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Environmental Health Effects of Multiple Exposures: Systemic Risks and the Detroit River International Crossing Study

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Geography

ENVIRONMENTAL HEALTH EFFECTS OF MULTIPLE EXPOSURES: SYSTEMIC RISKS AND THE DETROIT RIVER INTERNATIONAL CROSSING STUDY

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by

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ABSTRACT

This thesis examines cumulative exposures to traffic noise and outdoor air pollution on environmental and health related quality of life in Windsor, Ontario, and provides a critical analysis of the environmental assessment process for the Detroit River International Crossing (DRIC) Study. The research utilizes a systemic risk framework to understand environmental health and stress effects of cumulative exposures. The significance of this research is based on a relative absence of literature on the systemic health risks of cumulative exposures and the need to elucidate environmental annoyance as a health outcome for risk assessment. The objectives of the research were to (1) Demonstrate the impact of high volume traffic facilities on the noise annoyance dose-response; (2) Evaluate the effect of cumulative exposures and odour annoyance on noise annoyance; (3) Conceptualize and test a model for annoyance as a health outcome of multiple exposures, and; (4) Critically appraise the capacity of environmental impact assessment to address environmental health in megaproject planning.

Data from a community survey (n=610) in 2013 were combined with spatial data exposures to traffic noise and ambient nitrogen dioxide. Bivariate analyses, multivariate regression and structural equation modeling were used for the quantitative analysis. Document and media analyses were used to construct stakeholder discourses on environmental health and risk perceptions of relevance to the DRIC Study. The results of an ordinal location-scale model used to predict noise annoyance demonstrated a dose-response effect of noise, significant interactions between noise and air pollution, and a strong confounding effect of odour annoyance. A structural equation model for environmental and health related quality of life indicated that noise annoyance had a negative impact on functional mental and physical health, and that odour annoyance and levels of co-exposure were important covariates. The results of the quantitative analysis corresponded with community discourses on environmental health during the DRIC Study. Further analysis showed that the environmental assessment process obfuscated community health risks and stakeholder participation, lending support to the utilization of systemic risk perspectives and integrated environmental impact health assessments in megaproject planning.

The DRIC study findings were in disagreement with public perceptions and previous research that demonstrates strong contributions of border traffic to air pollution and significant associations between air pollution and health in Windsor. The results of this thesis complement these findings by showing that ambient stressors in Windsor and in the environmental context of the DRIC megaproject had a systemic effect on health. This provides a unique contribution to the environmental health literature on cumulative effects of exposure to environmental noise and ambient pollution. It also provides a methodological contribution to systemic health risk assessment for measuring impacts of multiple environmental exposures on health related quality of life. For future research on environmental health the results warrant explicit consideration of multiple exposures and their combined effects as ambient stressors.

Keywords: Environmental health, systemic health risks, risk perception, cumulative exposure, exposure assessment, traffic noise, outdoor air pollution, noise modelling, land use regression, odour annoyance, noise annoyance, noise sensitivity, quality of life, health related quality of life, SF-12, environmental assessment, health impact assessment, systemic risk assessment, Windsor, Ontario.

CO-AUTHORSHIP STATEMENT

This thesis is made up of a collection of papers which are currently being prepared for publication. While these papers were co-authored with my thesis supervisors and others, as the first author I conducted the majority of research and writing for Chapter Two and all research for Chapter Three, Four and Five relating to problem formulation, literature review, survey and traffic noise data collection, data analysis and writing. The co-authors provided guidance on revising the manuscripts, while Alison Grgicak-Mannion and Dr. Xiaohing Xu conducted the monitoring and modeling of air pollution.

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To my late grandfather Hjalmar Bjørklund, this is for you.

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CHAPTER ONE

1. INTRODUCTION

This chapter provides an overview of the literature that supports the research for the thesis. Major developments in health geography are outlined to provide context for the multidisciplinary perspectives utilized to understand links between transportation and environmental health. A discussion of relevant theoretical perspectives and methodological frameworks is provided to inform the reader on important considerations in the study of multiple and ambient environmental exposures, which is followed by a brief synopsis of current research challenges in this area of inquiry and a framework to address these challenges. Finally, the objectives of the thesis are provided in context of research needed to address these challenges, followed by a description of the thesis organization in terms of theoretical grounding and overarching objectives.

