical guidance to the EA community (i.e. practitioner, proponents, public, etc.) on uncertainty communication and consideration in EA and decision-making

3.2 Methods

The qualitative nature of the research encouraged the use of qualitative data generation and analysis techniques. Qualitative research was adopted due to its potential to explain and explore complex issues, and illuminate the contexts or settings for which particular dynamics, processes, or issues take place (Creswell, 2012). The data for the research comes from two principal sources: document analysis of the project's comprehensive study report (CSR); and semi-structured interviews with project practitioners, proponents, and stakeholders. Importantly, a thorough literature review was performed between September and May 2014.

This section begins with a basic overview of the case study followed by a thorough look into the specific methods of data generation and analysis used. The section concludes with the potential limitations and ethical concerns experienced during the study.

3.2.1 Case Study: The 407 East Transportation Corridor Project

Covering 31 000 square kilometres, the Greater Golden Horseshoe, in southern Ontario, is Canada's most heavily urbanized and populated area. It extends from Niagara Falls to Barrie in the northwest, and Oshawa in the northeast (Newbold & Scott, 2014). It is considered Ontario's economic hub and engine (Allen & Campsie, 2013) and, after nearly two decades of policy development, public debate, and planning, the Ontario Ministry of Transport (MTO) in consultation with the Region of Durham, its constituents and other surrounding municipalities have addressed the long-term transportation needs and deficiencies in the Region of Durham and Greater Golden Horseshoe Area by proposing the 407 East extension (Figure 3.1). Major deficiencies in the current transportation system negatively affect the movement of goods and services and MTO's proposal for the publicly owned and tolled transportation corridor is supported by the desire to facilitate transportation and relieve congestion on Highway 401, one of the busiest highways in North America (CEAA, 2011). In addition, the easterly extension of the 407 supports the transportation objectives in provincial policies, growth plans, and from an economic perspective, the proposal is in accordance with growing population and employment figures for the region (CEAA, 2011). The province estimate that 13 000 jobs will be created for Phase 1 alone (Ministry of Transport Ontario, 2011a). The project is a huge part of the government's Open Ontario Plan to create jobs and strengthen the economy (Ministry of Transport Ontario, 2011a).

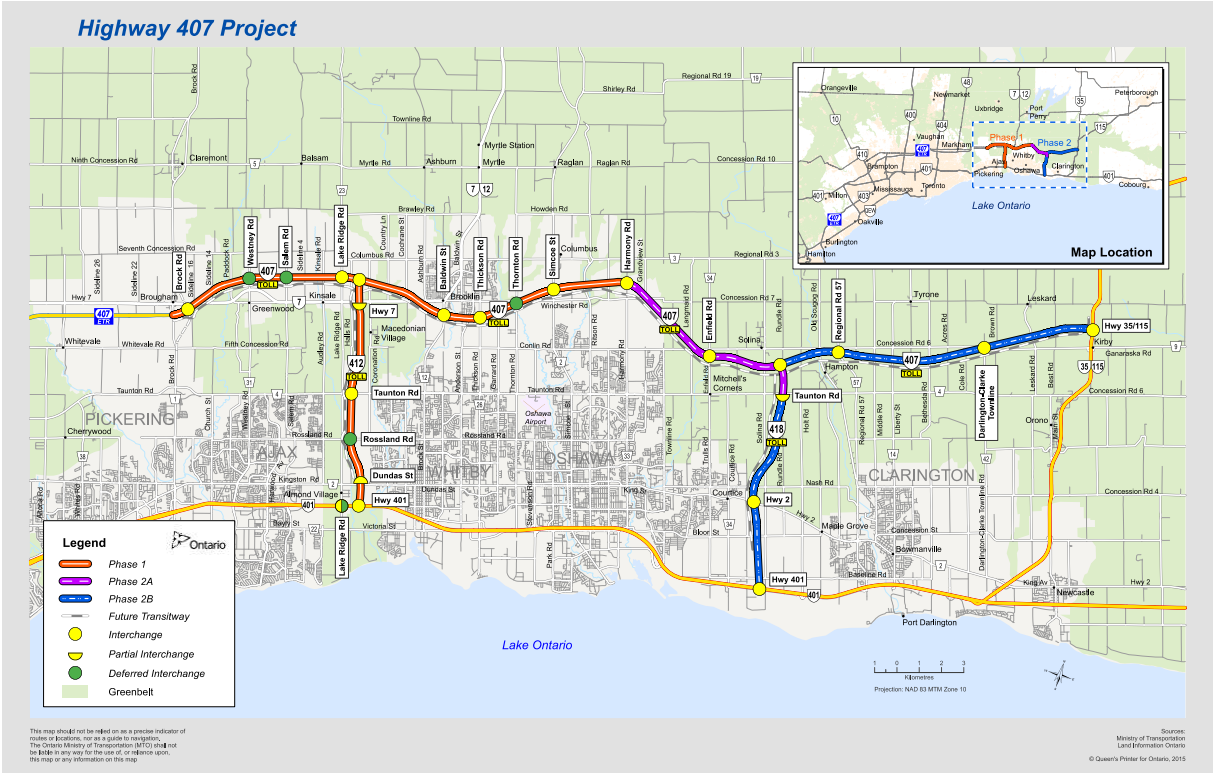

Figure 3.1: The 407 East Transportation Corridor Project (source: CEAA, 2011)

The 407 East Transportation Corridor is being implemented in two phases by Infrastructure Ontario (IO), in partnership with the Province of Ontario (MTO). Phase 1 includes the following activities:

- Highway 407 mainline (21 kilometers)(Infrastructure Ontario, 2016a):
  - Six-lane east-west extension of Highway 407 from Brock Road to Highway 412;
  - Four-lane east-west extension of Highway 407 from Highway 412 to Harmony Road; and
  - 6 interchanges
- Highway 412 (10 kilometers):
  - Four-lane north-south freeway link connecting Highway 407 to Highway 401;
  - 5 interchanges; and
  - A 5 kilometre (km) realignment of Highway 401 to accommodate Highway 412.

In all, there will be approximately 148 new lane kilometers with up to 11 interchanges, including two highway-to-highway links, 31 major water-crossing structures and 16 road crossings. The Province of Ontario has selected 407 East Development Group (407EDG) to design, build, finance, and maintain Phase 1 of the project for a 30-year period and the contract with the consortium was $1 billion in 2012.

The Province will own and control Highway 407, which includes Highway 412, and both highways will be tolled by the province. Scheduled completion of Phase 1 is Spring 2016.

Blackbird Infrastructure 407 General Partnership was selected to design, build, finance, and maintain Phase 2 of the project over a 30-year period with a contract value of approximately $1.2 billion in 2015 (Ontario, 2015). Construction began in March 2015 and is scheduled to be completed by late 2020. Phase 2 of the project will include (Infrastructure Ontario, 2016b):

- Highway 407 mainline (22 kilometers):
    - Four-lane east-west extension of Highway 407 from Harmony Road to Highway 35/115; and
    - 4 interchanges
- Highway 418 (10.4 kilometers):
    - Four-lane north-south freeway link connecting Highway 407 to Highway 401; and
    - 4 interchanges;

The Environmental Assessment Process for the 407 East Transportation Corridor

Under the Ontario Environmental Assessment Act (EAA), the Ontario Ministry of Transportation (MTO) submitted the Terms of Reference (ToR) for the proposed 407 East Extension Project to the Minister of Environment (MOE) in September 2004. MOE approved the ToR in January 2005 and MTO submitted the provincial EA in August 2009. The public was invited to comment during the preparation of the ToR and provincial EA. Approval for the EA was granted by MOE in June 2010 (MTO, 2009).

The federal process began as screening in May 2008. However, after the ruling by the Supreme Court of Canada in MiningWatch Canada v. Canada (Minister of Fisheries and Oceans et al.), deliberated on January 21, 2010, it was found that the responsible authority (RA) does not have the authority to reduce the scope of an assessment to fit it within a screening assessment. The RAs have the authority to enlarge a project scope but do not have the power to change the type of assessment to speed up the process (Hopkins-Utter, 2012). For the case of the 407 East Transportation Corridor, it was determined that the EA is required to proceed as a comprehensive study under CEAA.

The change in the EA requirements, from screening to comprehensive study, resulted in the addition of procedural steps such as additional opportunities for public and community involvement and participation prior to the EA decision by the Minister. The ruling also supports a cooperative EA by federal-provincial mechanisms which reduce duplication and overlap in the reports (CEAA, DFO, & TC, 2010). As such, the draft individual provincial EA report, the draft federal screening report, and other government or

public comments were used and coordinated as the basis for the comprehensive study document. The previous works were comprised into one body of documentation for the purposes of the CSR (CEAA, 2011). Important milestones leading to the approval of the CSR by the government of Canada under CEAA are illustrated in Table 3.1.

Table 3.1: Timeline of the 407 East Transportation EA Process

Date	Activity
Nov 2004	Terms of Reference for the Individual EA (for the Government of Ontario) submitted for the 407 East transportation project
Jan 2005	Terms of Reference for the Individual EA (for the Government of Ontario) approved by Minister of the Environment
Jan 2005	Individual EA (for the Government of Ontario) initiated
May 2008	Screening EA (for the Government of Canada) initiated
Aug 2009	Individual EA (for the Government of Ontario) submitted to the Minister of the Environment
Mar 2010	Supreme Court of Canada ruling in *MiningWatch Canada v. Canada [Red Chris]* prescribe that the project be continued as a Comprehensive Study EA
Jun 2010	Individual EA (for the Government of Ontario) approved by the Minister of the Environment under the Ontario Environmental Assessment Act (OEAA)
Jul 2011	Comprehensive Study Report (for the government of Canada) approved by the Minister of the Environment under the Canadian Environmental Assessment Act (CEAA)

Source: Canadian Environmental Assessment Agency (2011)

Mega project highway construction involves several stages and lengthy timeframes. According to the Province of Ontario, a typical highway expansion project spends 3 years to produce and deliver an EA, 2.5 years for design, 2 years for land acquisition, and then 3 years for construction (Ministry of Transport Ontario, 2011b). The EA process for the 407 East extension took went on for a period of 6 years—double the average duration. Also, to build the 407 East extension, acquisition of approximately 700 properties will be needed and it took upmost 3 years to acquire 311 properties for Phase 1 only (Ministry of Transport Ontario, 2011b). Additional legislative requirements, such as Species at Risk Act, Ontario Water Resources Act, Federal Fisheries Act, and Ontario Heritage Act, have lengthened the timeframes as well. In addition to the legislative requirements above, the following are some other requirements that have been identified for Phase 2: wetland and environmental mitigation for the East Durham Link; eight

significant watercourse/bridge crossings; one 300 meter wetland crossing; Utility relocations for a pipeline, hydro crossing and a CP Rail crossing, and; Two certificates of approval for contaminated sites (Ministry of Transport Ontario, 2011b).

The proposed project lies entirely within the Region of Durham and involves portions of the municipality of Oshawa, Pickering, Whitby, and Ajax, who have adopted official plans that recognize the need for the project and positive economic impact that it will have. The 407 East transportation project is one of the largest and most recent infrastructure mega projects that the province of Ontario has undertaken (Holmes, 2010). The environmental significance of the proposed project is enormous. The project right of way contains Greenbelt Lands, sensitive and protected areas, provincially significant wetlands, and habitats of federal and provincial species at risk. The proposed project encroaches on the Oak Ridges Moraine as well. The majority of the landscape affected by the proposal is comprised of active or recently retired prime agricultural land. The following are important considerations and natural features in the EA: The Oak Ridges Moraine; The Ontario Greenbelt; provincial watersheds; natural heritage; species at risk; and protected areas.

During the consultation process, the MTO notified the following Federal agencies: Canadian Environmental Assessment Agency; Fisheries and Oceans Canada; Transport Canada; Health Canada; Environment Canada; Canadian Coast Guar; National Energy Board; Department of Indian Affairs and Northern Development Canada; Canadian National Railway; and Canadian Pacific Railway. The Huron-Wendat Aboriginal community were among many to show an interest in the project, particularly in the study area by virtue of historic and cultural heritage issues.

3.2.2 Document Review

The Comprehensive Study Report (CSR) completed by the proponent and approved by CEAA for the 407 East Transportation project was the primary document used for the current thesis. The CSR contained valuable information about the EA process, data sources, methods, and about those who had been hired to work on particular parts of the EA. Although the document review was not a structured content analysis, the review and analysis of the CSR proved fruitful as a means to supplement primary data that was collected during semi-structured interviews. It is flexible, applicable to various types of information, and may be used to enhance, corroborate, verify, or even refute the data obtained through semi-structured interviews.

3.2.3 Semi-Structured Interviews

To capture the contextual dynamics associated with uncertainty in the 407 East case, it was necessary to conduct interviews with key case informants. Semi-structured interviews are open-ended, flexible, and allow respondents to discuss and comment on certain events giving the researcher valuable insights (Bryman et al., 2015). As opposed to structured interviews, the semi-structured nature permits the interviewer to explore opinions, values, and beliefs in detail, and provide flexibility in the timing and sequence of questions (Bryman et al., 2015; Tellis, 1997). To gain an understanding of the intricacies of decision-making and uncertainties involved, semi-structured interviews provided the primary source of data for the research.

Most of the participants, i.e. proponents and consultants, were identified in the CSR report. Other participants were identified on the project website or recruited by snowball sampling where participants that had already agreed or declined would refer the principal investigator to somebody else not previously identified (McIntyre, 2005). Interviewees were selected based on their role in the EA. In particular, we sought to find interviewees who had participated in producing or reviewing any part of the CSR or could provide input related to the research project. All participants identified were contacted via e-mail, or telephone, to request their participation in the research in late April and early May 2014. At this time, participants were given information about the research team and affiliations, the purpose and rationale for the research, and about the nature of their involvement either verbally or through the project fact sheet invitational PDF (refer to Appendix B for reproduction of introductory PDF). A copy of the consent form approved by the Concordia ethics committee and the interview schedule were also provided (full consent form is reproduced in Appendix C; interview schedule reproduced in Appendix A).

A standard interview guide was created by the larger SSHRC-funded research project "Speak no evil, hear no evil? Uncertainty analysis and communication in Canadian environmental impact assessment practice and decision making" that was used across all three case studies to help guide the interviews and compliment the themes of the research project (Appendix A). Because it was important not to lead the interviewees, the guide was flexible and provided a list of issues and themes to be addressed (Bryman et al., 2015). Questions were asked of each interviewee in a consistent and systematic order, but the interviewees were given the freedom to digress. The following five themes were developed by the research project team and applied in all three of the case studies involved in the larger research project, including this one: (1) Uncertainty in the Assessment; (2) Communication of Uncertainty; (3) Perceptions of Uncertainty; (4) Gauging Uncertainty, and; (5) Suggestions for Improved Practice. For the purpose of this current research, a final theme was added, (6) Contextual Dynamics of Influence (see App. A).

In total, 22 interviews with practitioners, proponents, First-Nation representatives, authorities, and a member of the public, all of which were directly involved with the 407 East project, were completed between July 2nd, 2014 and September 20th 2014. Although in-person interviews were generally preferred, the time constraints of the research and respondents made it recognizably difficult and as a result, two (2) were conducted over the telephone, one (1) by e-mail correspondence, while 17 were conducted in person in the Greater Toronto Area (GTA), Ontario, Canada and two (2) in Quebec City, Quebec. In the interest of the interviewees and for the sake of practicality, some participants were interviewed together with other members of their groups or organization. This was the preferred approach for the proponents (n=3), the First-Nation group (n=2), and some practitioners within the same organization (n=3). Grouped interviews had an average duration of 2 hours while individual interviews were approximately 30 to 90 minutes in length. Table 3.2 presents the distribution of interview participants by role.

Table 3.2: Distribution of interview participants based on role

Role	Description	Number of Participants
First-Nation Representatives	Representatives of First-Nation interests, including members and officials who are required to be consulted during the EA process	Two official representatives who work on behalf of the Huron-Wendat First-Nation group in Quebec City, QC.
Proponent	Persons or entities identified as the primary developers of the proposed development.	Three representatives from the Ontario Ministry of Transport (MTO) who were intimately involved in the 407 East Transportation Project EA.
Public	Members of the public and other local stakeholders that are consulted, funded, and involved during the EA process.	One local resident that received participant funding to ensure participation in the EA.
Practitioner	Individuals under corporate entity, or third-party experts who have the capacity to advise proponents during the EA process. Responsible for the preparation of the EA including collection of data, analysis, and evaluation. Experts offer advice and perform additional analysis where necessary.	Nine practitioners in total; seven practitioners who were selected and hired by the proponent (internal); three practitioners from different stakeholder groups, with experiences ranging from species-at-risk, traffic modeling, and wildlife mitigation, that received participant funding and participated in the EA as experts.
Authorities/Regulators	Representatives from the regional, provincial, municipal, and federal regulatory body who are responsible for coordinating the EAs and involved in managing and assisting in the EA.	Seven authorities in total. Three federal authorities: one representative from Transport Canada (TC); one representative from Environmental Canada (EC); one representative from the Department of Fisheries and Oceans Canada (DFO). One provincial authority representative from the Ministry of Environmental (MOE). Two officials representing provincial conservation authorities. And, one municipal government authority.

3.2.4 Data Analysis

The digital recordings were transcribed in October 2014 by the principal researcher onto digital Pages processing files on Mac. Transcripts were read several times and manually reviewed against the digital recordings in December 2014 to ensure completeness and accuracy. Each transcript was handled manually and the data was first standardized using the interview themes and questions. However, the semi-structured nature of the interviews allowed interviewees to deviate away from the predetermined questions and it was therefore necessary to organize the data further. The qualitative software QSR-

NVivo v.10 was used to organize, code, and analyze the data. For qualitative research, NVivo can increase analysis accuracy, transparency, and rigour of data analysis (Welsh, 2002).

The transcripts and CSR were uploaded onto QSR-NVivo v.10. and preliminary analysis involved coding the data using existing interview themes, concepts, or issues relevant to the research question such as communication, perception, contextual factors, gauging uncertainty, suggestions, and uncertainty in the assessment. When new concepts emerged, inductive coding was performed. The codes were then organized by interview question and theme wherever possible so that cross-examination and important disparities in responses could be extracted and analyzed. The research made use of two functionalities of the software: manual thematic coding, and query searches, which allow for quick word searches through text documents (QSR, 2015). Codes created and used during the analysis are provided in Appendix D.

3.2.5 Limitations of the Study

Qualitative research is often criticized for lacking "scientific rigour" (Mays & Pope, 1995, p. 109). Despite the strengths of the qualitative approach, such as depth of exploration, descriptions, and understanding, there is considerable resistance in the literature. First, there are concerns over validity; that is the credibility, reliability, and accuracy of the research process (Golafshani, 2003; Mays & Pope, 1995; Myers, 2000). Second, there are questions about subjectivity and a researcher's bias (Mays & Pope, 1995; Mehra, 2002). A third issue is reproducibility, i.e. a different researcher might not necessarily come to the same conclusion (Mays & Pope, 1995).

To give credibility to the study, the research project was structured according to a predefined set of themes and concepts that were gathered during the literature review, and used consistently during transcript analysis and content analysis. Replicability was not the primary goal of the research while partial generalizability is arguably still possible when applied to similar populations (Myers, 2000). To address potential biases, we adopted triangulation—a procedure that strengthens a study by combining qualitative and quantitative methods, and different data sources (Golafshani, 2003; Mays & Pope, 1995). The researcher used quantitative approaches by providing counts of the coding and themes that were created qualitatively wherever possible. Furthermore, such data came from two principal sources; interview transcripts and CSR analysis. Random sampling is uncommon in qualitative research particularly when the objective is to understand complex contextual processes (Mays & Pope, 1995; Creswell, 2009) and for this research, participants were identified based on their relevance to the research. To increase reliability (Mays & Pope, 1995), the researcher interviewed 22 participants with a wide range of roles, experiences, and backgrounds. The number of interviewees was based on observed saturation,

implying a point where no new information was forthcoming during the interview process. However, it was difficult to obtain an equal representation of all stakeholder groups (see Table 3.2). Members of the public and affected interest groups were hard to identify, while few even had the ability to comment on the matters pertinent to this research. This limitation will be explored further in the discussion.

Ethical concerns arising from the semi-structured interview methodology related principally to issues of confidentiality, informed consent, and freedom to discontinue. Adhering to the ethics approved by Concordia University's Behaviour Research and Ethics Board, these issues and concerns were addressed and all participants were made aware of their rights to remain anonymous, to discontinue from the study, and of the confidential nature of the information provided. To ensure compliance, the data was reported in aggregate forms and where quotations are used, participants are identifiable on the basis of their roles only so that those participants wishing to remain anonymous cannot be identified. The researcher carefully considered all issues related to ethics while also addressing potential methodological issues such as validity, subjectivity, and replicability.

3.3 Results

The analysis of the interviews (full interview schedule in Appendix A) and the CSR review revealed a number of prominent themes related to the research objectives. These results are project-specific. Direct quotations are used to illustrate prominent majority viewpoints, and frequency tables are used to show the distribution of references by the interviewees in the EA process. Perspectives that reflect disparate or conflicting viewpoints are reported where necessary to allow for a thorough understanding. When appropriate, some interview results are reinforced with findings from the CSR document review.

3.3.1 Uncertainties in the 407 East Transportation Project and EA Process

All 22 respondents acknowledged the presence of uncertainties in EA practice. The wider understanding of the participants was that predicting the future is impossible, and because predictions are the foundational element of EA practice, "we make necessary predictions and guesses all along the process" (PRAC-E3), as one participant said. However, the uncertainties that were elicited by the interviewees were not always specified accurately or detailed. Recollecting specific sources and occurrences within the 407 East Project proved to be difficult, and many participants were generally more comfortable discussing uncertainty loosely. Respondents shared unique perspectives about the perceived uncertainties in the process, but not all respondents were able to be specific in their examples and it was not always possible to discern which statements were speculations and which were well-founded.

There were 30 distinct uncertainties identified during the interviews (Table 7). When interviewees made a reference to one or several uncertainties, the references were coded and grouped according to like themes or 'systems': e.g. the environmental system (e.g. wildlife, wetlands, cold water streams, etc.), the social system (socio-political, economic, public, etc.), and the technical system (infrastructure, mitigation, design, etc.). The third column in Table 4.1 provides the number of interviewees who made reference to uncertainty, and the last column displays the number of times that the uncertainty was coded during the analysis. For example, six interviewees reported uncertainties about coldwater streams and these were referenced 10 times during the same interviews.

Table 4.1: Uncertainties reported by interview participants regarding the 407 East EA

System	Uncertainty	Number of Interviewees who made a reference	Number of references coded
Environmental	Species at Risk (not specified) - Butternut Trees - Red Side Dace - Blandings Turtles - Barn Swallows	9 3 2 3 1	32 3 2 7 1
	Cumulative Impacts	9	25
	Water Quality	10	13
	Wildlife	8	11
	Cold Water Streams	6	10
	Habitat Quality/Connectivity	5	6
	Wetlands	5	5
	Fish and Fish Habitat	4	5
	Air Quality	2	3
	Environmental General	5	9
Total Uncertainty Factors	14	Total Coded References	131
Socio-Political	Enabling environment (legislation, framework, policies)	12	27
	Institutional Uncertainty	8	20
	Project Implementation	8	8
	Agricultural Impacts	7	8
	Social Impact Mitigation	4	6
	Project Opposition	2	3
	Timelines and Budget	3	3
	Heritage and Cultural Impacts	2	2
	General Political	8	10
	General Social	7	11
Total Uncertainty Factors	10	Total Coded References	98
Technological	Project Design	12	35
	Stormwater Management	7	21
	Mitigation Measures and Compensation	8	13
	Data and Methods	7	10
	Follow-up & Monitoring of Project Impacts	6	9
	General Technological	3	2
Total Uncertainty Factors	6	Total Coded References	90

Environmental System

There were 14 uncertainties associated with the environmental system and were collectively referenced 131 times during the interviews. Participants identified uncertainties about species-at-risk *(18),* water quality *(10),* and cumulative impacts *(9)* most often. Analysis of the responses revealed differences and broad perspectives, however, not all respondents were able to specify their examples in detail. For example, there were three participants that openly stated that they could not elaborate because they were not as intimately involved or did not have the experience to detail their concern. Nevertheless, all participants perceived the environmental system as having the most significant uncertainties compared to other systems. Several (30%) mentioned that the potential impacts of the project on the environment are large and emphasized the importance of dealing with the uncertainties—for example, a proponent stated, "…with a project of this size and magnitude, the environmental side of things has the most uncertainty and it's our job to make sure that we have the right experts working on the project to help manage that uncertainty." (PROP-2).

Uncertainty about water quality was often discussed in association with salt and sediment runoff, groundwater, wetlands, fish and fish habitat, coldwater streams, and stormwater management. The majority of authorities identified water quality as being a 'huge' uncertainty, and other respondents made references about the lengthy negotiations that took place between the Province and the proponents related to water quality uncertainties. In particular, interviewees reflected on the impacts of road salt and the unpredictable impacts that the application of salt will have on the surrounding landscape. The belief was that because the project is going to be implemented in a previously undisturbed system, there would be more uncertainty about the potential effects on environmental components. The majority of responses particularly focused on the sensitive ecological features neighbouring the project, such as the Oak Ridges Moraine, the Greenbelt, and provincially significant wetlands. This was substantiated by a governing authority who described how it was necessary to request additional information from the proponents related to the proposed salt and stormwater management policies proposed so that the assumptions laid out could be better supported.

The large scale of the project was often linked with environmental uncertainties. Practitioners in particular discussed the difficulty in obtaining the necessary data to come forth with detailed and reliable predictions. One practitioner explained that, " …scale is a big thing here because we are looking at roughly 70 kilometres of highways and it's hard to get to such a certain level of detail…the larger the scale of the study, the more unknowns we have, the larger the geographical area, the more jurisdictions to deal with, the more actors, the more policies…" (PRAC-C6). At the same time, more specific

uncertainties such as those related to species-at-risk were also seen as being related to project size. One practitioner's concerns were related to the lack of baseline data for species at risk. Three other respondents mentioned that field studies could have reduced uncertainty about species at risk, but that resource limitations and time were constraints. Similarly, there were three participants who expressed the uncertainties regarding cumulative effects. For example, one authority said, "..you're not just building a highway and that's the only impact— but how do you talk about all the development and all the industries that will come on that highway? And how do you account for that if you don't really know how it'll come exactly? The uncertainties with cumulative effects are huge for the project…" (RA-F1). The uncertainty with cumulative effects was found to be closely related with the rapid pace of development in southern Ontario and the GTA.

Socio-Political System

Uncertainties that were about the EAs internal organizational processes, the regulatory framework, economic situation, political, or social factors were referenced 98 times. Participants presented an array of disparate sources of uncertainty in the socio-political system, however, the most prominent references were associated with the assessment framework and in particular, with the enabling environment (*12)* (i.e legislation, existing policies, etc.), institutional and organizational structure *(8)*, and implementation commitments *(8).* More ambiguous references were organized under general political *(8).*

The enabling environment was recognized as a source of considerable uncertainty during the EA. First, the procedural transition from the provincial EA to the federal screening and comprehensive study was described by several participants as having contributed to uncertainty. The change mostly affected public bodies (e.g. conservation authorities), municipalities, and provincial ministries or agencies—for example, one municipal authority stated that during the provincial process the proponents had a duty to consult their expertise, but when the process began under the federal government the role of the authority changed and became more vaguely defined: "we were still there during the detailed design stage but we had no authority….they would tell us what they would be doing and our advice wasn't required or even wanted" (CA-1). Regulatory changes shifted the dynamics and created confusion and uncertainty about procedural aspects of the EA, such as responsibilities.

Proponents mentioned that the abrupt change in the Species at Risk (SARA) Act in 2009 required them to modify their work concerning species at risk in the EA. The discussion with proponents further suggested that the lack of available operational guidance about how to implement the new Act quickly and efficiently within the established project timelines created a lot of internal pressure: "I think we tried to do

the best that we could in the absence of some very clear directions…nobody is to blame because it was just new legislation, but it was extremely frustrating for us trying to deliver a project with a moving target" (PROP-1). On the other side, proponents and practitioners remarked that it was important to adhere to the proposed timelines because of the contractual agreements with the consortium group selected to design, build, and maintain the 407 East Project.

Uncertainties in the institutional and organizational structure were related to the different, and sometimes conflicting, interests and priorities of the various actors involved throughout the process. Once again, the project scale was introduced as a contributing source of uncertainty because it introduced more and more actors to the process than smaller proposals. Participants expressed that the large-scale made the EA process less predictable because decision-making depended on interactions and negotiations among a larger number of actors. There was an overarching belief that there was a lack of practical institutional mechanisms for managing the diverse parties at the beginning of the EA process and, after transitioning over to the federal process, public participation grew even more and federal agencies became more involved.

Uncertainties that were raised about the implementation stage of the project were commonly associated with a concern about the transfer of knowledge and accountability. For example, a practitioner stated, "..seeing the next phase through is most often done by an entirely new team…so you've lost that knowledge base" (PRAC-C4). In contrast, another practitioner suggested that uncertainties can be reduced through strategies and policies that commit actors to subsequent follow-up and implementation plans. This was not the majority view, however.

Technological System

Interviewees collectively referenced uncertainties associated with the technological system 90 times. Most of these were about the project design *(12)* and proposed structures for mitigation *(8)*.

The location of the proposed highway and the phased implementation approach were heavily conflicted aspects of the 407 project during planning and decision-making. Most of the concerns were related to Highway 418 (formerly known as the East Durham Link of the 407 East). The East link received the most criticism during the route selection phase from opposition groups, communities, land owners, provincial authorities, and other affected interest groups. According to three interviewees who remained opposed to the decision of implementing the East link stated that the authorities and proponents did not reliably justify the Eastern section. In regards to the traffic models, it was said that, "…the province had done

demand modelling four to five years earlier and we pointed out that they were actually using very old assumptions" (PRAC-E3) and explained that they provided proponents and CEAA with a traffic demand modelling study which concluded that the East link was not needed. While proponents agreed to re-evaluate their own models, the practitioner said that he believed the report was actually ignored by the agency and the Eastern link remained in the plans.

Participants also discussed uncertainties with regard to the proposed mitigation measures such as wildlife passages, fencing, habitat compensation, and stormwater management. The uncertainties were due largely to the limitations in the knowledge available to determine the effectiveness of the proposed structures. Participants often stated that wildlife is unpredictable, and in terms of stormwater ponds, several interviewees were not confident that the measures would be reliable. Five interviewees were pessimistic about the likelihood that the planned compensation for wetlands and habitats would be successful. However, proponents discussed that they sought the input from experts that helped determine suitable locations for mitigation measures via hot spot analysis, and other structural design recommendations.

Uncertainties in the Stages of the EA Process

Interviewees were invited to discuss particular stages of the assessment where they perceived uncertainties to be associated with the activities or approach. Table 4.2 depicts the distribution of uncertainty in the EA process.

Table 4.2: Uncertainties in the stages of the EA process that were reported during interviews with participants in the study

Stage	Activity	*n*
Preliminary Assessment		
	Screening	*1*
	Scoping	*17*
Detailed Assessment		
	Impact Prediction	*9*
	Impact Assessment	*14*
	Mitigation	*13*
Follow-up		
	Monitoring and Management	*10*

(1) Preliminary Assessment

The majority of uncertainties described in the preliminary assessment were the result of the chosen level of detail, data availability, time, and resources available, especially during the selection of the proposed route and scoping. Participants in the proponent, practitioner, and authority groups felt that uncertainty is inescapable in the preliminary stages, but that it can be reduced as the process progresses with the appropriate approaches (i.e. new information). For example, this epistemic uncertainty was identified here by a proponent who explained that during the EA they experienced a lot of uncertainty at the very beginning and it was not possible to address all of it, "…some uncertainties you need to wait until you are down to the final line…" (PROP-2), and that as the process progresses many uncertainties can become more refined, "..we start with large uncertainties and get to smaller ones." (PROP-3). Ambiguity-related uncertainty due to multiple frames of the actors involved was also identified. For example, during scoping, several participants felt that there were biases to include Valued Ecosystem Components that had major regulatory and legal backing, such as provincially listed species at risk, while the others, such as locally significant species, were given lesser consideration.

(2) Detailed Assessment

Uncertainty was a critical feature during the detailed assessment stages of the EA. Participants made a number of references about the limitations in knowledge and their limited ability to predict with accuracy. Both epistemic and variability uncertainties were predominantly found in the stages of the detailed assessment stage and activities (i.e. impact prediction, assessment, etc). For example, prediction uncertainties due to data challenges were more commonly referenced by practitioners who were intimately involved in the prediction activities and the uncertainties were generally the result of incomplete, or lack of useable and reliable data.

In the impact assessment stage, participants felt considerable uncertainties as a result of the criteria, assumptions, and subjectivity involved when determining the significance of the impacts. The nature of such uncertainty was ambiguity. The proponents interviewed expressed the difficulties associated with this stage of the EA referring to a *balancing act* between satisfying the agencies and the public. The process introduces additional uncertainty as the result of the different disciplines coming together to assess the impacts. One practitioner explained that, "depending on your discipline, you are going to follow a different guideline and your data will be set up differently. The uncertainty comes when all the disciplines sit down together and try to make sense of it all, weight it up, and add values to it" (PRAC-C4). Similarly, a provincial authority highlighted the importance of transparent communication when disciplines and experts are coming together at this stage because "some of the uncertainties can be built into the background knowledge of a particular discipline and others might not be able to pick up on it…" (CA-2). The interpretation of uncertainty may therefore vary strongly among disciplinary teams or even stakeholder groups making it increasingly difficult to recognize.

Proposing and planning mitigation involved uncertainties related to the effectiveness of the proposed mitigation measures, and predominantly about stormwater management, compensation ratios for habitat and wetland complexes, wildlife passages, and noise. The lack of suitable comparable data or studies to verify the reliability of the proposed mitigation relates to epistemic uncertainty, but at other times, participants reported that there was ambiguity in terms of what exactly was being proposed.

(3) Follow-up

The project had just recently been approved (July 2011) and with construction underway, interviewees felt a lot of pressure and uncertainties with the follow-up stages that are largely due to the fact that construction and implementation had been assigned to a contractor. Many felt that while uncertainty was communicated and considered during the EA, that there was a great deal of uncertainty remaining in terms of how the contractors or follow-up consultant team would monitor and manage the impacts. MTO

is undertaking the follow-up program under the Canadian Environmental Assessment Act (CEAA). The program stipulates that MTO must submit an annual report for compliance with provincial conditions of approval and, it should include progress and results on the project development, monitoring, and mitigation plans for surface water; major biological features; vegetation restoration; construction noise and air quality. Some important implications were raised about professionalism, commitment, and staff turnover. Many described how over time, monitoring and follow-up commitments can be neglected as study teams change and people move on to newer projects. According to the proponents, the follow-up reports will address the uncertainties by overcompensating for potential negative effects. However, the other respondents felt that the follow-up program in place was minimal or biased to focus on regulatory backed components (i.e. Fish and Fish Habitat, Species at risk, etc). First-Nation interviewees stated that they were very uncomfortable with the program, especially in terms of being able to monitor and avoid cultural impacts that may arise during construction and after implementation. For example, interviewees in these groups discussed the prevalence of cultural artifacts in the area and ancestral burial grounds. The uncertainty relates to empirical uncertainty because these groups felt like the studies that were done lacked knowledge and could have benefitted from more time and resources to refine the anticipated impacts. Ancestral burial grounds were found and reported but both First-Nation interviewees did not feel as though proponents were honest in their findings and may not adequately report other cultural sites.

3.3.2 Uncertainty Perception

Participants' perspectives on uncertainties were different, but all interviewees acknowledged the presence of uncertainty in EA practice in general and particularly in the 407 East project. Proponents and practitioners alike interpreted uncertainty as an unavoidable feature of EA practice while other participants, especially affected interest groups and authorities, emphasized that it was unavoidable but also important for it to be communicated to them. An important fear was that misunderstandings of the inherent uncertainties can delay the project actions. The public's perception was viewed as a significant factor that could impede the process if information is not presented with caution. Interviews frequently insinuated that members of the public did not share the same appreciation for uncertainties as EA practitioners and thus are more likely to misinterpret uncertainties as a deficit in the work being done: "we don't want the public thinking that we do not have enough information or don't know what we are doing" [CA-2]. However, project proponents assured that it was not in their interest to hide uncertainty from the public and that it would only create social unrest and mistrust: "we found that with our experiences over the years it is not worth hiding information from the public " [PROP-1]. The public's attitude was in many ways a precursor for the development of an enhanced public consultation program. Past experiences that presented the public and stakeholders with limited opportunities for engagement and

participation did not always go smoothly and proponents seemed to agree that the 407 East was intended to be different. Nevertheless, one authority revealed that proponents may be hesitant in communicating uncertainties to the public because the public might delay the project: “the more the proponents communicate, the more the public can twist the information and use it against them” [RAP-1].

Impact significance, alternatives to, and selection of indicators were some of the most common challenges relating to varying perceptions and often times, these activities involved conflicting perceptions about valuation, weighting, or scoring of impacts and alternatives. The issue of uncertainty extends to how complete the knowledge base is, and what the scientific standards are, as there is a lack of shared or agreeable criteria for determining significance and weighing out the various components of the assessment. The amount of information in EAs is synthesized and there are trade-offs between the quality of information and the quantity of manageability of information. With regard to the 407 East, three practitioners acknowledged that if the process were to be done all over again that it would not necessarily have the same outcome because, for instance, different information may have been presented, different trade-offs may have been made, and other criteria could have been suggested and used. Due to the multi-disciplinary nature of an EA and sheer volume of the assessment report, there is a good chance that stakeholders do not get the opportunity, or have the capacity to understand all the uncertainties. Currently, the only way for uncertainties to be presented during these important discussions is usually through the information that is presented during the meetings with practitioners, proponents, and experts. Practitioners in particular discussed how it is not easy to determine impact significance for instance, while at the same time, proponents stated that it was impossible to satisfy everybody and that often, such discussions may lead to disagreements or misunderstandings. A lack of transparency can create a level of mistrust among practitioners. Every practitioner interviewed agreed that when all consultants and stakeholders know more about uncertainties, trade-offs are made with more confidence and decision-making can be performed with more confidence.

Nearly all participants discussed how at such a large scale, the 407 East was particularly sensitive to social and political conflict, and authorities, proponents, and several practitioners put forward that a lack of political or public support will seriously thwart proposals. For instance, the proponents reported on the potential economical and political factors shaping perceptions by stating, “As a government agency we always try to weigh the cost of things and decisions like that are really difficult because everyone has different agendas and understandings, but we also have dollar signs in the back of our heads…” [PROP-3]. Other times, decision-making bodies were viewed as inherently biased towards a predetermined outcome that would serve their institutional interests. For example, it was said by a practitioner that

uncertainties did not influence the decision because the project was significantly backed politically and socially.

3.3.3 Communication of Uncertainties

The research identified two principle ways that information about uncertainties was communicated during the EA process: (1) verbally, via consultation and other participatory approaches, or (2) in writing, or disclosed in the CSR report.