1.1 **Environmental health perspectives**

Environmental health can be defined as "the aspect of public health concerned with all the factors, circumstances, and conditions in the environment or surroundings of humans that can exert an influence on human health and wellbeing" (Last, 1987, p. 131). Current knowledge production on the effects of environmental exposures on human health reflects technological and social development broadly, and theoretical and methodological advancements in social science and medicine more specifically. Technological advances during the nineteenth and twentieth centuries had profound impacts on everyday life and required new forms of governance that were tasked with balancing the benefits and costs of such advances. This precipitated an enduring demand for knowledge on public health and the environment, which became the domain of four complimentary and interdisciplinary research fields in particular: Environmental toxicology, social and environmental epidemiology, environmental psychology and health geography. Topics of interest in these adjacent fields overlap, but the first two are primarily concerned with establishing causative links between environmental exposures and health outcomes, while environmental psychology and health geography extend the causative framework to sociocultural and political processes, of which processes that organize space and place are of particular interest to health geographers.

The historical development of medical geography as a sub-discipline of geography and the relatively recent paradigm shift towards geographies of health illustrate how this sub-discipline facilitates the study of environmental health. Seeking to document the development of this sub-discipline into a coherently bound field of research, the editors of "A Companion to Medical and Health Geography" (Brown et al., 2010) were challenged by the breadth of theories and methods currently employed. Nonetheless, a brief and artificially simple overview of medical and health geography and a description of relevant theories will illustrate past contributions that facilitated the completion of this thesis.

1.1.1 ***Space, place and environmental health***

Following the quantitative revolution and cultural turn in the social sciences at large, medical geography and its historical focus on disease ecology and health care access and utilization was challenged by a call for more humanistic and cultural studies that looked beyond the spatiality of disease to understand the experience of illness and health

(Rosenberg, 1988; Kearns, 1993; Brown et al., 2010). Kearns and Moon (2002) argue that several sub-disciplinary transitions during the early 1990s were instrumental to this end. They point to considerations of composition and context in health sociology and embodiment as particularly important catalysts. In the inaugural issue of Health & Place, Litva and Eyles (1995) argued that as a social science, and despite inconsideration of social theory, medical geography relied on positivism, Marxism, feminism and other epistemologies as models for explaining social relations.

The challenges associated with 'humanizing' medical geography were reflected by separate entries in the 2000 edition of the Dictionary of Human Geography for medical geography, stressing the biomedical model of health and quantitative methods, and the geography of health and health care, thematically defined by place, the socio-ecological model of health and a methodological pluralism (Johnston et al., 2000). Kearns and Moon (2002) operationalize the different conceptualizations of place within these fields as "[…] a living construct which 'matters' as opposed to being a passive 'container' in which things are simply recorded" (p. 587). A recent review of environmental health geography research shows that it draws on methods in 'traditional' medical geography, as well as a pluralism of theoretical perspectives used in critical and humanistic studies representative of health geography (Luginaah et al., 2014). Therefore, and as a field within medical and health geography, the types of questions being posed are perhaps more informative than identifying a methodological coherence when outlining the development of environmental health geography (Luginaah, 2009).

Two particular lines of questioning environmental effects on public health are of relevance here. These relate broadly to exposure analysis and structure versus agency in the experience of environmental quality and its management. Along with the discipline at large, environmental health research benefited from advancements in spatial analysis (Gesler, 1986). Public access to GPS technology and development of software for geographic information systems (GIS) transformed quantitative methods in geography and facilitated new areas of research. Relevant contributions from geographers concern the assessment of environmental quality and exposure (e.g., Briggs et al., 1997; Jerrett et al., 2003; Kanaroglou et al., 2005; Luginaah et al., 2006; Oiamo et al., 2012), and the role of environmental exposures in health inequalities (e.g., (Buzzelli et al., 2003; Jerrett et al., 1997; Jerrett et al., 2001; Jerrett et al., 2003; Luginaah et al., 2001; Oiamo et al., 2011).

Apparent linkages between the environment and health inequalities facilitated the integration of critical and humanistic perspectives with quantitative methods in spatial analysis and public health research in general (Buzzelli and Veenstra, 2007; Buzzelli, 2007). This built on a significant body of literature that questioned the democracy of environmental risk assessment and risk governance processes (Beck, 1992; Cutter, 1993). Consequent research by geographers have made substantial contributions to the understanding of environmental health perceptions (e.g., Bickerstaff, 2004; Elliott et al., 1999; Baxter and Greenlaw, 2005; Parr, 2006; Day, 2007), public participation in environmental decision-making (e.g., Driedger et al., 2002; Hirsch and Baxter, 2009; McMullan and Eyles, 1999; Wakefield & Elliott, 2000; Wakefield et al., 2001), and effects of the environment and risk perceptions on health and wellbeing (e.g., Atari et al.,2009; Luginaah et al., 2000; Masuda et al., 2008; Wilson et al., 2004). Research on these and other topics in environmental health by geographers has contributed to, and been aided by, several theoretical perspectives on the social production of health.

1.1.2 *Sociocultural perspectives on environmental health*

The application of social perspectives over several decades of environmental health research has helped the development of nuanced explanations for the relationship between the environment and social inequalities in health and wellbeing, which provide a theoretical grounding for associations between the environment and health inequalities. Kulkarni and Subramanian (2010) distinguish health inequality from social inequality in health by the "presence or absence of social factors and conditions in describing and evaluating health differences and hence as the potential of invoking or avoiding the notion of fairness and justice" (p. 376). Studies on environmental hazards made important contributions to the current state of knowledge on the environment and social inequalities in health, in particular those landscapes defined by technological hazards (Eyles et al., 1993; Elliot, 1993). Consequently, the dominating social perspectives in contemporary environmental health geography are the outcome of research on technological hazards that integrated geographic perspectives with concepts from other disciplines. Of particular value was work in environmental psychology, as geographers incorporated theories on environmental stress and risk perception to inform geographic explanations for the health effects of technological hazards (Taylor et al., 1991; Taylor et al., 1997).

Different types of environmental stressors can be generalized as cataclysmic events, stressful life events, daily hassles, or ambient stressors that distinguish more continuous and relatively stable, yet intractable conditions of the physical environment (Evans and Cohen, 1987). The physiological perspective on stress is discussed in more detail in following sections, while the psychological perspective on stress responses characterizes such responses as dependent on the individual's interpretation of an ambient stressor [primary appraisal], followed by an evaluation of coping resources to deal with the stressor [secondary appraisal] (Lazarus, 1966). Psychosocial factors that mediate environmental stress and coping are characterized by the stressor, the individual, his or her social network, and the wider community system (Taylor et al. 1993). As such, the interaction of social and psychological factors "suggest that knowledge, power, and resources influence health not only through their direct effects on the material conditions of life but also in relation to the symbolic and meaningful social interactions that take place between individuals and groups" (Kulkarni and Subramanian, 2010, p. 383). A detailed account of cognitive and behavioural processes that make up the environmental stress response and coping mechanisms are beyond the scope of this review, but the concept of risk appraisal warrants special attention because of its psychosocial constituents and relevance to the environmental assessment of health risks in the Detroit River International Crossing (DRIC) Study.

Early research on risk perception focused on the psychometric paradigm, seeking generalizable and cognitive explanations for different appraisals of risk by experts and the public, outcomes of which included the information deficit model (Slovic, 1987). Arguably, this clarified the message of 'risk society,' which essentially pointed out that expert systems take advantage of the information deficit to usurp power in environmental management (Beck, 1992). Arguably, a consequence of this was the erosion of trust and faith in science to solve social problems (Ortwin, 2008). While the psychometric paradigm offered a useful framework for examining different perceptions of risk by experts and the public, work in geography and other disciplines showed that both primary and secondary appraisals of ambient stressors, and therefore risk perception in general, cannot be divorced from the geographic context within which they occur (Bickerstaff and Simmons, 2009; Dake, 1992; Elliott et al., 1993; Taylor et al., 1991). The sociocultural and geographic perspectives on risk perception inform the quantitative analyses in this thesis as well as the analysis of uncertainty and tensions surrounding the health risk assessment for the DRIC Study (Douglas and Wildavsky, 1982). Cooperation and trust between experts and the public in risk assessment facilitates perceived control of the ambient stressor, which is important for the appraisal of coping mechanisms (Johnson & Slovic, 1995).

While appraisals of ambient stressors by available coping mechanisms characterize certain aspects of the stress response process, research in environmental psychology promotes a relational perspective on the influence of different aspects of the stress response, which is broadly conceptualized as occurring “when there is an imbalance between environmental demands and response capabilities of the organism” (Evans and Cohen, 1987, p. 573; Lazarus, 1993). It is the evaluation of this imbalance based on environmental meanings that is relational because it depends on a recursive process of appraisal, coping and adaptation, as well as interactions between individuals and their social and physical environments, a central area of study in human geography (Williams & Patterson, 1996).

Similarly, the conventional dualism of context versus composition (i.e., place vs. people) as influential on health is giving way to relational geographies of health (Cummins et al., 2007). The relational perspective on health geography recognizes places as nodes in networks (as opposed to fixed locations), within which social and geographical ‘boundaries’ are fluid and dynamic, continuously responding to, and reconstituting how, people interact with their environments, in turn affecting health and wellbeing (Cummins et al., 2007). Complementing the relational perspective on health geography is the ecosocial perspective in social epidemiology (Krieger, 2001). Both perspectives emphasize those interactions between people and their environment that affect health, however the former is more concerned with *process* while the latter is focused on *outcomes.* More specifically, ecosocial theory presents an alternative to the biomedical model of health in epidemiology, which seeks to identify singular and causal pathways to disease.