Verbal Communication of Uncertainties

The majority of the participants in the research were satisfied with the verbal communication of uncertainties and credited the proactive participatory process engaged. The approach included the Community Value Plan (CVP), Public Information Centres (PICs), Regulatory Advisory Group (RAG), Community Advisory Group (CAG), and the Municipal Technical Advisory Group (MTAG). The proponents interviewed remarked that the standard template they use for public and stakeholder participation was specifically enhanced for the 407 East, and other respondents confirmed that the approach adopted was different, accommodating, and much more flexible than other EAs they had experienced. Three practitioners said that in their experience project proponents will often try and avoid public and stakeholder participation but that MTO not only encouraged, but also broadened the scope for engagement. The majority of research participants discussed personal and broader benefits of the program in managing and addressing uncertainties. Proponents and practitioners felt confident that the consultation program helped reduce uncertainties by sharing information, solicitation expert and public knowledge, filling in gaps wherever possible, and providing a forum for uncertainties to be raised and addressed. For example, one practitioner's experiences demonstrated how uncertainties about assumptions for which inaccessibility to private property prevented data collection were resolved during community consultation and meetings with property owners. Enlarging the scope for engagement allowed this consultant to reach out to community members and access information that was not previously available.

Despite the instrumental value of the participatory framework employed, the communication of uncertainties to lay people was still viewed as difficult. The application of the participatory framework made it easier for uncertainties to be raised during informal decision-making but proponents explained, "they might not agree with what we are doing and how we got there; but at least they were given the opportunity to be heard, and I think that made a lot of people feel better…" [PROP-2]. Three interviewees were dissatisfied with their participatory influence on decision making and stated that the degree of accommodation they received as an affected interest groups was much less than what they had expected:

"…they had a duty to consult with us but we received the minimum and that is part of a political problem which creates full of uncertainties for us…" [FN-1]. The presentation and communication of uncertainty, according to most respondents, was carefully considered by those involved in producing it because of the perception that lay people have difficulty understanding the technical reports. Because of this, the information provided to the public is not necessarily the same as the information disseminated to the agencies, and according to one proponent interviewee, "…when we present something to the public, usually our text is something that someone from a grade 8 level can read and also, over the years we found that using maps and drawings are more effective than textual approaches…" (PROP-1). The information that is made public should be easy to understand because the assumption was that the public continuously misinterprets the information and can get lost in the numerical statements.

Disclosure of Uncertainties in the CSR Report

A query search was performed to locate the words 'uncertainty', 'uncertainties', and 'uncertain' in the Comprehensive Study Report (CSR) produced by the Canadian Environmental Assessment Agency (CEAA) for the 407 East Transportation project, as a supplemental exercise to performing the interviews. The purpose was to determine the extent to which uncertainty was disclosed in the CSR and corroborate with findings from the interviews. The query extracted five references of words related to 'uncertainty' (Table 4.3).

Table 4.3: Query results for 'uncertainty' and related words found in the CSR

Section	Sub-Section	Page #	Reference
Executive Summary	Follow Up	7 - 8	The purpose of a follow-up program under the Act is to verify the accuracy of the environmental assessment and determine the effectiveness of mitigation measures. In accordance with the requirements of the Act, a follow-up program is required for the Project. The program will focus on those environmental components where there is a relatively larger degree of **uncertainty** about the predicted effects. MTO will provide annual follow-up reports on vegetation (including wetlands), surface water, groundwater, wildlife, fish and fish habitat.
6.4 Surface and Subsurface Geology and Soils	6.4.4. Government and Public Comments	42	NRCan inquired MTO whether conducting additional studies could minimize **uncertainty** as to whether some deep cuts would be above or below the water table. MTO confirmed that additional geotechnical borehole drilling has been conducted at 31 deep cuts and high fills and that geotechnical studies are ongoing and will be completed to support future detailed design phases. The results of these studies will be taken into account in the site-specific foundation designs to mitigate effects on groundwater.
6.8 Fish and Fish Habitat	6.8.2 Effects Analysis and Mitigation	63	The unique aspects of this project in relation to the large structures required to accommodate the ultimate design scenario may require further specific restoration considerations, as outlined in the site-specific mitigation measures. Specifically, the vegetation loss and die-back under the ultimate design structures is anticipated to have potential implications for maintenance of channel form, morphology and associated habitat elements under the structures. The degree and type of potential adjustment and habitat related effects will vary with the specific fluvial geomorphologic and habitat conditions associated with the affected watercourse reach. Therefore, to address this **uncertainty** and inform the refinement of the design of watercourse crossings that require relocation, particularly where the watercourses are sensitive to erosion and/or support sensitive species or habitats, the following measures are recommended….
6.10 Species at Risk	6.10.3 Residual Effects	71	For Redside Dace, the overall effects will be reduced through the implementation of mitigation measures however, the likely residual effects still include disruption to Redside Dace habitat at 8 watercourse crossings due to shading from large scale structures and associated loss of vegetated 'deep' pool refuge habitat used by Redside Dace, as well as general **uncertainty** associated with potential for indirect effects on channel stability and form related to vegetation loss.
6.15 Consideration of Effects on the Capacity of Renewable Resources	6.15.2 Effects Analysis and Mitigation	81	In most cases, large structure spans have been designed to avoid direct impacts to fish and fish habitat, but shading and associated loss of vegetated 'deep' pool habitat, as well as general **uncertainty** associated with potential indirect effects on channel stability and form related to vegetation loss will result in residual adverse effects on fish and fish habitat. However, these effects are very localized and are not likely to threaten fish stocks within the watercourse, nor across a broad geographic area such as the RSA.

Source: *Canadian Environmental Assessment Agency (CEAA), 2011. 407 East Transportation Corridor. Comprehensive Study Report.*

The word 'uncertainty' appeared in the executive summary of the report in relation to the follow-up program. Another related to mitigation and design was referenced in section 6.4 about surface and subsurface geology, and in section 6.8 for fish and fish habitat. The word was used more generally in the section 6.10 related to species at risk, and in 6.15 about renewable resources.

During the interviews, participants were further encouraged to discuss how uncertainties were presented and communicated in the CSR report to verify the above findings. It became clear from the responses that not all participants had read the final report in its entirety, and some not at all. Despite the report being publicly available to all stakeholders and non-experts, it was not possible for participants to easily identify uncertainties disclosed within the reports. Proponents explained that it was their responsibility to make sure all the legislation and regulatory concerns are addressed, and that the information is transparent. Regulatory authorities further emphasized their responsibility in properly reviewing the reports provided to them before handing them over to the minister. On the other hand, the practitioners hired on behalf of MTO are usually responsible for carrying out particular studies (e.g. hydrogeology, air quality, etc.) and thus, many practitioners felt that reading beyond their specific section was unnecessary because, according to them, the coordinated process was sufficiently conducive. One practitioner mentioned, "..most consultants will just work in silos but, in our group, we encourage discussions and we synthesize" (PRAC-C1). Another practitioner highlighted the project-specific context: "The beauty of this EA was that it was truly integrated, and we were allowed to throw in enough resources to get it there by writing, reading, rewriting and referencing each other along the way" (PRAC-C2). Many practitioners suggested that uncertainties or knowledge gaps were handled through such an integrated approach, and two practitioners believed that it made the EA appealing to decision-makers which was why it did not take long for proponents to be granted approval.

Ultimately, of the nine practitioners interviewed for the research, and part of the teams hired by MTO to perform the analyses and activities of the EA, five of them mentioned the fact that they were not asked to explicitly disclose uncertainties in their assumptions or methodologies. These practitioners were sometimes wary of their reputation because being hired by a reputable government agency like MTO can make consultants feel more pressure to comply and please because, "…they don't want consultants that are headaches…" [PRAC-E2]. Most practitioners would argue that although it was not entirely prohibited, uncertainties were mostly not disclosed in the reports because it was not explicitly required by the proponents for them to do so or prescribed under EA guidelines that they were following. According to a practitioner, "…because they did not ask us, we just built certainty…" (PRAC-C 2).

Authorities and all the proponents interviewed were satisfied with the final report. However, proponents candidly said that they do not use the word 'uncertainty' in the written reports: "We wouldn't use the word uncertainty, I would be surprised if you found it…" (PROP-2). Proponents and several practitioners claimed that disclosing uncertainties would be impractical, confusing, and even unnecessary. Most

practitioners were also explicit about the improbability of coming across the word uncertainty, or any related terms in the documents. One consultant explained that the word uncertainty is not part of the vocabulary of the average consultant and said, "…we did not use the term uncertainty the way you are using it, it is just not part of our professional discourse… we very carefully chose those words like 'may', and 'could', and 'would', and 'will'.." (PRAC-C4).

There was a notion that the EA report should be salient—relevant to the potential users in order to be influential. It was important for the respondents that the report would contain information that meets the requirements of the agencies and authorities as well as the needs of the decision makers. Therefore, current practice does not necessarily include the disclosure of uncertainties. Proponents and the majority of practitioners argued that too much emphasis on uncertainty could give way to unnecessary discussion and project delays, and that the uncertainty information disseminated should therefore be limited and as policy relevant as possible. Authorities revealed that they have their own internal experts to rely upon that help make sure the information provided by project proponents is sound. Therefore, as one of the proponents mentioned, it becomes important to effectively manage the uncertainties during the process. The uncertainty information, according to most authorities, was disclosed to them accordingly and where gaps in the information occurred, or the quality of the information was questioned, the proponent was forthright with additional information and answers. Proponents of the 407 East thought that delays would only worsen if stakeholders believed information was kept from them and authorities were particularly confident with MTO as a proponent. According to the authorities, developments with a government proponent can benefit from more time and financial resources, and are usually more sophisticated and responsible proponents. One authority remarked that if the proponent left something out, they will most likely find out and it will just be more work for the proponents.

The Responsibility of Communicating Uncertainties

Respondents were asked to explain where the responsibility for communicating uncertainties lay, and overall, participants were in agreement that the responsibility was shared, but the ethical obligation to communicate uncertainties was seen to be with project proponents. This, according to many, was because proponents have ultimate control over the EA and therefore are in obligation to disclose and communicate the information publicly and to the decision-makers.

The authorities interviewed assumed their responsibility in making sure that the process is open and transparent, but they also emphasized their limitations. One authority said: "…all parties are responsible but in the end it's a proponent lead process and it's the proponent's job…" (RA-P1). Authorities maintained that it was important for them to be given all the information about the predictions and

underlying assumptions so that they are able to provide a rational recommendation to their government bodies (i.e. Agency or Minister). However, there was an awareness of the inherent biases involved in the process and the possibility that the project team may be strategically hiding valuable pieces of information to get quick approval, for example, "…there is always different ways that information can be presented and as a reviewer our job is to determine whether this report is being spun in an overly optimistic way, or in a way that diminishes significant effects and hides uncertainties…" (RA-F1). Authorities emphasized that there should be integrity used at every level of the assessment process.

3.3.4 Uncertainty Handling and Consideration

Participants remarked that they encountered many different types of uncertainties in their work and equally diverse ways of handling them. The majority viewpoint was that uncertainties should be reduced wherever possible and that only significant uncertainties and those that cannot be reduced internally should be addressed and communicated to the decision-makers so that these could be considered in the decision outcomes.

Acknowledgement of uncertainties was described as being a fundamental step towards incorporating uncertainties in the process. Even though participants in the study had relatively high awareness about the inherent uncertainties in EA practice, participants expressed that the most rational way of dealing with them were to determine which uncertainties are the most important, in terms of having a significant effect on the outcome, and which are not, because so many types and sources of uncertainties are present. Interviewees from authority groups stated that transparency in the process is important for them because too often proponents will provide reports that are biased and fail to recognize the assumptions and limitations in their work. In section 3.3.3, results show that there was a deliberate avoidance in disclosing uncertainties in the CSR report. Documenting the initial uncertainties and the approaches used to treat them was viewed impractical by the majority of participants. The alternative ways to handle uncertainties in the process according to interviewees in the case study are the following:

- Soliciting expert opinion (e.g. mitigation measures)
- Use of professional judgment (e.g. subjective value judgments based on experience)
- More information to improve knowledge (e.g. collection of additional data)
- Communication of salient uncertainties
- Software and analytical solutions (e.g. models and simulations)
- Use of decision criteria (e.g. reasoned argument approach)

The participants were encouraged to discuss the ways in which the uncertainties encountered throughout the process, communicated, and considered have improved or influenced decisions. Most respondents indicated that uncertainties would most likely play a big role in the development of the follow-up program and that the follow-up program would also be the most important tool to address and manage remaining uncertainties. The importance of communication was expressed by an authority here, "in order to utilize the tool effectively, we need to have had communicated where the areas of greatest uncertainty were" (RA-F1). Many interviewees agreed that when uncertainties are disclosed, these are generally addressed by putting fairly rigorous monitoring and follow-up commitments for the subsequent operations.

Precautionary Principle and Adaptive Management

A query search for the words 'Precautionary Principle' and 'Adaptive Management' performed on the interview transcripts determined the extent to which the terms were mentioned by the respondents in different groups (Table 4.4). The references are counts of the number of selections within each source. For example, there were three provincial authorities interviewed and altogether, the words "adaptive management" (AM) were found 31 times in their interviews.

Table 4.4: Query results for the terms 'adaptive management' (AM) and 'precautionary principle' (PP) in the interview transcripts

Stakeholders	*n*	AM References	PP References
First Nations	2	0	0
Proponent	3	5	0
Public/Local Stakeholder	1	1	0
Practitioner/Expert	9	55	3
Authority/Agency	6	61	20
Municipal Government	1	0	0
total	22	122	23

The precautionary principle was discussed much less than adaptive management during the interviews. Only three participants mentioned, commented on, or discussed the precautionary principle. In addition, a query search of the CSR of the term 'precautionary', 'precaution', and 'precautionary principle' returned no results from the main text of the EA and only one mention of the PP in the comments section that was

not significant. The principle, according to two interviewees, is no longer being fully embraced and adaptive management is seen as a more practical approach.

The interviewees that spoke about adaptive management perceived it as a valuable tool for uncertainty consideration. However, four participants remarked that the benefits of this approach is strongly connected with monitoring activities. To ensure that EA is meaningful, another federal authority described the importance of addressing the uncertainties via an adaptive management approach and that the follow-up program is the most viable tool for incorporating adaptive measures: "You need to know your uncertainties so that you can put emphasis upon them in the follow-up reports, which ultimately is the most important tool for ensuring an effective EA" (RA-F1).

Five practitioners remarked the importance of follow-up monitoring and adaptive management and claimed that it is an effective way of handling uncertainties that can arise. One of them said, "…whenever we want to monitor something that isn't fully certain, or we need confirmation, then adaptive management is where we turn to…" (PRAC-C3). In terms of ecological work specifically, opportunities to monitor post-EA are the only way to see how things evolve and to check the accuracy of the predictions. Practitioners made important comments regarding monitoring and adaptive management in particular for wildlife crossings and ecological restoration (i.e. wetlands). It was said, "It's one thing to put a few passages here and there, but it's another to monitor and see if they are actually being used" (PRAC-E2), and "…you need to monitor adaptively the ecological restoration works—I've seen areas slotted for compensation that years later are just dead wetland or inundated with weeds…" (PRAC-C5). Whether or not the commitments to monitor and follow-up are actually being enforced is difficult to say. Three practitioners and one authority recognized this flaw in the regulatory process.

The characteristics of the project, namely project type and project size, were said to be highly important in determining what the follow-up program would entail and how it would be carried out. Some implied that the purpose of follow-up was to determine the accuracy of the predictions but not necessarily to correct them, and fewer respondents assumed that the follow-up program would be adaptive and reactive. According to a proponent, the purpose of EA follow-up is to address uncertainties: "It's one of the reasons why we do it" (PROP-1). Authorities, proponents, and several practitioners discussed how follow-up was important for the 407 East because of the remaining uncertainty, issues of liability, accountability, and to ensure that future projects can benefit from the findings and performance of the project.

However, the ability to address the uncertainties during follow-up is undermined by institutional factors such as capacity, time, and accountability. For example, one practitioner said that in EA practice, people generally move on to bigger and better projects, "..when the consultants are changed, and then the upper management players are gone there is no system left to track these things and it makes follow-up difficult to manage" (PRAC-E3). An emergent challenge raised by a number of participants in the study was that of the continuation of the knowledge once the EA is complete and the project is awarded to the consortium. This would often result in a lot of post-EA uncertainties.

3.4 Discussion

In this section of the thesis we will explore the main findings of our research by providing a brief explanation of the uncertainties in the 407 East Mega-Project and the contextual dynamics. The research revealed that uncertainty was due to incomplete knowledge (epistemic), inherent randomness (variability), and to different and multiple interpretive frames (ambiguity). Furthermore, elements of the context, including project features such as size and location, contributed to some of the uncertainties identified by participants of our study. In the process, uncertainties were reported in all of the stages but were more relevant during the preliminary assessment and detailed assessment stages. In terms of communication, we explain how contextual variables and dynamics, including institutional, administrative, political, socio-economic, and cultural factors, influenced uncertainty communication and disclosure practice. Lastly, we present and propose recommendations for future practice.

3.4.1 Uncertainties in the Project

In order to address uncertainties, it is important to assess the nature of the uncertainty (Walker, Rotmans, et al., 2003). This is important because uncertainties that have a different nature will generally require different coping strategies (Brugnach, Dewulf, Pahl-Wostl, & Taillieu, 2008; van der Keur et al., 2008; Walker, Rotmans, et al., 2003). For example, if epistemic uncertainty is identified, additional research may improve the quality of the knowledge and thereby reduce the uncertainty. However, this strategy is not always appropriate for solving situations of variability or ambiguity-related uncertainty. Therefore, in this section we present the most frequently mentioned uncertainties and assess their relative nature assessed.

Environmental

As shown in section 3.3.1, all interviewees made at least one reference to uncertainty belonging to the environmental system. Reasons offered by respondents for the uncertainty in the environmental system

included: Project type, location, size, and lack of time, of appropriate data, of familiarity with impacts and techniques, and questionable relevance of methods for determining environmental impacts specifically.

Ecological impacts related to water, aquatic wildlife and habitat, and terrestrial wildlife and habitat were identified as having elements of both variability and epistemic uncertainties. Fundamental was the existence of natural variability or inherent randomness stemming from the chaotic and unpredictable behaviour of the natural processes under investigation (Ascough II, Maier, Ravalico, & Strudley, 2008; Sigel et al., 2010; Walker, Harremoës, et al., 2003). For example, we found that authorities and external stakeholders expressed a lack of knowledge about what the effects of road salt would be on both terrestrial and aquatic species' and their habitats. Interviewees considered the potential effects to be highly important yet largely uncertain. On the other hand, several claimed that the predictions were based on inaccurate information and were not confident in the work that was done to predict and assess the impacts of road salts. For some, this epistemic uncertainty was linked to the idea that proponents' and authorities have a vested goal to under emphasize the impacts of road salts. Compared to other provinces, Ontario is the largest user of road salt and it has been estimated that some 1,148,570 tonnes of road salt are applied annually (Environment Canada & Health Canada, 2001; Morin & Perchanok, 2000). At the same time, the Ontario Ministry of Transportation (MTO) remains one of the largest single users of road salts in Canada and uses on average between 500,000 and 600,000 tonnes of road salt annually. Surprisingly, proponents and consultants hired by the proponents did not display the same concern about water quality. In fact, we found a published review predicting a 20% reduction in salt loads and salt concentrations in Toronto-area streams performed by the same consulting firm hired by MTO for the 407 East Transportation EA. We found no other study to corroborate the reduction but rather, one study performed in Pickering, Ontario, showed that up to 50% of the salt applied to roads end up in groundwater (Meriano, Eyles, & Howard, 2009), and a report by an NGO group suggested that MTO has actually increased road salt use since 1996 (Riversides Stewardship Alliance & Fund, 2006). In general, subjectivity and assumptions within models being utilized was found to be a concern by several practitioners in the 407 East case.

Epistemic uncertainty was observed most often in the environmental system and our results show that the location and scale of the project may have enhanced this type of uncertainty. For example, the majority of the project is being implemented in an area not yet touched by development and participants described data gaps, limitations, and uncertainties due primarily from a lack of baseline knowledge. Epistemic uncertainty may in fact be reduced by further research (Walker, Rotmans, et al., 2003) but a few participants suggested that proponents are reluctant to go get the missing information or expert advice.

External practitioners were particularly concerned with the adequacy of the data being used to make predictions, claiming that they were not always convinced that the appropriate data was used, or collected, to reflect the scale and scope of the project. Some respondents felt that some uncertainty could have been reduced in the absence of strict budgetary and time constraints. Others did not identify budget and time as constraints but rather, they viewed these as realities involved in any large-scale EA and suggested that it would be unrealistic to perform the detailed study that so many requested due to the vast extent of the project. However, the quality of an EA is arguably dependent on the skills, access to knowledge, funds, and time available (Kolhoff, Runhaar, & Driessen, 2009). The disparity here may have caused proponents to use readily available data (van der Sluijs et al., 2004) and minimize the collection of additional data. Our results correspond with other works that address the data limitations commonly associated with ecological impact assessments of transportation infrastructure projects (Treweek, Thompson, Veitch, & Japp, 1993).

Socio-Political

Participants in our study expressed a number of uncertainties related to the socio-political system. There was a relationship between project size and ambiguity-related uncertainty. In mega projects, collaboration among diverse groups is necessary, but can result in conflicts due to different mandates and modes of rationality (van Marrewijk et al., 2008), and participants discussed that many disagreements between parties originated from variations in organizational mandates and legistlative requirments. According to actor-network theory, uncertainty is an inherent characteristic of actor interactions (Koppenjan & Klijn, 2004). This theory also can be used to explain how power can influence problem framing and be used to create and close down facts by influential actors (Latour, 2005). For example, some stakeholders felt that there was insufficient protection awarded to locally and provincially sensitive species and, that only federal regulations seemed to matter and take precedence in final decisions.

In particular, participants experienced ambiguity in relation to their roles and responsibilities which stemmed from institutional hierarchies and arrangements that were unclear. We presume that this was directly related to the size of the project and the lack of strategic guidance in terms of managing the overlapping governance structures (i.e. municipal, provincial, regional, etc) and the diversity of different, competing, and vested interests. Jurisdictional and municipal boundaries were crossed which also complicated decision-making. Proponents and authorities felt the pressure to accommodate everyone, but the internal conflicts and dynamics are, according to Bartlett and Kurian (1999), ‘unavoidably biased’, and correspond with the power relationships expressed in the research interviews. The main ones identified in the research were between proponents and First Nation representatives, federal authorities

and local authorities, and internal (e.g. practitioners hired by proponents) and external practitioners. However, the general impression was that the EA itself was effective and most concerns were about the post-decision activities and follow-up commitments.

The mega-project literature considers that changes in requirements, public resistance, new regulations, budget cuts, and inflation as realities that create complexity and uncertainty (Miller & Lessard, 2008). We observed how two abrupt changes, first the Red Chris Mine decision and then to the Species at Risk Act, contributed to operational uncertainties that necessitated quick, efficient, and adaptive action. This is because the uncertainty originated from a change in the institutional political process and beyond the scope of the proponents; a kind of societal variability that is major contributor to uncertainty (Walker, Rotmans, et al., 2003).

Technological

Mega projects are marred by a number of uncertainties including those that are related to technological design (i.e. innovation, size, etc.) and implementation (i.e. public-private partnership, complexity, commitment, etc.) (Flyvbjerg, 2007) and both of these were raised a number of times during the research interviews.

Despite the confidence in the planning and EA, respondents reported uncertainty about project design and mitigation that involved epistemic, variability, and also ambiguity-related uncertainty. For example, we observed that some participants were concerned with side-effects and mishaps associated with the novel and innovative infrastructure technologies being proposed. At the same time other participants welcomed and spoke highly of the technological novelty associated with the project. Building large and innovative projects has become important for economies around the world (Flyvbjerg, 2014). In a case study of the San Fransisco-Oakland Bay bridge, for example, it was argued that the 'technological sublime' dramatically influenced the design and project outcomes (Frick, 2008). Frick (2008) introduced the term as the excitement engineers and technologists get from building large and novel projects, i.e. the tallest buildings or *first* of anything. Flybjerg (2014) proposed three additional sublimes: political, economic, and aesthetic. In our study, we found no explicit evidence to suggest that the project outcomes were heavily influenced by the project's technological novelty but a few participants did make it clear that they felt the project was extremely important for the province, i.e. economically and politically, and that therefore the EA had little influence on the overall approval. There was also incomplete knowledge largely because according to a number of participants, the project was 'one-of-a-kind' and therefore the technologies being proposed had not yet been tested or trialed in southern Ontario and participants felt

uncertain about how well the project design would reflect the landscape, and at the same time, how well the landscape would withstand or respond to the project.

Uncertainties with regard to implementation were particularly related to ambiguity regarding the capacity of the contracting team and, as previously stated, the design of the Eastern link. Despite considerable public and stakeholder resistance during the selection of alternative routes, the Eastern link remained on the table as a viable option. It was interesting to receive input from an expert who provided decision makers with an updated traffic demand model because, according to the individual, the model which was used to determine the final decision was using outdated data and assumptions. It is not uncommon for road traffic forecasts to be wrong; in fact, Flyvbjerg (2007) performed a demand study for 208 projects and found that 50% of road traffic forecasts were wrong by more than 20%. For the 407 East, the refined model with updated data and assumptions disclaimed the need for the East link; yet according to the expert modeler and three additional respondents, the uncertainty only worsened when proponents and decision makers did not reassess the alternatives using the updated model. According to these four participants, proponents and authorities avoided to provide a justification for their decision to keep the Eastern link in the plans despite the evidence that it was not technologically nor environmentally feasible. Similar discourses were identified by Rozema and Bond (2015) who found that the flawed justification of two controversial infrastructure projects rendered the assessment process as ineffective. The choice of alternatives is often subjective and arbitrary while opposition to the selected alternatives may have came too late into the process (Steinemann, 2001). Moreover, the literature has argued that political powers and compromise-making are often more powerful than the actual scientific evidence for reaching decisions (Bartlett & Kurian, 1999; Cashmore, 2004; Geneletti, 2002; Miller & Lessard, 2008; Salet et al., 2013). Similarly, a study of EAs in the United States found that analysis of alternatives are often informally determined by agency agendas and foreclosed before public participation begins (Steinemann, 2001). Alternatives may have reflected the political and technological project objectives and agendas because expert and public opposition seemed to have little relevance in redirecting the proposal. Notwithstanding the significant ecological concerns associated with the virginal landscape and the degree of public resistance against the Eastern link, the lack of evidence-based justification of this option led to more distrust and uncertainties for actors in the 407 East EA. Duncan (2012) gives an account from a major energy infrastructure project known as the Basslink case where flaws were found in a simulation model only when it was no longer possible to perform additional simulations and that still, the proponents were able to make the bias appear negligible and convinced the assessment panel to authorize the project. As it would appear only later, the outcome of the model bias resulted in severe environmental consequences that could have been avoided at the onset if the proponent had realized legitimate disclosure (Duncan,

2012)

3.4.2 Uncertainties in the EA Process

Case study participants identified uncertainties at every stage of the EA process, but uncertainties were mainly identified in the scoping activities and detailed assessment stages.

Compared to all stages in EA, uncertainties that occurred during scoping were found to permeate into other stages. For example, interviewees criticized the scoping phase for being too narrowly focused, incomplete, and even inadequate. Interest groups were particularly critical of this stage and felt like they were not sufficiently involved in the decisions at this stage. According to Hellström and Jacob (1996), scoping is dependent on the political system and the ability of the technical specialists to identify and reach relevant stakeholders. It is important that everyone can participate during scoping to ensure that all concerns, issues, and uncertainties will be addressed during the detailed assessment. For example, we observed that for First Nation representatives, uncertainty during scoping could have been reduced if proponents would have reached out to them earlier, this would have allowed them to mobilize their experts on the proposed site early on so that they may have produced more thorough archeological mapping. Doing so may have avoided accidental excavations of burial grounds during construction. Similarly, the member of the public discussed how issues related to local watersheds received little attention during scoping and were therefore inadequately addressed during the EA. According to the interviewee, proponents and federal authorities were focused on larger federal mandates and largely ignored the concerns of the public regarding the adverse impacts of the project on local wetlands and watersheds.

Although all participants were deeply aware of the heightened presence of unavoidable uncertainties in scoping generally, no measures were found to have been introduced to address uncertainty specifically. Indeed, several practitioners, proponents and members of authority group in our study affirmed that due to the scope of the project, it was unrealistic to produce a more detailed study and therefore, the scoping activities warranted a ‘broad brush approach’. There were numerous opportunities for all interests to participate during scoping, however, some participants felt like there was a lack of willingness to actually consider the input provided by interest groups, members of the public, NGOs, and other stakeholders. Active and open participation as well as accountability would have reduced uncertainty and improved trust. It is largely believed that the context plays an important role during decision-making particularly

when trade-offs among social, environmental, political, and economic factors are being made—usually behind "closed doors" (Sadler, 1996).

Collectively, the detailed assessment stage, which includes impact prediction, assessment, and mitigation activities, involved the most uncertainties. Many of the uncertainties were the result of the diverse and multiple perspectives of the actors involved in the process which we described as ambiguity-related uncertainty and institutional uncertainty. Respondents expressed this by discussing the disparate approaches and methodologies, accuracy and reliability of the predictive methods, and subjective judgments that came together in the detailed assessment stages. For example, a practitioner commented that it was difficult to merge all the disciplines together and integrate their work because the criteria and methods are not the same across the different fields. Our results support Duncan's (2012) finding that unifying the works of various experts and teams of consultants into one consolidating report reduces transparency about uncertainties. Despite coordination and multi-disciplinary integration, both strategic uncertainty with how actors frame and develop their studies and strategies, and institutional uncertainty with regard to procedures, rules, and integration were present. Epistemic uncertainty was also discussed for all three activities (i.e. impact prediction, impact assessment, and mitigation). For example, participants discussed how predictions were constrained by the range of available data and strict timelines of the process. Generally, an EA conducted by the Agency must be completed within 365 days and, in our study, proponents had to adhere to both Agency and developer timelines. Costs also seemed to be influential in determining the direction and quality of the prediction process. For instance, one consultant stated, "Because cost is obviously a concern, sometimes you have to work with existing data that is pretty dated or from other places or from a smaller set of data than what you should be using, but you make conclusions based on what you have access to as opposed to spending time and money finding answers on the ground" (PRAC-C5). Prediction activities are resource consuming especially when the proposal involves a large undertaking because the extent of the impacts is greater. Proponents can experience pressure from decision-makers, stakeholders, and project timelines (Ross et al., 2006). EA prediction performance studies have shown displeasing results regarding the accuracy of predictions (Buckley, 1991; Tennøy et al., 2006b; Wood et al., 2000). However, most interviewees felt confident enough in the quality of the work, but there were a few interviewees who felt that the predictions were unreliable and could have been improved or expanded with more data.

Impact significance was perceived to be highly uncertain by the respondents. The scholarly literature has acknowledged the importance of significance determination in EA and argues that it remains one of the most complex and least understood activities in EA (Lawrence, 2003; Söderman, 2005; Wood, 2008;

Wood & Becker, April, 2004). In Canada, impact significance interpretation involves general guidance tools like sample criteria to give a sense of which impacts are more or less important for consideration. The definition of significance in Canada is quite narrow (i.e. adverse effects only) (Lawrence, 2003) and, according to our interview results, uncertainty arose at this stage due to subjective and professional judgments, a reliance on expert feedback, a failure to recognize the broader context (i.e. social, economic, and environmental), lack of formal criteria, disparate methodologies, interpretation of impact significance, and others. According to our findings, significance determination inferred a lot of ambiguity-related uncertainty due to the differences in the actors' perceptions, frames, and organizational values. Significance is not value-free. It is subjective, normative and value-dependent and therefore, significance determinations should be explicit, substantiated and most importantly collaborative and inclusive to all stakeholders, including affected interests and members of the public. We found inconsistencies in how participants felt about the manner in which significance determination was conducted. For example, we found that two interviewees were unhappy with the judgments and claimed that the discussions were biased to favor federal agency concerns (e.g., fish and fish habitat). Significance determination procedures should indeed be focused matters critical and relevant to decision-making, including regulatory requirements and agency concerns however, all judgments should be traceable so that other parties can independently reconstruct how judgements were derived. This could reduce biases and ensure that judgements are appropriate. In our study, only a few practitioners were able to describe the significance thresholds that were used during the process. We got the impression that determining significance is not systematic nor easily traceable. However, practitioners that were from the same consulting firm described how determining significance was performed as a group and this made the work come together in a comprehensive way rather than in 'silos'. However, care should be taken not to exclude or marginalize other forms of input. The public should fully participate in developing thresholds and criteria's and in the interpretation of significance, alongside practitioners, proponents, and regulatory figures. Making significance determination inclusive, participatory, and transparency is thus highly dependent on effective public participation.

Respondents placed considerable attention on the need for following-up, but we observed that there was considerable ambiguity about the degree to which monitoring and effective adaptive actions would be carried out. Follow-up is often poorly developed and the prescriptions can be limited (Lobos & Partidario, 2014). In our case study, because follow-up has not yet begun, participants could only speculate about it, and the prominent viewpoint was that the prescriptions would be too narrow and biased by federal agency concerns. The Agency, in consultation with federal authorities, defined the scope of the follow-up program and determined which factors warranted inclusion. Currently, federal authorities (i.e., TC, DFO)

are responsible for the implementation of the follow-up program under the coordination role of The Agency, while MTO is responsible for providing annual progress reports on impacts, mitigation, and project implementation. The importance of follow-up for this project resonated in every interview yet several participants discussed feeling worrisome about the degree of commitment on the part of MTO. Usually, proponents will employ a team of specialists and consultants to obtain the input necessary for compliance, in this case, an annual report. Participants in our study reported that proponent practitioners often lack the resources and capacity to carry out follow-up activities. At the same time, it is equally challenging to obtain adequate funding and other resources to supply follow-up activities long term (Wood et al., 2000) since proponents have a tendency to focus on monitoring programs and compliance that satisfies public opposition and regulatory agencies during the process, but not necessarily after approval is granted. Because the 407 East EA has just recently been approved, we cannot determine the degree to which monitoring and follow-up commitments are being satisfied, but the literature suggests that once a project is granted approval, monitoring activities are often neglected (Morrison-Saunders & Bailey, 2001).

Legislation should validate the scope for sound follow-up and ensure that all appropriate components, impacts, and concerns will remain under close watch; yet, it has been argued that the Act and the requirements for follow-up in Canada places a narrow focus on mitigation of adverse effects and discourages follow-up on social and economic components (Noble & Storey, 2005). Similar points were raised by respondents in our study who called for improved social impact mitigation and follow-up. The scope of follow-up should be consistent with the definition of 'environment' under the Act which spans the biophysical, social, and economical dimensions of development, and our study suggests that improvements are still needed in putting this requirement into practice. Unfortunately, changes to the former Act have actually greatly reduced the scope of EA (see Gibson, 2012).

Another important finding is the perception by respondents that follow-up effectiveness depends on the degree to which knowledge is transferred, communicated, and carried through post-decision. According to Morrison-Saunder and Bailey (2001), proponents and practitioners tend to move on quickly during land development projects and there is no continuity in project management and monitoring because responsibilities are transferred to various agencies. This observation is consistent with our findings where participants reported that the uncertainty was due to limited knowledge transfer to post-decision stages and activities. This can be problematic especially if there is a lack of knowledge transfer and individuals in charge are not made aware of the uncertainties.

3.4.3 Communication about uncertainties

Uncertainty communication is good scientific practice that promotes accountability and involves being open to both decision-makers and the public (Wardekker et al., 2008). Information about uncertainty should be effectively communicated to the public, decision-makers and other stakeholders (Budescu, Por, & Broomell, 2011). While many scholars have argued that the context of EA—politics, culture, society, and the organization and institutions—influences the effectiveness of EA (Bina et al., 2011; Bina, 2008; Owens, Rayner, & Bina, 2004; Wang et al., 2012), we observed that the context can further influence how information, including information about uncertainties, is communicated. Our results indicated that there were several factors that either hampered or contributed to uncertainty communication and consideration (Table 5). Every EA has its own unique context (Hilding-Rydevik & Bjarnadóttir, 2007) and interviews with project participants helped identify specific elements of the context for the 407 East EA. These are explored below.

Table 5: Factors that hampered (-) or contributed (+) to uncertainty communication and consideration

Factors that hampered (-) uncertainty communication and consideration	Factors that contributed (+) to uncertainty communication and consideration
1. Practitioner professional culture of minimizing uncertainty	1. Mega project features leading to adjustments in project aspects (i.e. accountability)
2. Lack of formal requirements or incentives for uncertainty disclosure	2. Improvements in participatory program
3. Institutional arrangements	3. Proponent's desire to maintain trust
4. Limited public participation	4. Regulatory oversight and review
5. Lack of time or commitment for reading and reviewing CSR	5. Internal practitioner dynamics

1) Institutional culture constraining uncertainty communication

Our results suggest that cooperation and communication between organizations and actors was heavily nuanced by institutional culture. In accordance with other studies, we found that some participants felt that communicating uncertainties, limitations, and assumptions was much less important (R. K. Morgan et al., 2012)—even unnecessary. For most practitioners it appeared to be common practice to deal with

uncertainties internally—and only when they could not be reduced or managed by the teams of consultants and experts themselves should they be communicated and passed on to the proponents. Part of the reason might be that practitioners feel a responsibility to their client in terms of getting their projects approved without social or public opposition. Not specific to the 407 East EA, the following quote describes the cultural barrier of uncertainty communication: "transparency is difficult because consultants certainly do not get hired again if they are too honest—proponents do not want to hear that because they are worried they won't get their approval" [RAF-1].

We agree with Larsen et al. (2013) who argued that the need or desire to avoid conflict or mistrust in experts and authority can lead to intentional uncertainty avoidance. In particular, it was found that participants in our study did not feel as though the public shared the same appreciation for uncertainty and as a result, may misinterpret uncertainties as a deficit in the work being carried out. This led participants to describe how uncertainty disclosure is often intentionally minimized during public deliberations. According to Frewer et al. (2003), scientists' perceptions of uncertainties revealed that the majority of scientists believed that the public was unable to conceptualize uncertainty and that providing them with such information would only have negative consequences (e.g. mistrust in science). Expectedly, the scientists in their study supported a 'deficit' model of communication which encourages the withholding of uncertainty information by experts.

Interestingly, we found that practitioners with a close professional relationship with the proponents (i.e. hired by the proponents to perform a specific task) showed greater inclination to minimize, reduce or avoid uncertainty communication compared to other interviewees who, although involved in the EA, had fewer or no direct professional responsibilities to the proponent. These individuals appeared to be more inclined to criticize the way professional culture has placed a reliance on objective science and on making uncertainty appear certain, and encouraged a more accessible, open, and transparent approach to uncertainty communication among professionals and between major actors, including proponents, authorities and members of the public.

2) Institutional and administrative arrangements as a barrier to uncertainty communication

Participants often described how the size of the proposal and the scope of the EA made it increasingly important albeit challenging to get everybody on board and cooperating. The majority of interviewees discussed how they frequently communicated about the uncertainties that they had been faced with and how they sometimes communicated these uncertainties to other actors for further handling. This was

predominantly observed during interviews with members of the same organization or agency (e.g. consulting firm). Inadequate and insufficient knowledge sharing was especially seen between disciplines, and often between major actor groups from different organizations or agencies (e.g. practitioners and public).

The diversity of agencies, groups, organizations, and authorities involved was previously identified as a source of uncertainty (See section 3.3.1). Closer examination revealed that this presented a barrier for uncertainty communication because of the presence of many different legislative, administrative, and institutional frameworks that influences how actors interpret what *is uncertain* and what *is not.* For example, one interviewee that was involved in the social components of the EA explained how it remains practically impossible for natural scientists and social scientists to see eye-to-eye. Also, the interviewee revealed that often uncertainties are not communicated to other disciplines or agencies because the issue may have not been an uncertainty in isolation but becomes one when it is combined with other variables in another field. This is among one of the many problems associated with inter-agency coordination in EA (Brugnach et al., 2011; Matthew Cashmore et al., 2004; Kørnøv & Thissen, 2000; Spiegelhalter & Riesch, 2011; Zhang, Kørnøv, & Christensen, 2013).

Many interviewees in our study highlighted that insufficient coordination between departments was a major problem and our interpretation of the results suggests that cooperation was successful within professional organizations (e.g. consultation firm), but beyond this, interagency cooperation and integration was found to be lacking. There was inconsistencies between methods used in the EA as well as tensions related to the variations in EA paradigms of the different disciplines and groups involved (Lee, 2002). This led to mistrust, particularly among local, provincial, and federal agencies who displayed limited coordination between and within their sectoral departments. We argue that the unexpected changes to the political and institutional structure (i.e. change in EA process) created confusion among those involved and that there may have been a lack of administrative support to clarify and allocate responsibilities and roles amongst organizations.

The lack of information sharing in EA among actors and departments is not a new finding (see: Bina et al., 2011; Tennøy et al., 2006). Results from our study suggest that external experts and actors felt that they are typically given limited opportunities to openly engage in and contribute to EA. In contrast, interviewees from other groups, such as proponent consultants, proponents, and federal authorities felt confident about the way in which the 407 East EA included, engaged with, and enhanced opportunities for the public and stakeholders. Consultation plans, meetings, and participatory programs certainly helped

disseminate and share information about the project and the EA, but there are also discrepancies regarding how useful these efforts were in terms of shaping or influencing outcomes. In the transport sector, Bina (2008) states, "the rigidly hierarchical structure, combined with the culturally and institutionally embedded divide between technical experts, bureaucrats, and senior leadership limited the quantity and quality of information being disseminated from the top down." (p. 723-724). Institutional hierarchies and arrangements may have constrained the opportunities for external experts, members of the public, affected interests, and other lower-tiered groups to provide input and interact with the EA in this case. For example, one local authority said that everyone had an opportunity to raise concerns, provide input, and comment on the EA but that once the EA was approved and planning commenced they were no longer being heard, particularly their concerns with the construction activities.

According to Kørnøv and Thissen (2000), when decision-making involves several organizations or actors, mutual dependencies and power inequalities among participants becomes an important issue that influences the process. For example, there are more people, more voices and, more concerns raised. Interviewees in our case study revealed examples of how teams or individuals responsible for different parts of the EA actively took part in cooperative processes or other means of information exchange to ensure that the EA was integrated. Practitioners in particular described the importance of maintaining close contact with one another in order to strengthen an interdisciplinary study. The integration of different specialities supports shared learning that serves to increase the robustness of EAs (Hildén et al., 2004). However, as the process unfolded, synthesizing assessment information was met with difficulties. First, there was *strategic uncertainty* resulting from the presence of various actors—each with their own perceptions, strategies, and agendas. Correspondingly, this relates to the concept of 'interprofessionalism' that refers to teams of practitioners from different professions working collaboratively on a specific task (Morgan et al., 2012). Assessors frequently disagree about matters of assumptions, methods and interpretations, and may also question the quality of each others work (Koppenjan & Klijn, 2004). Participants described how they are mutually dependent upon one another during the EA process, i.e. impact assessment and significance, and that often these critical interactions and partnerships may be confounded by individual actors steering towards their own agendas or preferences. Participant views and underlying motivations are not predictable and neither are the decision outcomes (Kørnøv & Thissen, 2000).

3) Cultural and social variables enhanced possibilities for uncertainty communication

Every participant interviewed made reference to the exceptional participatory program, which included the creation of community, professional, and public groups, and numerous PICs (public information centers)—and a few interviewees perceived them to be motivated by the proponent's desire to appear to be doing their due diligence and 'spin' the project in the eyes of the public and regulators in order to get approval smoothly: "these little checks and balances only to make sure that they are getting the communities involved, that they are liaising." Diduck and Sinclair (2002) argue that public involvement can be controlled by proponents by way of setting the terms of debate and ensuring that participation is on track with their hidden agendas. Notwithstanding, we agree with the majority of participants who felt that these initiatives were adapted to the project context (i.e. large number of affected interests requiring more care), which allowed for more opportunities for uncertainty communication. We observed that the decision to adopt strategies that heighten stakeholder and public involvement during the process was influenced by contextual factors. For example, proponents mentioned how the participatory program was enhanced due to the enlarged scale of the study and the desire to appease public and stakeholder mistrust. The shift in attitude resulted in comparatively high degrees of public and stakeholder engagement. The EA regulations that applied to the 407 East Project, including requirements for greater public engagement, may explain the reason why the process was characterized as being more inclusive. In a recent study, Hansen and Wood (2016) found that engagement and disclosure of information depended on the likelihood of encountering public opposition, the size and location of the project, and the perceptions of the affected stakeholders. In our study, the public's perception was viewed as being one of many reasons for broadening the participatory approach.

The influential role of context in the field of planning has been addressed by Sager (2001) who stressed that factors other than those related to the institutional setting can shape planning styles, such as pressure groups and powerful stakeholders. According to Sager (2001), planning is not carried out in an institutional vacuum but is actually a political activity where pressure groups and powerful actors can shape the outcomes. In our study, for example, trust and transparency were identified as important factors. Mega projects are often subject to public opposition (Flyvbjerg, 2007; Vidal & Marle, 2008) and the 407 East was certainly subjected to resistance. For fear of damaging their reputation and to address the pressure from regulatory agencies and the public, proponents and professionals will likely enter the debate especially when there is a need to communicate uncertainties, risks, and limitations involved (Harding, 2002). The negative perception of the proponent, the project, and the EA was driven by some mistrust that could be due to previous transportation project failures, the proponent's reputation, and other reasons. Slovic and Fischoff (1982) showed that past experience has a tendency to bias future judgments and Sandman (2012) stated that concerns can arise when the risk is man-made, novel, when there is

uncertainty, when there is memory of prior mistakes, and when information is withheld. In our current study, the proponents and authorities responded to this danger by proactively broadening the conventional participatory approach. Therefore, our findings suggest that the level of participatory involvement and the engagement approach in this case was indeed influenced heavily by contextual factors.

Our findings indicate that different and multiple perceptions, selection of information relevant for consideration, lack of uncertainty recognition, and lack of appreciation for the broader social and political context were among the most significant drivers for improving communication by the proponents and authorities during the EA process. Sharing the information with the public and increasing public awareness have been described as worthy means of building trust (Sandman, 2012) and the redefined participatory program of the 407 East EA certainly increased communication during the process. Over the course of the EA process, consultation involved presentations, individual meetings, workshops, fact sheets, websites, flyers and other visual cues, toll free phone numbers, First Nation councils, public information centers (PICs) meetings, and advisory groups. The program established three main advisory groups (MTAG, RAG, CAG) which gave an opportunity for individuals to meet with their respective counterparts regularly and discuss relevant project matters. Respondents explained that in this way information could be disseminated appropriately to the various interests. Methodological details and technical information would most likely be discussed in the Municipal Technical Advisory Group (MTAG), while less technical information would be communicated during the Public Information Centre's (PICs). The information is tailored to a target audience, which is in accordance with the concept of 'progressive disclosure' that applies to the reporting of uncertainty in EA reports (Kloprogge et al., 2007). Similarly, Kuhn (2000) argues that the disclosure and retrieval of uncertainty information should in fact concentrate on how the targeted audience perceives uncertainty since, besides being highly important, it may not always be appreciated and or of interest to them. On the other hand, consultation is verbal and interactive and there is a danger that there might be non-disclosure of valuable information (Lawrence, 2003). We found that the perception of the public interestingly shaped the way uncertainties were handled and communicated. Our findings reveal that many participants held the view that the public and non-technical actors do not conceptualize uncertainties in the manner in which the project team does, and participants remarked that what is presented during public meetings will most likely not delve into the methodological aspects. We have seen that uncertainties were not reported in the CSR and suspect that they would not be unless brought up by a concerned party. According to Lawrence (2003), there is a resistance for proponents and organizations to engage in processes that reveal uncertainty which compliments our findings of the 407 East accordingly.

Our results show that there was an overall appreciation for the participation program and that it was valuable as it helped provide a platform for issues to be raised, questions to be addressed, and information to be shared. However, we hypothesize that the main viewpoint might have differed if our participant sample pool had involved more members of the public and affected interest groups because our study involved primarily professionals. It is argued that individuals have a tendency to judge risks and uncertainties as more serious when the agency or proponents seem unresponsive to their concerns about it (Sandman & Johnson, 1992). We found that opposition and resistance to the 407 East mega project to have been reduced, but not eliminated, by the enhanced participatory scheme. According to our findings, proponents favored integrity and credibility stating that they have learnt over the years that withholding information from the public and regulatory agencies only leads to opposition and mistrust. Thus, they applied what they had learnt to the EA for the 407 East and expressed their satisfaction in doing so.

4) Lack of administrative framework to encourage uncertainty disclosure

Despite the academic literature urging for better uncertainty communication in EA practice (Tennøy et al., 2006; Wardekker et al., 2008b) our results of the content analysis show that uncertainties were not explicitly disclosed in the Comprehensive Study Report (CSR). The lack of uncertainty disclosure is typical as confirmed by other studies and authors in the literature as well (Andrews, 1988; Geneletti et al., 2003; Leung et al., 2015; Tennøy et al., 2006; van Asselt, 2000; Wardekker et al., 2008b; Wibeck, 2009; Wood et al., 2000). Andrews (1988) refers to the study by Caldwell et al. (1982) which looked at the disclosure of uncertainty in 74 EISs in the United States. They found that uncertainty was not acknowledged in more than 22% of the cases and that no report did so in a systematic way. Similarly, Tennøy et al. (2006) reviewed 22 Norwegian EA reports (decision documents, EISs) and found that 43% of the reports did not mention uncertainty, 13% mentioned but did not explain nor discuss uncertainty, and 37% of the reports failed to disclose the underlying assumptions in the data and models used in the prediction process. Similarly, our study found only five mentions of the word ‘uncertainty’ in the CSR report. This is surprisingly few. Also the descriptions were limited and we could not always discern what the uncertainty was about, which was because of a lack of standard practice for reporting and disseminating uncertainty in the reports (Leung et al., 2015). Our results are comparable to those of Lees et al. (2015) demonstrating that the disclosure of uncertainty in EA reports lacked consistent reporting, procedure, and terminology. Implicit disclosure of uncertainty and vague depictions such as ‘may’, ‘could’, ‘probably’, and others may still be used, but our study was limited to words directly related to ‘uncertainty’. Vague terminology is also problematic as it may create difficulties for decision makers to readily identify the importance of the issue (Lees et al., 2015).

The EA process resulted in numerous reports and large quantities of environmental summaries that were synthesized for the CSR. According to proponent interviews, all accompanying studies, meeting minutes, and information was made available to the public and any interested stakeholders. Irrespective of quality, we argue that such publicity increased transparency and promoted accountability by way of making the data, assumptions, and justifications relatively public. Despite the lack of uncertainty disclosure in the CSR, this was understood as a benefit of the 407 East participatory program. Proponents and their consultants in our study explained that disclosing uncertainties in the reports is not standard practice and they do not recommend it. Not surprised by the lack of uncertainty disclosure in the CSR, participants expressed that uncertainty is not necessarily hidden, but strategically omitted so that only salient uncertainties are communicated to decision makers and the wider society to ensure that they are not confounded by unnecessary information. We did not find evidence that would suggest that proponents are intentionally concealing uncertainties (see Wood, 2008), but rather choose to selectively disseminate information on the basis that it will have positive implications for the decision outcome, which is somewhat different than deliberately concealing uncertainty.

With a lack of guidance and good-practice disclosure requirements, practitioners and proponents may continue to discount uncertainty in their reports and choose to strategically report uncertainties which they deem necessary on their own. Cashmore et al. (2010) explain that impact assessment instruments reify governance norms and determine how issues are framed, analyzed and debated, which means that governance structures can have a direct influence on what types of knowledge are pertinent to decision making.

5) Tensions between growth priorities and environmental concerns limit uncertainty communication and disclosure practice

The underlying purpose of the EA can be articulated as, "Are the potential impacts of extending the 407 East acceptable?" This question led the EA to determine the acceptability or not of the proposal as it was presented, including alternatives to. However, one external practitioner claimed, "The EA did not matter" because there was such a strong economical, political, and social desire for the project to be approved that it was expected that all environmental concerns would be subverted. It has been argued that decisions are made on the basis of organizational and institutional structures, and are framed by the dominant political and social contexts (Bartlett and Kurian, 1999). If this is true, then the dominant political and social

context may have played an influential role in the way in which uncertainties associated with the EA were or were not communicated or considered.

For example, in a study involving 40 cases across the UK, Wood and Jones (1997) found that although EA enhanced the provision of information to decision-makers and, to a lesser degree, assisted in making project modifications, EA had no influence on the decision outcomes. In the same way, we found that in general, participants in our study did not feel like the presence of more or less uncertainty would have influenced decision outcomes. Our results further suggest that although uncertainties are not explicitly disclosed, decision makers felt that they were sufficiently aware of the underlying and unavoidable uncertainties. Despite insufficient information about uncertainties being handed over to the public and decision makers, there was a general consensus that the information was adequate to determine the approval and recommendations for project follow-up. Uncertainty consideration was deemed important by study participants. Authorities interviewed in our research agreed that they expect proponents and consultants to be ethical and transparent about uncertainties. And our results are in agreement with Tennoy et al. (2006) who found that decision makers are not made fully aware of the uncertainties in EA, on the basis of the reporting documents. However our findings from interviews with authorities would indicate that as intermediaries, authorities do their best to make sure that project proponents provide transparent reports. For example, two authorities described how they went about asking MTO for better and more objective information about matters such as stormwater management and noise impacts. Unlike the findings by Tennoy et al. (2006), we argue that decision makers are to some degree aware of the inherent uncertainties despite the lack of disclosure, but that they are most satisfied with the way in which proponents handle uncertainties. Many authorities claimed to place a high value on the information contained in the CSR, but like other studies (Cashmore et al., 2007) it was difficult to determine the instrumental role of the information on the decision outcomes. In addition, some authorities were explicit about having not enough time to read through the entire reports. Similar conclusions by other authors support our findings that stakeholders and decision makers may miss important information due to time constraints in reviewing the documents (Cashmore et al., 2007). Our findings suggest that the preference would be to consider uncertainties that have a bearing on the decision to be made. At the same time, the assumption was that potential environmental and technical issues would be raised by the authorities, a finding which was also given by Cashmore et al. (2007) and Wood and Jones (1997). However, our interviews with authorities reported that reviewing the documentation was time consuming and the possibility for oversight is highly likely. Consideration of all potential uncertainties was seen as impossible due to time and financial constraints. Duncan (2008) concludes that decision makers may not intentionally address uncertainties that are presented to them and, therefore it can be said that decision

makers for the current 407 East project prefer that uncertainties are disclosed particularly when they have a direct effect on the decision to be made (i.e. salient uncertainties). Our interviews with authorities provide evidence that when information was vague or unsatisfactory, authorities would ask for more information about the predictions and uncertainty. Examples are the stormwater management and salt practices. This information allowed authorities to provide decision makers with the best information for their deliberation (Duncan, 2008; Geneletti et al., 2003).

On the other hand, interviewees that belonged to external groups (i.e. NGOs, affected interests, members of the public, etc.) had a different view. According to our results, several participants in these groups felt that uncertainties were not well handled or communicated by project proponents and that these were therefore not appropriately considered by decision-makers.

3.4.4 Perception

The interviewees revealed that uncertainties are perceived in individually different ways. For example, project proponents and experts typically relied on past experience and subjective professional judgments to deal with uncertainty. On the other hand, several practitioners expressed that consensus building and professional judgments can introduce more uncertainty to the process. Actor-network theory considers uncertainty to be an inherent characteristic of actor interactions (Koppenjan & Klijn, 2004) and our results have confirmed that participants acknowledge this to be relevant in the 407 East EA. We found further evidence to support the uncertainty classification by Koppenjan and Klijn (2004), where uncertainty strongly originates from complex actor networks and actor behaviors resulting in either substantive uncertainty (uncertainty about how other actors interpret or frame knowledge), strategic uncertainty (uncertainty due to the unpredictable actions or behaviours of other actors), or institutional uncertainty (uncertainty due to the complex and dynamic presence of diverse actors from different organizations).

Our findings highlight that to better communicate uncertainty in EA, it is important to select an appropriate communicative approach that is suitable for the receiving audience. Actors in any EA are coming together in partnerships and need to take into consideration the wider context that incudes other actor's perceptions, paradigms, responsibilities, and approaches. Participants in our research had varying perceptions of uncertainty and we found that their views corresponded with the degree to which they were involved in the process. Generally, the practitioners who were engaged in data collection and analysis perceived uncertainty as a 'day-to-day' reality, whereas affected interest groups and participants that were more distanced from the knowledge production had a tendency to expose higher concerns about

uncertainty. The 'overconfidence effect" is a relevant heuristic that was discussed in Kloprogge et al. (2007) which explains how some actors or experts may place unrealistically high degrees of confidence in their own personal work. We observed that several practitioners' in our case study attributed very high levels of confidence in their work completed for the EA. At the same time, other practitioners from other firms did not always feel confident in the work other actors were completing. Shackley and Wynne (1995) observed contradictory evidence among climate change practitioners who would attribute high certainty to the knowledge produced by other practitioners than those practitioners would attribute to themselves. Practitioners in our study had a tendency to place more certainty in their work than in that produced by other firms' or other experts. There was a lack of trust between external practitioners, those not hired by proponents or regulatory agencies, and internal practitioners. There was a fear that because the practitioners were being financed by the proponent, their work might be biased.

According to our findings, individuals perceived high uncertainty and discontent when they believed that their concerns were not being addressed during the EA (Frewer, Scholderer, & Bredahl, 2003; Rowe, 2005). For example, we observed how changes that were brought as a result of the transition between a provincial and federal EA left some provincial authorities feeling more uncertain about how well their prior concerns were being addressed. It can be argued that with increasing distance from the knowledge, such as provincial and local actors who felt as though they were no longer as involved as they used to be, now created higher levels of perceived uncertainty. Duncan (2008) argued that distance from the location of knowledge production can make knowledge claims appear more reliable than they actually are, however, our findings suggest that the greater the distance and the less involvement actually made claims appear less reliable. We also observed that it was more likely that external practitioners, those not specifically hired by the proponent and that were in charge of providing particular or specific knowledge, acknowledged limitations in their work including the presence of uncertainty much more than internal practitioners. Most internal practitioners attributed high degrees of certainty to their work in a way that made uncertainty manageable and reducible. According to Mackenzie's 'certainty trough', those directly involved in the production of knowledge, such as practitioners and proponents, will present high levels of uncertainty. In our study we found that internal practitioners and proponents had a tendency to attribute certainty rather than uncertainty to their work and external practitioners attributed high uncertainty. However, we certainly do not reject the idea that increasing distance relative to where the knowledge originates from (i.e. model, database, field study, etc) can conceal the contingencies of the knowledge claims, but on the basis of perception, our results indicated otherwise in the case of the 407 East EA.

The greater distance seemed to make people feel more uncertain about the knowledge claims and predictions which is in accordance to Mackenzie's 'certainty trough' as described and applied in Duncan's (2008) study of the Basslink process. Furthermore, authorities and proponents that use the knowledge derived by their chosen team of assessors appeared to give high levels of certainty to the work that was provided to them. Authorities would often use the word 'trust'. According to the 'certainty trough', authorities are at medium distance and will likely attribute low levels of uncertainty to the knowledge.

The literature has shown a discord between science and the public's perspectives on uncertainty that welcome conflict and disagreement in public policy and EA (Jasanoff, 1999; van Asselt, 2000). Our contextual study identified perception as a constraining factor to uncertainty communication—encouraging selective communication under the assumptions that uncertainty information is too difficult for the public to understand, susceptible to misinterpretation, likely to cause delays, and therefore is avoided (Wynne, 2006). Some practitioners in our study revealed that proponents will often warrant that they report less information in fear that too much information will expose them to scrutiny. The ambiguity around the social dimensions of uncertainty comes from the contested perspectives, justifications, and wider meanings that are tied with a particular issue (Stirling, 1998). In our study, we found that the government as a proponent (MTO) negatively affected the degree of credibility and trust. Government sources are often seen as being least credible sources of reliable and trustworthy information (Frewer et al. 1996).

Particular attention and effort should attempt to illuminate the varying perceptions among the actors to improve communication. Results from the case study suggest that the majority of the respondents believed communication of uncertainty information should be clear, concise and policy relevant. Uncertainty perception was addressed implicitly during the participatory program and important references were made towards the adoption of participatory methods during the 407 East EA to accommodate information sharing, feedback, and commentary. The authorities mentioned that open and transparent processes provide valuable commentary from NGOs, members of the public, and others, that might otherwise have been missed. Renn et al. (2011) argue that social learning is necessary to properly communicate and frame issues of uncertainty, complexity, and ambiguity—claiming that "it is not enough that communication is organized" (p.242). While the responsibility of providing appropriate information throughout the EA rests with the project proponents (Wood, 2008), respondents in our study generally agreed that the responsibility was shared among those producing (i.e. practitioners) and disseminating (i.e. proponents) the knowledge.

Our findings and the reflections in the literature reveal that uncertainty perception is a critical element that shapes and steers the discursive process and the consideration of uncertainty in the process. Furthermore, perception varies and likely differs with contextual factors, much like political culture, world views, dominant social values, source credibility, and trust (Hood et al. 2002; Covello 1989; Frewer et al. 1999).

3.4.5. Consideration

The analysis showed that most of the documents recognized uncertainties but presented them in an implicit and unstructured way. Inconsistencies with respect to how uncertainties were being disclosed in EA documentation were also recently found by Lees et al. (2016) who concluded: "Uncertainties were sometimes identifiable, but it was often not clear what the uncertainty was about" (p. 7). Furthermore, the terminology used to report about uncertainties in the EAs explored by Lees et al. (2016) varied considerably. For example, the authors identified a number of expressions, such as 'may', 'probably', 'maybe', or 'could', that were used when uncertainty was present but was not explicitly stated. The results of the query search for the 407 East EA revealed only five instances of explicit uncertainty disclosure, however, searches for words related to uncertainty, such as those mentioned by Lees et al. (2016), were not given further analysis. However, one interviewee stated finding words implicitly related to uncertainty, such as 'could', 'would', or 'may', would be much more likely than the word 'uncertainty'. A proponent similarly added that it would be surprising if we were to find mentions of the word 'uncertainty' anywhere. Proponents in our study did not appear to intentionally want to hide uncertainties in the reports (see Wood 2008). Proponents and their practitioners felt that it was is more practical to implicitly present uncertainties in a way that would be obvious for experts and authorities and not overly negative or difficult for members of the public, and other stakeholders to understand and interpret. This perspective, we speculate, is problematic and may promote uncertainty avoidance practices especially seeing that there was no measures or tools in place to explicitly disclose uncertainties to decision makers. According to Duncan (2008), proponents can have a vested interest in making their EISs appear politically palatable and defensible, thereby resulting in a practice of minimizing uncertainties. Our results are consistent with other findings (e.g. De Jongh 1988; Tennøy et al., 2006; Duncan 2008), showing that the information being communicated in EA about uncertainty is often simplified, hidden, or incomplete.

A general assumption for understanding how EA actors handle uncertainties is to check whether or not the uncertainty in question is acknowledged (Larsen et al., 2013). Despite all of our interviewees

demonstrating their awareness of uncertainties only a few were able to describe how the uncertainties were further handled. For example, more than half of the practitioners interviewed in our study expressed that it was not asked of them to explicitly discuss or describe any uncertainties underlying their work and therefore they avoided doing so unless absolutely necessary. Of course, even though large and obvious uncertainties associated with the project were incorporated in the EA, we anticipate that the way in which uncertainties are being addressed might thus lead to decision outcomes that do not represent uncertainties and are based on inadequate knowledge. According to our findings, only uncertainties that are judged to be significant would therefore be accommodated or addressed in some way, considered, or disclosed appropriately, while those deemed minor, or inherent, would not. In other words, the decisions regarding the issue, impact definition, or the importance of an uncertainty is left to the assessor. Subjectivity in the EA and decision-making permeates into the project outcomes (M Cashmore, Gwilliam, Morgan, Cobb, & Bond, 2004; Duncan, 2008; Wilkins, 2003). The literature has shown that subjectivity due to values, worldviews, and judgments can hinder the quality of EAs (Geneletti, 2003; R. Morgan, 2012).

According to Wilkins (2003), the extent to which practitioners seek out new information to narrow data or knowledge gaps is affected by social values. For example, some practitioners discussed internally handling uncertainties by communicating them to other practitioners in their firm while another expressed how professional experience was enough to evaluate what to do facing a particular uncertainty. Proponents and authorities also described instances where expert input was needed to help address an uncertainty or provide clarification in case of incomplete knowledge.

Of course, participants in our study understood that not all uncertainties could be reduced or managed, while many placed a great deal of importance on deliberating and collaborating with their firms and other experts to address inconsistencies in the knowledge. Nevertheless, it remains highly unlikely that actors can appropriately disclose all uncertainties or knowledge gaps (Duncan, 2012). In particular, we found evidence suggesting that there are difficulties when quantitative and qualitative practitioners negotiate or work together. Decisions made during the process are not discreet, are usually made collectively and iteratively during an EA, and often take the form of negotiations, bargaining, or compromises (Deelstra, Nooteboom, Kohlmann, van den Berg, & Innanen, 2003; Hildén, Furman, & Kaljonen, 2004; Kørnøv & Thissen, 2000; Retief, Morrison-Saunders, Geneletti, & Pope, 2013). Unfortunately, when experts and practitioners collaborate and work together, disagreements and difficulties about problem framing and interpretations are not unusual (Stirling, 2010). Similarly, in their broad study, Cash et al. (2003) found that active, iterative, and inclusive communication mobilized knowledge for action and improved

legitimacy and credibility of the information. They also reported that stakeholders or interests excluded from these processed often rejected and opposed the information produced.

The lack of uncertainty disclosure suggests evidence of Tennøy et al.'s (2006)'s "black box". The black box is an expression illustrating the lack of transparency and accountability about uncertainty information towards the public and decision-makers. Even though uncertainty was acknowledged by interviewees, not reporting uncertainties as 'uncertainties' is troublesome and according to Bond et al. (2015), may lead to decisions and eventually follow-up programs and plans which fail to accommodate some uncertainties.

Decision makers were aware that there were uncertainties in the work that was being given to them, and they also acknowledged that not all uncertainties would be explicitly discussed. However, we agree with Bond et al. (2015) who suggest that the lack of uncertainty consideration in IA is a problem which leads to decisions that fail to incorporate uncertainties in the outcomes of planning and development decisions. Despite our results which suggest that decision-makers were aware that uncertainties were present, we agree with Tennoy et al. (2006) who argued that decision-makers are not made *fully* aware of uncertainties in EAs because these we found that uncertainty was not being disclosed appropriately in the documents presented to them. However, we found that decision-makers claimed that it was good practice to go ahead and request additional work be completed to reduce or address inconsistencies in the work performed by proponents. One authority described several instances where the proponent was asked to clarify or provide additional information regarding specific elements of the EA, and other authorities added that it happens often, especially if the information is vague or incomplete. Requests for additional information, experimentation, or monitoring by decision-makers is viewed as good practice as it may promote more prudent strategies and better informed decisions (Geneletti, Beinat, Chung, Fabbri, & Scholten, 2003; Reckhow, 1994).

Recently, Leung et al. (2015) proposed that further research is needed to help EA practitioners identify, interpret, and communicate information about uncertainties to one another and the wider audience so that they can be appropriately considered. However, it is equally important to determine how decision-makers are using the information about uncertainties to ensure that it is properly considered during final decisions. Once uncertainties have been identified and disclosed, participants in our study revealed that consideration of these would most likely be demonstrated in monitoring activities during follow-up. Mostly, practitioners expressed how they would disclose contingencies or gaps in their knowledge but were not certain as to what decision-makers or proponents would do about them. According to the study by Tennøy et al. (2006), when decision-makers were made aware of the uncertainties in a road tunnel

project called Grualia-Bruvolle in Norway, mitigation and monitoring programs were set up to detect any possible disasters in the face of uncertainty. We suspect that the ambiguity over the way decision-makers in our project would deal with uncertainties may be partly due to the fact that the 407 East Extension has just recently received approval and construction is still ongoing. Nevertheless, we find similarities with the results of the study by Lees et al. (2015) which show that uncertainties are often addressed through follow-up programs. The majority agreed that follow-up addresses uncertainties, but it remains unclear whether or not these programs are directly aimed at addressing uncertainties that have been disclosed.

3.4.6 Precautionary Approach and Adaptive Management

Interviewees discussed the importance of adaptive management much more often than precautionary approaches. Although the precautionary principle (PP)[1] is legally recognized, authorities were among the few to discuss its importance in dealing with uncertainties. According to Gullet (1998), in order for EA to embody the PP there is a need to strengthen its integration in legislation. Since PP is not a rule, and strongly relies on value judgment, its interpretation and application is also important (Hellström & Jacob, 2001). For example, precaution is in some ways inherent to EA practice (Gullett, 1998; Lawrence, 2003) and, this may be why it was not discussed by interviewees as much as adaptive management. However, Gullet (1998) explains that EA is a procedure and PP is a rule that should inform decisions.

Both PP and adaptive management were interpreted differently by participants, while one even stated that they were the same. In their analysis of Canadian EAs, Lees et al. (2016) found that the PP was often mentioned without detailed information about how it was going to be applied. Notwithstanding the numerous precautionary measures needed to manage anticipated impacts, risks, and uncertainties (Gullett, 1997), the PP was not mentioned in the case study CSR. PP involves accountability and can contribute to reducing and coping with uncertainty; PP affects decision making (i.e. taking precautionary actions, weighing uncertainties, etc) and influences EA (i.e. measures to be followed) (Gullett, 1997; Lawrence, 2003). Criteria, procedures, decision rules and institutional arrangements are needed to ensure that PP is being applied (Lawrence, 2003). On the basis that PP was not mentioned, we argue that the precautionary

[1] The precautionary principle is an appear to prudence that encourages proactive decision making under situations characterized by high risk or uncertainty (van der Sluijs, 2012). The 1998 Wingspread Consensus summarized the precautionary principle this way: “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically” (“Wingspread statement on the Precautionary Principle,” 1998).

principle does not appear to have been adequately endorsed both as a procedural requirement, not as a rule for decision makers in considering the risks associated with scientific uncertainties.

On the other hand, case study participants discussed adaptive management as a favorable approach for handling uncertainties. The newness of the 407 East Extension Project (i.e., technologies, landscape, scale) appeared to be an important reason for adopting sound monitoring and AM. A common criticism is that AM can lead to situations where the ability of proponents to actually regulate unexpected outcomes is grossly overestimated (Brugnach et al., 2008; Wehling, 2006). Yet, as our results have shown, many ambiguities and uncertainties during the 407 East EA came as a result of changes in legislation, politics, and actors, and adaptive and flexible approaches to planning allowed for remedial actions to help cope with such ambiguity. Similar studies have demonstrated that adaptive approaches facilitate learning that leads to better coping strategies (van der Keur et al., 2008). Many respondents were hopeful that AM would be successful in reducing and coping with uncertainties and unknowns during construction and after.

3.4.7 Recommendations for Future Practice

In order to improve the way information about uncertainties are communicated and considered in EA, we offer the following recommendations. First and foremost, we propose adopting an uncertainty typology to stimulate a shared understanding of uncertainties amongst the EA community, members of the public, and decision-makers. Thereafter, uncertainties should be identified and addressed in a consistent manner, and communicated in a way that is understood by all actors involved. Decision-makers, stakeholders, and other interest groups may not be aware of the uncertainties hidden in impact predictions (Tennøy et al., 2006) without an explicit typology. We also suggest that stakeholder mapping and techniques that help deal with decision trade-offs can help better manage uncertainties. Finally, we encourage explicit disclosure of uncertainty via documentation that is aimed at the public and provided to decision-makers. An Uncertainty Report (as part of an Environmental Impact Statement) can bring all the uncertainties to light as well as specify the means by which they are being addressed or reduced (Glasson et al., 2005). This would urge proponents, practitioners and decision makers to be more accountable for their choices and generate a higher level of trust. Most details about these recommendations now follow.

1) Adoption of Uncertainty Typology

Uncertainty classifications are important tools that should be used more often to ensure that all relevant uncertainties are communicated during EA. This research and that of others has shown just how broad the nature of uncertainty is (De Jong, 1988; Leung et al., 2015; Walker, Harremoës, et al., 2003). Our

findings are comparable to those of Wardekker et al. (2008) who looked at uncertainty perception and communication in the Dutch science-policy interface and found that policymakers and scientists held mismatched perceptions about uncertainty. Typologies and classifications are therefore helpful and can reduce ambiguity, prevent miscommunication and interpretational problems, and improve understandings of uncertainty (R. Morgan, 2012; Walker, Rotmans, et al., 2003; Wardekker et al., 2008). Because of this, we agree with authors like Walker et al., (2003) who see the need to adopt a mutually agreeable and consistent uncertainty typology however, there is limited guidance in the literature in terms of adopting a common approach to uncertainty, such as a conceptual framework (Leung et al., 2015). However, typologies like the one proposed by Walker et al. (2003) may prove to be highly useful in stimulating a shared understanding of uncertainties, including their nature, sources, and locations in EA.

Typologies should pay attention to the particular EA context it is attempting to interact with (i.e. national, country specific legislation, etc.). We find that it is important to agree upon a standard uncertainty typology for EAs in the Canadian context (e.g. CSR's, panel review assessments, class EAs, etc) specifically and urge other countries and nations to adopt their own similar, context sensitive uncertainty typologies that will be adapted to the dominant EA approaches, paradigms, and perspective. Broadly, we propose that academics work alongside practitioners, proponents, and other actors to develop an uncertainty typology that is suitable and appropriate for the particular context as well as practical for the EA community of a particular country or institutional setting. Furthermore, the typology should provide a clear definition of uncertainty. The typology should also describe the nature of uncertainty, i.e. epistemic, variability, and ambiguity-related uncertainty, explain the many different sources of uncertainty in EA, i.e. models, assumptions, subjective choices, and identify the common activities and stages of an EA where uncertainties exists. Workshops, certifications, resources, and practical templates could also assist the development and shared understandings of uncertainty (van der Sluijs et al., 2003).

2) Guidance for Reporting and Disclosing Uncertainty Information

Based on our findings and review of the CSR, we find that uncertainties were not appropriately disclosed. With only a few mentions, the word uncertainty was sparingly used and vaguely explained in the documentation. It seems to have been avoided entirely. In their review of EAs, Lees et al. (2016) found that when uncertainty was disclosed it was typically qualitative, implicit and variably reported using different terminology. This is a common problem (Walker, Harremoës, et al., 2003) that can be improved with an uncertainty typology (see above recommendation). Information about uncertainty needs to be made more readily available and that it should be better documented by all of those involved in the

process such that the ensuing reports are transparent and explicit and the information related to uncertainty is effectively transmitted to decision-makers (Budescu et al., 2011).

There is an impressive amount of research about the implications of non-disclosure yet almost no practical guidance about how to go about disclosing information about uncertainty (Duncan, 2012; Harremoës, 2003; Leung et al., 2015; Tennøy et al., 2006; Wardekker et al., 2008). Too often it is practitioners that are blamed for not adequately disclosing information about uncertainties. However, reporting uncertainty is not legally mandated and practitioners are not always equipped to deal with uncertainty. Guidance about uncertainty reporting would help present all the information about uncertainties in a clear and consistent manner. Assumptions, methodologies, trade-offs, and choices would be explained and readers would be better informed (Wesselink, Challinor, Watson, Beven, & Allen, 2015). In our study, there were several accounts made about how it was often difficult for different disciplines to come together and share their knowledge. The use of a mutually shared approach for reporting information about uncertainties can prevent these problems from arising (Stirling, 2010).

With a lack of guidance and good-practice disclosure requirements, practitioners and proponents may continue to discount uncertainty in their reports and choose to strategically report uncertainties which they deem necessary on their own. For example, proponents and practitioners may have a vested interest in making their work politically desirable and defensible (see Duncan, 2008), which would result in EA practice that seeks to minimize uncertainties. Several scholars have argued that transparency about uncertainties and the limits of scientific knowledge is necessary in order to gain public confidence (Brown, 2004; Wibeck, 2009; Wood, 2008; Wynne, 2006). In our study we found evidence of mistrust and misunderstandings that were the result of multiple frames and interpretations while also, different expectations as to how and why uncertainties should be discussed. The integration of different specialties supports shared learning that serves to increase the robustness of EAs (Hildén et al., 2004).

3) Mapping Stakeholder Involvement and Dealing Effectively with Trade-Offs

Reaching a wide spectrum of stakeholders requires the use of equally broad means of producing and disseminating information. Clear linkages between the information (e.g. studies, plans, surveys, baseline data, assumptions, etc) and the EA should be made clear to all stakeholders (Hildén et al., 2004). However, we realized that as the 407 East EA process unfolded, decision difficulties arose when decision makers and stakeholders involved subscribed to different viewpoints and when roles were no longer clear. Although the involvement and collaboration of various actor groups and disciplines was advantageous in this case, it caused strategic uncertainty and mistrust for several participants in our study. We found that

there was hardly any effort being paid to who is participating in the assessment, why, and how all these individuals and teams would cooperate and integrate their knowledge. An example was provided by the situation where the sharing of responsibilities between the regulators and municipal, or local authorities was ambiguously laid out. To improve on this point, we recommend that actor roles, expectations, and organizational mandates are made clear from the onset. This would reduce strategic uncertainty, promote accountability, and prevent actor biases. For instance, if practitioners are financially dependent they may be exposed to various attempts to influence the results in some way (Kruopiene, Židoniene, & Dvarioniene, 2009), thus mapping out stakeholder groups would ensure that all partnerships are made explicit.

Important decisions and trade-offs should not be made without negotiations and discussions amongst practitioners, proponents, and stakeholders (Hildén et al., 2004). In our study, although participants described how they were mutually dependent on one another throughout the process, it appeared that certain groups and individuals had more power than others during decision making. Both First Nation representatives, two external practitioners, two authorities, and the member of the public interviewed felt more detached and more concerned with trade-off outcomes and decisions than other study participants. This shows that while apparently there was a commitment to make the EA more open, transparent, and receptive to a diversity of forms of knowledge inputting, the concerns and information produced was not always being communicated, mobilized, or considered into decision making. There is still a tendency to view the decision making process as largely rational and science-based (Partidario & Sheate, 2013). Thus, we argue that more effort should be dedicated to ensuring that responsibilities are well understood, that trade-offs are better assessed and more openness about how particular conclusions are reached is needed to ensure transparency, promote trust, and increase confidence in EA.

Those producing the EA should discuss uncertainties and information, reasons and contingencies in order for trade-offs to be better assessed (Wesselink et al., 2015). Participant views and underlying motivations are not predictable and neither are the decision outcomes (Kørnøv & Thissen, 2000). Formal decision aiding techniques, such as multi-criteria analysis (MCA), according to Retief et al. (2013), may help clarify the meaning of the weights assigned to evaluate specific decision making problems in EA (e.g. alternatives). In terms of uncertainty communication and consideration we recommend that MCA techniques explicitly disclose any uncertainties so that decisions are better informed.

4) Trust, Transparency and Engagement

It is important that authorities and proponents are open and receptive to all the forms of knowledge input for the EA (O'Faircheallaigh, 2010; Partidario & Sheate, 2013). Public participation and community engagement, as observed in our study, can play a key role to ensure trust and accountability, but does not necessarily improve the communication or disclosure of uncertainty. Participation was present in many forms (e.g. CAG, RAG, MTAG, etc) and gave stakeholders and affected interest groups the opportunity, albeit restricted, to communicate uncertainties and raise concerns on the deliberation agenda. Willingness, capacity, access to information, timing and trust were important factors for adequate participation (M Cashmore, Bond, & Cobb, 2007; Stewart & Sinclair, 2007). Public participation may be used by proponents to look as though they are being responsible or to persuade the public to do what they want to do, without really considering their needs or input (Zhang et al., 2013). Therefore we propose that transparency be improved during consultation and public participation forums. We find it necessary that proponents not only attain and maintain trust among all parties but also improve their uncertainty discourse during these crucial deliberations seeing as these are important milestones in the EA. Proponent's should also make it possible for all parties to engage equally. For example, it is important that all affected interests are aware of their roles and responsibilities as well as the uncertainties. To do this, once again, we recommend a better uncertainty discourse.

5) Clear and Responsible Uncertainty Consideration and Management

Our results further suggest that although uncertainties are not explicitly disclosed, decision makers are sufficiently aware to some degree of the underlying and unavoidable uncertainties. Nevertheless, we urge that decision-makers better disclose information about what uncertainties remain and how these will be monitored, reduced, or avoided. Despite insufficient information about uncertainties being handed over to the public and decision makers, there was a general consensus that the information was adequate to determine the approval and recommendations for project follow-up, yet, no such information about remaining uncertainty was discussed. The uncertainty discourse appears to fade once projects receive approval and this is particularly alarming. Without appropriate commitments to address knowledge gaps and uncertainties, anticipatory actions may not be sufficient or successful in detouring potential catastrophes.

Consideration of uncertainties firstly requires that uncertainties are communicated. However, several participants were explicit about having limited time to read through the entire reports, including the final CSR. Similar conclusions support our findings that stakeholders and decision makers may miss important information due to time constraints in reviewing the documents (Cashmore et al., 2007). Our findings suggest that there was a preference would be to consider uncertainties that have a large bearing on the

decision to be made. At the same time, the assumption was that potential environmental and technical issues would be raised by the authorities, a finding which was also found in Cashmore et al. (2007) and Wood and Jones (1997). However, our interviews with authorities reported that reviewing the documentation was time consuming and the possibility for oversight is highly likely. For proponents and practitioners as well, consideration of all potential uncertainties was seen as impossible due to time and financial constraints. If proponents and practitioners are rushing to complete assessments in order to fulfill timelines and budgetary constraints than we anticipate that assessments may not be given the appropriate level of care and that uncertainties would be covered up or not given suitable consideration. With that we recommend that suitable time and funds be allocated to external reviewers in order to verify that all aspects of an EA are covered sufficiently. More time and more funds can improve the performance of EA in this way. However, doing this may be difficult and would require changes at both provincial and federal levels of governance. The ultimate fate of projects remains in the hands of the authorities who would be the ones able to bring to light these necessary improvements. Regulations or the simple allocation of more resources such as time and funds would ensure that assessments are done properly and fully. On the other hand, we can propose a more readily applicable alternative that would force project proponents to disclose these limitations in both time and financial resources. This transparency would allow for further studies to be conducted where gaps in the knowledge remain, for example. We also encourage that when uncertainties are disclosed, decision makers are explicit about the approaches that will be enforced to address and manage the uncertainty. This can be done by using a checklist of uncertainty wherein uncertainties and their sources would be listed in a way that makes them more easily identifiable. This would ensure that potential uncertainties in each section of the EA have been looked at. Finally, it would be beneficial for proponents to report on any uncertainties that influenced parts of the EA, such as trade-offs. This information would be useful to decision makers as it would allow them to see the trajectory that the uncertainties have been through.

Lastly, concerning uncertainty management we recommend that uncertainty reporting tools be used to promote and facilitate the transfer of knowledge for follow-up and monitoring. According to Morrison-Saunders and Bailey (2001), proponents and practitioners tend to move on quickly during land development projects and there is no continuity in project management and monitoring because responsibilities are transferred to various agencies. This is consistent with our findings where participants reported that some uncertainty was due to limited knowledge transferability between post-decision stages and activities. Participants informed that staff turnover in both proponent and regulator agencies alike, as well as lack of commitment, financial capacity and time, can lead to failed follow-up programs. Frequent staff turnover means that there is a loss of knowledge (Morrison-Saunders, Baker, & Arts, 2003),

including information about uncertainty. Therefore, we recommend that the EA community adaptively monitor uncertainties that have previously been identified and disclosed in EAs. This would mean that knowledge is being updated and the potential for unanticipated impacts can be reduced.

6) Paying Attention to Context

Understanding the elements and dynamics of the context which EA is to be implemented has been viewed as being highly important for ensuring effectiveness (Bina, 2008; Hilding-Rydevik & Bjarnadóttir, 2007), and our examination of the 407 East EA found that context also influences uncertainty and the way in which information about uncertainties is communicated and considered. Projects will exhibit varying types and levels of uncertainty and the way in which these are communicated and considered throughout an EA process will vary considerably. For example, in our case, the location of the project was found to be a source of uncertainty which would not necessarily be the same for a project located elsewhere. Therefore, in order to identify the types and sources of uncertainty influencing a project, we recommend that EA processes be aware of the particulars of the context within which it is interacting with. Our results and analysis demonstrate how opportunities to address and disclose uncertainties were broadened once the project became a federal undertaking and proponents enlarged the participatory program. Hilding-Rydevik and Bjarnadóttir (2007) argue that "it seems that certain contexts are receptive to tools when… the political will, the organizational commitment, the professional skill and learning motivation exists" (p. 673-674). They also highlight that it is important to have context sensitivity in order to integrate environmental perspectives in EA and decision-making. Also, recognizing the context as a dynamic and causal element can better prepare practitioners and decision-makers for the inevitabilities that may arise, a point that was strengthened by findings in our study. This recommendation would require that suitable background and baseline studies are conducted for each undertaking. Current practice appears to desire quick and hasty preliminary work in the hopes that the EA goes smoothly. However, we have shown that for the 407 EA, unexpected changes in legislation for example require quick decisions and alterations. To this, we recommend that a less rigid and more adapted process be adopted now and to all future EAs. Proponents should have a suitable understanding of all the elements of the project so that better anticipatory measures could alleviate potential bumps in the road. Better uncertainty communication and consideration may be embedded in or reinforced by a diverse range of contextual factors including legislative frameworks, planning paradigms, and worldviews.

Several assumptions in our paper indicate that there is still a need for studies to elaborate further on the relationship between uncertainty communication and context.

Chapter 4: Overall Conclusion

Among the concerns dealt with in EA, the communication and consideration of uncertainties is a relatively new one that has received increasing attention over the past decade. The current study explored how uncertainties were communicated, handled and considered by those involved in the EA for a Canadian mega transportation project. Thus far, EA and megaproject governance literatures have remained relatively separate, with the former having paid hardly any attention to the specific challenges or needs of those undertaking large megaprojects, and the megaproject literature continually limiting its scope largely to risk- or cost-benefit assessments, and failing to develop key lessons informed by EA realities and requirements. However, we found that both bodies of literature shared a common ground when it came to the problem of uncertainty (See for e.g. Flyvbjerg, 2014; Jay, Jones, Slinn, & Wood, 2007; Priemus, 2010; Salet et al., 2013; Tennøy et al., 2006; Walker, Harremoës, et al., 2003; Wardekker et al., 2008). The present thesis aims to make this connection, by making an assessment of uncertainties in the 407 East transportation case. By drawing on lessons presented in the two bodies of literature, we attempted to understand the way in which information about uncertainty is perceived, communicated, and considered in a transport megaproject EA.

The primary endeavor of the present thesis was to explore how contextual dynamics influence the communication and consideration of uncertainties in the 407 East EA. The rationale was that by exploring what the key uncertainties were, in particular how these are perceived by the actors involved in the EA, it would be possible to develop more systemic ways of identifying, communicating, and considering uncertainties. To explore the influence of context, the study investigated how these uncertainties were communicated during the EA and considered for decision-making. The research revealed a number of important findings including the many factors that both hampered and contributed to uncertainty communication and consideration.

First, the analysis confirmed that indeed the 407 East transportation case involved a complex and broad set of issues including many uncertainties. As pointed out by previous studies, uncertainties were present in all stages of the EA process (De Jong, 1988; Duncan, 2008; Geneletti et al., 2003; Hellström & Jacob, 1996; Söderman, 2005; Tennøy et al., 2006; C. Wood et al., 2000) and there were no systematic approach for identifying uncertainties (Walker, Rotmans, et al., 2003). Many of these uncertainties could be better addressed and managed by improving certain aspects of EA practice such as increasing uncertainty disclosure practices during participatory processes with affected interests, members of the public, and with multi-disciplinary teams, enhancing regulatory oversight, or adopting less rigid timeframes to

complete assessments, not to mention introducing an uncertainty typology or template to better identify and address uncertainties.

At the same time, our study revealed other types of uncertainties that occurred as a byproduct of environmental, social, political, and technological elements of the context. These were the results of complex and dynamic contextual factors, e.g. socio-political arrangements, environmental setting, regulatory arrangements, etc., and most of which were of an ambiguity or variability nature (Ascough II et al., 2008; Brugnach et al., 2011; Jones et al., 2005). Like most mega-project EAs, the project was large-scale, involving a broad range of provincial, federal, and municipal government actors, numerous community groups and concerned citizens, and was being implemented in a setting that heightened uncertainty, especially in terms of ecological concerns. The scope of the EA was resultantly very wide, and the many actors, components, and interacting elements of the context introduced a number of issues and uncertainties that are different than those inherent to the process and practice of EA, and may not be present in EAs smaller in scale and scope. Much debate on uncertainty in EA relates to process uncertainties, e.g. in terms of prediction accuracy and assumptions, models and projections, etc. At the same time, it is widely recognized that context significantly influences EA and the decision-making outcomes (Gazzola, Jha-Thakur, Kidd, Peel, & Fischer, 2011; Hilding-Rydevik & Bjarnadóttir, 2007; Maxim & van der Sluijs, 2011; Refsgaard et al., 2013). It therefore seems that a deeper appreciation and awareness of the complexity and dynamics of project contexts would enable EAs to be more reactive to potential uncertainties and more effective in informing decisions. Approaching contextual uncertainties, just like those related to the EA process, is likely to improve the effectiveness of EA as a decision-making tool (Gazzola et al., 2011). Paying attention to context will reveal new information and may make the EA more relevant in addressing issues and uncertainties relevant to the project, the context, and the actors involved.

Second, the current study found that information about uncertainty was not explicitly disclosed in the EA. Notwithstanding the presence of uncertainties throughout the assessment, our interviews with project proponents and practitioners revealed that the word ‘uncertainty’ is strategically avoided in the CSR. Avoidance behavior practice is evident here because it seems that proponents were aware of uncertainties but chose not to disclose them further, similar to the case reported by Duncan (2008). Although all participants acknowledged the presence of uncertainty to some extent, more than half of the practitioners interviewed and all the proponents expressed that disclosing uncertainties was not practical nor useful. The remaining interviewees were either expecting uncertainties to be reported, as good practice, while others were aware and displeased with the current practice of avoidance occurring amongst the

practitioners and proponents. In line with Mackenzie's 'certainty trough', Duncan (2008) argued that the distance from the location of knowledge production can make knowledge claims appear more reliable than they actually are. We found that the greater the distance actually made claims appear less reliable from an actors' perspective. For example, those alienated from the knowledge production, such as affected interests, felt high levels of uncertainty compared to those producing the knowledge, like internal practitioners. Internal practitioners had a tendency to attribute high levels of certainty and confidence to their work. According to Mackenzie's 'certainty trough', those directly involved, and in this case particularly proponents and internal practitioners, should present high levels of uncertainty—which was not the case here. However, our findings are in parallel when it comes to those at a medium distance; the knowledge users (e.g. decision makers) attributed low levels of uncertainty and seemed to place a great deal of trust into the work performed by the proponents. As previously mentioned, we do not reject the idea that increasing distance relative to where the knowledge originates can conceal contingencies of the knowledge claims, but that on the basis of uncertainty perception it may not be applicable. It would appear that those directly involved in the product of knowledge perceive uncertainty to be controllable and reducible, and that perceptions of uncertainty increase as we increase the distance to where the knowledge originates.

Looking back at Tversky and Kahneman's (1979) Prospect Theory which argues that individuals tend to be risk averse when stakes of losses are high, and risk seeking if the stakes of losses are low, we can see evidence that individuals have a tendency to prefer situations with less uncertainty. For example, we noted that proponents preferred to keep the uncertainty discourse to issues of relevance and did not want to overwhelm the public and other stakeholders with too much uncertainty information because of fears that the information would be misused. Practitioners, because they are tasked with compiling much of the information within the reports and have much control over privileged information with regards to measuring, predicting, evaluating, and reporting, whilst meeting the bare requirements of the relevant policy and legislation, are well-placed to influence proponents to include environmental and social considerations early in the process (Beattie, 1995). Therefore, we recommend that better tools, such as a typology for uncertainty, be made available for practitioners to report and assess uncertainties more consistently throughout the process.

Third, project proponents were afforded the opportunity to provide uncertainty information to decision-makers and the public. However, they appeared to not have taken full advantage of this opportunity because they feared that the public might perceive this information as a deficit in the work, and that information about uncertainties would not be useful to decision-makers in reaching a final decision. We

found that a very limited amount of uncertainty information was provided and made available to the audiences, and it was made available only when it was asked to do so, e.g. during public consultations or by decision-makers requesting additional information. It would appear that the importance placed upon an uncertainty depended on individual perceptions. This once again can be linked back to prospect theory wherein decisions that are more uncertain are riskier and therefore we expect that the communication of uncertainty will be affected. On the basis of our research, proponents do not encourage practitioners to disclose uncertainties explicitly, and practitioners are inclined to under-report uncertainties because they do not want to lose their credibility or reputation. This can lead to situations where uncertainties are presented as certainties and lends into the phenomenon called the certainty effect which describes the tendency to overweigh certain outcomes relative to outcomes that are merely 'possible'. As a result, it was not widely disseminated to other experts, the public, or decision-maker. Thus, we find it necessary to encourage proponents and decision-makers to push practitioners and experts to disclose and make known the uncertainties that they come across, rather than using professional judgment to 'hide' or minimize uncertainty.

Our contextual study identified perception as a constraining factor to uncertainty communication—encouraging selective communication under the assumptions that uncertainty information is too difficult for the public to understand, susceptible to misinterpretation, likely to cause delays, and therefor avoided (Wynne, 2006). Also, different parties will perceive uncertainty differently. The ambiguity around the social dimensions of uncertainty comes from the contested perspectives, justifications, and wider meanings that are tied with a particular issue (Stirling, 1998). Looking at uncertainty as an inherent characteristic of actor interaction follows actor-network theory wherein Latour (1987) suggested that scientist and powerful players may be able to close down uncertainties by creating facts through assumptions. In our current study we saw that decision-making processes do not occur in a vacuum but are actually influenced by several factors including actor networks. Therefore, borrowing from actor-network theory, Koppenjan & Klijn (2004) discuss strategies that can be used to the help manage uncertainties via a network approach. This approach implies a strategy that maps the distance between the perceptions of the different parties involved to help reduce the distance and achieve better consensus. The authors argue that uncertainty management is about reaching a 'common ground', "a minimal basis for communication that enables further interaction and common learning" (p. 245). This requires that proponents and practitioners disclose information about uncertainties and encourage mutual, coordinated learning, establish links between groups, actors, and organizations, and strengthen the process integrity. The 407 East case would have benefited from such an approach to uncertainty management.

Although uncertainties were not disclosed in the CSR, it was still assumed that everyone would be more or less aware of them as an inherent part of the process, e.g. assumptions, prediction errors, model uncertainties, etc. This perspective can be detrimental for uncertainty communication and consideration because it hinders transparency. Our analysis shows that uncertainty is not only inherent to EA and decision making but that it is also a dynamic variable, influenced by context, perception, and actor interactions. For example, several respondents indicated how they perceived the public as being unable to conceptualize uncertainties and felt that providing them with information about uncertainty would only generate confusion and distrust. Mackenzie's 'certainty trough' argues that those directly involved in the production of knowledge and those further alienated from it will have high levels of uncertainty, and we found that those directly involved in the production attributed lower levels than those alienated from it. Being more transparent and open about uncertainties may reduce the high levels of perceived uncertainty of those alienated from the production of knowledge. Transparency and uncertainty disclosure would likely increase trust as well as stimulate the effort to resolve and handle uncertainty (Bijlsma, Bots, Wolters, & Hoekstra, 2011). We observed how many practitioners and proponents take ultimate control of the dissemination of information to the general public, and many of which discussed the need to simplify information (e.g. minimize, avoid, or remove information about uncertainties) in order for lay people to understand (Frewer, Hunt, et al., 2003). Additionally, according to prospect theory the choices adopted by decision-makers are controlled by past experiences, by information availability, and partly by norms, values and personal characteristics (Tversky & Kahneman, 1981). The dissemination of uncertainty information to decision-makers and authorities may also experience these transformations. We see this as avoidance behavior practice. Our case showed that decision makers expressed that they knew there would always be uncertainties in the work that is being given to them, to some extent, even if these uncertainties are not explicitly identified. Without established uncertainty reporting tools, or requirements for explicit disclosure, uncertainties can easily go unnoticed and projects may be ill equipped to deal with unanticipated impacts. And, without suitable mention or explanation, it is unlikely that decision-makers are made adequately aware of the implications that the uncertainties can have on the decision outcomes, including the efforts in place to address them.

Fourth, as we have briefly touched upon above, our research showed how context influenced the way uncertainty was not only communicated but also considered. We find that stakeholder involvement broadened the frame to include additional options and stakeholder criteria. For example, efforts to resolve uncertainties from the public and communities were prioritized in the hopes of reducing opposition, resistance, and dissatisfaction. For the most part, it was not clear from the CSR to what extent uncertainties were considered, and our empirical study found that when uncertainties were considered it

was not always in line with expectations of stakeholders such as authorities, practitioners, or First Nation representatives. For example, the procedures for excavating First Nation burial sites was one uncertainty discussed by both First Nation representatives. Even after voicing their concerns federally and receiving participant funding, their input was not given due consideration and the uncertainties about excavation methods remained because they are not permanently in Ontario. According to them, having a member of the First Nation group present during these activities would have ensured proper consideration and improved their confidence in the EA. This was an example of an uncertainty that was considered but not to a level that met with the expectations of the affected interest. Overall, our results and analysis provided indicative evidence of how the regulatory, organizational, and social context influences the way uncertainties were considered.

Finally, this study importantly illuminated the many influences of context on uncertainty communication and consideration in mega transportation project development. Mega projects involve planners and governments worldwide but our research shows there these actors need to be skilled in handling uncertainties that are brought about by dynamic changes in political regime, legislation, environmental issues, and the substantive uncertainties from dynamic actor networks and interactions. EA for megaprojects should proceed by enhancing participatory approaches that encourage multi-stakeholder dialogue through the development of open institutional frameworks. Considerable improvements in uncertainty identification and analysis is also needed at various stages of the environmental process. Adopting an uncertainty typology and uncertainty reporting tool would certainly encourage better uncertainty communication and consideration. It would also promote a shared understanding of uncertainty and help manage strategic uncertainties, improve trust, and facilitate transparency. Because mega projects are often subject to public opposition (Flyvbjerg, 2007; Vidal & Marle, 2008), we strongly recommend stakeholder and public participatory approaches that is both receptive and reactive to knowledge inputs and concerns. For fear of damaging their reputation and to address the pressure from regulatory agencies and the public, proponents and professionals will likely enter the debate especially when there is a need to communicate uncertainties, risks, and limitations involved (Harding, 2002). The negative perception of the proponent, the project, and the EA was driven by some mistrust that could be due to the previous transportation projects failures, the proponent's reputation, or other. Sandman (2012) stated that concerns can arise when the risk is man-made, novel, when there is uncertainty, when there is memory of prior mistakes, and when information is withheld.

This current study has provided a valuable point after which more detailed empirical research can be undertaken in an attempt to improve uncertainty communication and consideration in EA and decision-

making. As there will always be uncertainties in impact predictions and assessments, more attention should be given to developing approaches that better manage uncertainties such as precautionary approaches, adaptive management, conservative estimates, or sensitivity analyses. Guidance is needed for both practitioners and decision-makers to better consider uncertainties in EA as well. It should also be known that EA is a rapidly evolving field and perceptions of uncertainty are hardly stagnant. We hope that the appreciation for uncertainty in EA improves and we propose the development of a Canadian uncertainty typology that encourages a mutual understanding of uncertainty for all those involved in EA, especially the future EA community. In addition to a shared uncertainty perspective, we propose that practitioners, experts, and proponents involved in the dissemination of information and EA report writing actively participate in a practice that explicitly discloses uncertainties. However, this study shows that uncertainties are not adequately communicated throughout the EA, and that much of the responsibility to do so lies with project proponents. Therefore, guidance for proponents as well so that they could encourage the disclosure of uncertainty is needed. Uncertainties could be better managed and recognized through the use of classifications. We feel like there should be a separate section in the EIS or EA where uncertainties, including sources and types are discussed, the linkages between each uncertainty and decision making illustrated, and there should be justification for the ways in which these are being managed. We understand that identifying uncertainties and attempting to classify them is not easy. These recommendations would most likely benefit from more flexibility, and more importantly from reforms in the legal realm. In particular, we find that practitioners are concerned with appeasing proponents, and that proponents are concerned with appeasing regulatory and agency demands. If uncertainty disclosure was legally mandated by regulatory agencies and legal prescriptions, proponents would more likely be willing to be explicit about information about uncertainties and also encourage their practitioners to disclose uncertainties. EA frameworks that take into consideration the influence of context would also be much more effective, adaptive, and better suited to communicate and consider uncertainties.

Chapter 5: References

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Chapter 6: Appendices

Appendix A: Interview schedule used for the case study research

Interview schedule used for the case study research

Theme and Questions	Explanations and probing
Introduction	
What was your involvement or role in the 407 East Project EA?	Follow-Up: How were you involved either in the provincial EA process or the federal EA process?
Theme 1: Uncertainty in the Assessment	
1. Can you recall some of the main uncertainties related to the project development?	Probe: For example, in relation to the project's design, baseline studies, impact predictions, management of the impacts and alternatives, etc.?
2. In your view, what factors contributed most to the creation of uncertainties that you've mentioned?	Probe: For example, environmental, social, technological, economic, political, scientific, or others?
3. Did the uncertainties in the assessment affect your confidence in the EA process that took place (i.e. approval/recommendations)?	
Theme 2: Communication of Uncertainty	
1. What were some of the things that were done during the EA process (from the Provincial through to the Federal CSR), if anything, to identify and or communicate uncertainty?	Follow-Up: How were uncertainties identified and communicated? By whom? To whom? Did you initiate any of these activities? Probe: Do you recall uncertainty being brought up in the preliminary stages (i.e. collection of data) or during the evaluation of impacts?
2. Was enough information about uncertainty shared, and were the right people involved?	Follow-Up: If not, what would have been a better way?
3. During the EA process did you ever feel that you (or others involved) couldn't communicate openly about uncertainty for fear of some consequence?	Probe: Is there a particular example that you can share?
4. Do you recall of any information about uncertainty being used in the EA process?	Explanation: In other words, did this information influence the way impacts were predicted, management measures, the projects decisions, etc.? Probe: Can you think of an example?
5. What would you have done differently to communicate about uncertainty, and with whom, if you had the opportunity?	Probe: Why? Can you explain?
Theme 3: Perception of Uncertainty	
1. What information about uncertainty is important to you?	Explanation: In other words, are there certain instances or issues, in general, where knowing about any uncertainties is of particular importance?
2. Might you have responded differently or viewed the project or decision differently if you had more (or less) information about uncertainty?	Probe: Why? Can you explain?
3. Looking back on this project, what would you identify as the benefits to disclosing (or not disclosing) information about uncertainties to the affected interests (e.g. proponent, decision-maker, NGOs, public)	Follow-Up: Were there any negative outcomes or risks created because uncertainties were or were not reported? Follow-Up: More generally speaking, beyond this particular project, what are the benefits of disclosing or not disclosing uncertainties? The risks?
4. As a stakeholder, you are involved in the communication about uncertainty during the EA process. How do you think other stakeholders view your approach to handling uncertainty?	Follow- Up: How do you think other stakeholders view uncertainty in EA, or would use the information about uncertainty?

Interview schedule used for the case study research

5. How did the decision-makers, or other stakeholders react to or address any uncertainties that may have been presented in the preliminary design, in the IEA, or in the CSR?	Follow-Up: Was the response appropriate in your view?
Theme 4: Gauging Uncertainty	
1. Were you satisfied with the way uncertainties were dealt with (i.e. communicated and considered throughout project management and decisions)?	Probe: Why or why not? Follow-Up: Do you think other stakeholders were aware of and satisfied with how uncertainties were communicated?
2. Would you say that there is a gap between the potential range of the project's effect that may occur in the long term, in combination with other projects, and the range of our knowledge or in the responsibility taken to manage these effects?	Follow-Up: How important is uncertainty communication to closing or at least understanding this gap?
Theme 5: Suggestions for Improved Practice	
1. What were/are the main challenges to communicating uncertainty in the 407 East Project?	Follow-Up: Are there any aspects of uncertainty communication you think are done well?
2. Who is (or should be) ethically responsible for disclosing uncertainty?	Follow-Up: Are there or should there be legal obligations to do so?
3. What could, or should, decision-makers do with information about uncertainty in an EA when they receive it?	Probe: What approaches, concepts, or principle are being used?
4. Is there a need to improve uncertainty communication in EA? Why or why not?	Probe: How is it best communicated (i.e. visually, graphically, verbally, etc.)?
5. What are your suggestions (if any) for how we can improve uncertainty communication and consideration in EA to improve decision-making?	
Theme 6: Context Dynamics of Uncertainty Communication and Consideration	
1. Were there any factors related to the project environment or stakeholder dynamics that contributed to uncertainty or influenced the way uncertainties were communicated and considered by individual actors? (e.g. situational, environmental, sociopolitical context)	Follow-up: Did the location or extent of the undertaking have any influence on the evaluation of the impacts? Follow-up: Did the socio-political or economic context have any influence on project decisions?
2. What uncertainties regarding ecological road effects were identified or communicated during the assessment that you are aware of? This includes indirect and cumulative effects.	Probe: Was anything done to reduce the uncertainties (e.g. collection of more baseline information, quantification of uncertainty, etc.)? Probe: Were you satisfied with all that was done to address indirect and cumulative impacts? Follow-up: Do you recall any discussion related to mitigation of the potential ecological effects of the road such as fencing or passages?
3. What uncertainties do you face during the preliminary assessment, the detailed assessment and post-EA stages?	Follow-up: How did the 407 East process react to address the uncertainties in the relevant stages? Probe: How does the project compare with others you have worked on?
4. Do you recall any information on uncertainty being considered or communicated as part of the post-EA plans such as Follow-up or other impact management proposals?	Follow-Up: Do you think the presence of uncertainty in the VECs or any other issues influence the extent to which it will be covered in the post-EA management plans (i.e. CSR follow-up, monitoring, auditing, etc.)? How? Do you have an example? Probe: What is factored in when determining what goes into follow-up? (i.e. regulatory backing, bias, practicality, etc)
5. Do you feel that enough consideration to the uncertainties about species at risk, groundwater, and wetland impacts were given when making the final decisions and recommendations?	Probe: Can you give me a particular example of a mitigation measure or recommendation related to wildlife, species at risk, wetlands, or salt management?

Interview schedule used for the case study research

6. Do you feel the 407 East EA was explicit in recognizing potential uncertainties related to the undertaking?	Follow-Up: How important is transparency in impact assessment processes?

Appendix B: Introductory e-mail

Introductory e-mail sent out to potential research participants

Request for Participation in Research Interviews

UNIVERSITÉ Concordia UNIVERSITY
Geography, Planning and Environment
1455 de Maisonneuve, W., Suite H1255-26
Montreal, QC, H3G 1M8

Uncertainty Perception and Communication in Environmental Assessment Practice and Decision-Making: Lessons from a Road Infrastructure Project in Ontario, Canada.

A research project funded by the Social Science and Humanities Research Council of Canada (SSHRC)

Primary Investigator:
Samia Tabarah, MSc. Candidate
Concordia University, Montreal, QC.
Office.: +1 (514).848.2424 ext. 5485
Cell: +1 (514).622.7266
e-mail: samia.tabarah@concordia.ca

Research Supervisor:
Jochen A. G. Jaeger, Ph.D.,Concordia University,
Montreal, QC. Office.: +1 (514).848.2424 ext. 5481
Web: http://gpe.concordia.ca/faculty-and-staff/jjaeger/
e-mail: jochen.jaeger@concordia.ca

Project URL: http://homepage.usask.ca/~bfn571/EA_Uncertainty.html

Dear Potential Interviewee,

I am Samia Tabarah, a graduate student at Concordia University, Montreal. Requisite for the fulfillment of my Masters' of Science degree, I am pursuing a study under the supervision of Dr. Jochen Jaeger, Department of Geography, Planning, and Environment, Concordia University. My interests in environmental impact prediction and EA practice have, in large part, inspired this research project.

RESEARCH PROBLEM AND PURPOSE:

Since predictions make up the crux of environmental assessments (EAs), uncertainty becomes an inherent and largely unavoidable feature; however, prediction processes are hardly transparent and uncertainty is not always communicated or considered. Through an investigation of the processes by which surround and essentially construct an EA, this study will attempt to disentangle the problem of uncertainty and gain insight into the treatment and consideration of uncertainty in a Canadian and road-related context. The research will examine the circumambient conditions of uncertainty by reporting individual and divergent perceptions of uncertainty and communication practices. More specifically, within the context of road construction projects, too few studies have addressed uncertainty in the assessments, and no study has been done on the current treatment of uncertainty in Canadian EA practice. And so, on account of its unique context and recent approval process, The 407 East Transportation Corridor Project, Ontario, was selected for the study. As part of a larger Social Science and Humanities Research Council (SSHRC) initiative, my research can contribute to the overall potential improvement of uncertainty assimilation and treatment in EA, and in the

interest of future road and transportation projects, findings can support practical solutions.

THE SPECIFIC OBJECTIVES OF THE RESEARCH PROJECT ARE TO:

1. Investigate the types and sources of uncertainty in the 407 East EA reports, to determine how they were treated and presented between assessments; and
2. Document uncertainty perception and communication among the relevant actors and interests that participated in the 407 East EA process, by gauging the divergent understands, communication practices, and the potential implications of uncertainty disclosure in decision-making; and
3. Identify opportunities and obstacles for uncertainty perception and communication in EA, and to develop recommendation to improve uncertainty communication and prediction transparency in Canadian EA practice.

THE RESEARCH INVOLVES:

I. **Phase 1: Document-Content Review (ongoing)**
A review and examination of 407 East Transportation Corridor screening report, comprehensive study report, and final decision document(s) to provide background information and identify the location, types, and sources of uncertainty.

II. **Phase 2: Semi-Structured Interviews (upcoming)**
Semi-structured interviews will be conducted with stakeholders (i.e. proponents, consultants, practitioners, NGOs, members of the public, responsible authorities) which were directly involved in the 407 East Transportation Corridor project EA. Approximately 25-30 interviews will be scheduled with the intent to discuss views, reactions, and experiences with uncertainty. These interviews will be approximately 25-50 minutes.

- **Status**: You have been identified as a potential participant based on your professional and organization involvement in the EA process of the 407 East Transportation Corridor project EIA. You are being asked to participate in this phase of the research.

In the weeks following this notice, I will follow through with you to address any remaining questions, and ultimately determine your interest in participating. Meanwhile, should you have any questions or concerns, please feel free to contact the researcher(s) using the information provided at the top of page 1.

Kind regards,

Samia Tabarah
M.Sc Candidate,
Concordia University, Montreal, QC.
Office.: +1 (514).848.2424 ext. 5485
Cell: +1 (514).622.7266
e-mail: samia.tabarah@concordia.ca

Appendix C: Participant consent form

Research participant consent form

Université Concordia University

Concordia University
Geography, Planning and Environment
1455 de Maisonneuve, W., Suite H1255-26
Montreal, QC, Canada, H3G 1M8

PARTICIPANT CONSENT FORM

Uncertainty Perception and Communication in Environmental Impact Assessment Practice and Decision-Making: Lessons from a Road Infrastructure Project in Ontario, Canada.

A research project funded by the Social Science and Humanities Research Council of Canada (SSHRC)

Primary Investigator:
Samia Tabarah, MSc. Candidate
Concordia University, Montreal, QC.
Office.: +1 (514).848.2424 ext. 5485
Cell: +1 (514).622.7266
e-mail: samia.tabarah@concordia.ca

Research Supervisor:
Jochen A. G. Jaeger, Ph.D.,Concordia University,
Montreal, QC. Office.: +1 (514).848.2424 ext. 5481
Web: http://gpe.concordia.ca/faculty-and-staff/jjaeger/
e-mail: jochen.jaeger@concordia.ca

PURPOSE

You are invited to participate in a semi-structured interview and I have been informed that the purpose of this research is to investigate uncertainty perception and communication practices in the context of the 407 East Transportation Corridor Project EIA, Ontario, Canada.

PROCEDURES

- Approximately 25-30 interviews will be conducted and I understanding that my participation in the study will last approximately 25-50 minutes.
- I understand that these will be performed in person; however, if such an arrangement cannot be met, a phone interview can be conducted as an alternative.
- Interviews will be recorded using a digital recording device, and notes will be taken during the interview process by the primary investigator.

POTENTIAL RISKS

- I understand that there are no personal risks to physical or psychological welfare from participating in this study.
- I understand that my participation in the study is voluntary and I may discontinue from the study, for no reason, and at any time during the research without penalty; during the interview, you may refuse or refrain from answering particular questions and, following the completion of the interviews, you will be given 30 days to withdraw from the study and information obtained can be returned to you, or destroyed at your request.

POTENTIAL BENEFITS

- Develop recommendations for the international environmental impact assessment (EIA) community about how to more readily acknowledge, consider, and communicate uncertainty.
- Benefit practitioners and decision-makers which participated in the 407 Transportation Corridor project EIA by drawing attention to the treatment and communication of uncertainty.
- Contribute to best practice guidance for uncertainty communication in Canadian EIA.
- While the above benefits are expected, I understand that these benefits are not necessarily assured.

CONFIDENTIALITY

- Names and personal information will be kept confidential and not published in any results from this study; names and personal information information will only be seen by the primary investigator and research supervisor.
- The data will be stored and kept on a hard drive temporarily and stored safely in the possession of the research supervisor for the duration of the study and time needed to produce the expected dissemination, publication(s), and/or conference documents.
- The information obtained from the interviews will be used strictly for academic purposes, not for commercial gains.
- The data will be reported anonymously in an aggregated fashion, such that the information you provide in the interview will be combined with the other interviews performed in the study. However, based on the information you provide, and on the context of the study, it may be possible that your involvement be detected and identifiable by those involved in the 407 East project; even so, all reasonably efforts will be made to try and protect participants' anonymity.
- Direct quotations may be used in the research dissemination.

There are several option for you to consider if you decide to take part in this research. You may select all, some, or none. Please place your initials on the corresponding line(s) that grants me your permission to:

I grant permission to be audio taped: Yes:____ No:_____

I grant permission to have my organization's name used: Yes:____ No:_____

I wish to remain anonymous: Yes:____ No:_____

I wish to remain anonymous and with an alias: Yes:____ No:_____

The alias I choose for myself is: _____

You may quote me and use my name: Yes:____ No:_____

FOLLOW UP:
To obtain results from the study, please contact the primary researcher to request the master's thesis or academic paper to be published; a summary of the findings can be supplied to you once the research is complete.

QUESTIONS OR CONCERNS:
If you have any questions or concerns related to the study, please do not hesitate to contact the researcher(s) using the information at the top of page 1

- This research project has been reviewed and approved by the Departmental Ethics Committee at Concordia University on May 27th 2014. Should you have any concerned regarding your right as a participant and involvement, you can contact the Ethics Committee at +1 (514) 848-2424 ext.: 2050

CONSENT

Your signature below indicates that you have studied and understood the description provided above.

"In signing, I agree that I have been given the opportunity to ask questions and raise concerns, and that these have been answered satisfactorily. I consent to participate in the research project. A copy of this consent form has been given to me for my personal records"

I freely consent and voluntarily agree to participate in the study under the terms described above.

_____ _____

Name of Participant (please print) Date

_____

Signature of Participant

_____ _____

Signature of Research Date

A copy of this consent will be left with you, and a copy will be retained by the researcher.

Appendix D: Code list (selection of the most important codes used)

Process.uncertainty
Environmental.uncertainty
Social.uncertainty
Economic.uncertainty
Species.at.risk
Regulatory.process
Follow.up
Federal
Provincial
Stakeholder.engagement
Transparency
Public.view
Perception
Timelines
Wildlife
MTO
Fish.Fishhabitat
Adaptive.management
Regulatory.agency
Review.process
Uncertainty.terminology
Communication.uncertainty
Data.limitations
Location.context
Agricultural.impacts
Governance
Location.of.uncertainty