The inadequacy of the biomedical model for explaining health outcomes caused or moderated by the environment has led to the recognition of several constructs as important for studying the social production of disease. It should be emphasized that the relational and ecosocial perspectives conceptualize environmental health outcomes as the result of upstream social processes that interact with individuals and their physical environment, leading to varying exposures and responses characterized by psychological and physiological stress responses. The outcome of these interactions is embodiment, which forms one of the central constructs of the ecosocial perspective along with pathways of embodiment and the cumulative interplay between exposure, susceptibility and resistance (Krieger, 2001). To recognize embodiment and pathways to embodiment as important is to acknowledge that environmental health outcomes are situated in temporally and spatially specific bodies, and that spatiotemporal exposures are structured by societal arrangements, culture and biology.

1.2 Noise, air pollution and health

1.2.1 *Multiple exposures: assessment and health implications*

Although ambient stressors are in general a central topic in environmental health geography, understanding the effect of place on risk perception and the stress process has received more attention than the effect of place on pathways to embodiment. Pathways to embodiment in this case refers to the interactions between different *types* of ambient stressors in the physical environment and place, to which end questions would address, for example, how health effects of multiple exposures can be explained by place. Influential works by geographers that contribute to this include how vulnerable populations face the 'triple jeopardy' of environmental exposure, socioeconomic disadvantages and reduced agency (Jerrett et al., 2001). However, limitations in exposure assessment thus far have resulted in the consideration of standalone environmental exposures such as air pollution. Cumulative exposures to ambient air pollution and environmental noise are of particular concern here, but other co-exposures such as to light pollution, radioactivity and vibration are also worth consideration.

As mentioned previously, geographers have made significant methodological and conceptual contributions to research on air quality and health, and much of the above discussion on social perspectives on environmental health is based on air pollution research. Geographers were instrumental in the development of land use regression

(LUR) models to estimate air pollution exposure, which has become the dominant form of exposure assessment for health research because of its high resolution and relatively low cost (Jerrett et al., 2005). Exposure assessment previously relied on distance to major emission sources or buffers around central monitoring stations, and although advances in personal monitoring and dispersion modeling provide more accurate data than LUR models, they are cost-prohibitive for estimating emissions from multiple sources on geographically dispersed and large samples (Ryan and LeMasters, 2007).

The focus on air pollution in environmental health research is in part a reflection of its ubiquity as an environmental hazard in industrialized societies historically, and its recognition as such by environmental regulation during the 1960s and 1970s. The introduction of catalytic converters on motor vehicles to reduce harmful emissions crystalized air pollution as a significant environmental health hazard, although the consequent determination and implementation of national standards for ambient concentrations differed widely. At the federal level in Canada, air quality standards for fine particulate matter and ozone, the major contributors to smog, are voluntary objectives, while additional standards for nitrogen dioxide and sulphur dioxide are currently under development. The implications of voluntary objectives are that environmental assessments for projects such as DRIC are not obliged to demonstrate an improvement in air quality, even if baseline conditions exceed national standards. Under the Ontario Environmental Protection Act and Environmental Assessment Act, air dispersion models are required to determine the contribution of emissions from a regulated facility to air standards, and compliance is only required if assessment determines that facility emissions impinge on background concentrations that exceed national standards.

A similar framework exists for the assessment of environmental noise, which in Ontario requires that new facility noise emissions do not exceed baseline levels by more than 5 A-weighted decibels [dB(A)]. The A-weighting adjusts for the non-linear relationship between auditory stimulation and sound pressure levels by penalizing high frequency sounds. Traffic noise was identified as a public health hazard nearly a century ago, but industrialized countries including Canada did not begin regulating community noise until the rapid post-WWII increase in freight and passenger vehicles became an apparent problem (Price, 1972). Amendments to the Canadian Ministry of Environment's *Environmental Protection Act* in 1975 provided municipalities the legislative authority to adopt noise by-laws. In 1978, the Ontario Ministry of Environment (MOE) published the "Guidelines for Noise Control in Land use Planning," in which a model by-law recommended that equivalent or average sound levels (L_{eq}) for indoor exposure should not exceed 40 dB(A) for bedrooms and 45 dB(A) for living rooms. In 1997, the MOE updated its policies with the "Noise Assessment Criteria in Land Use Planning: Requirements, Procedures and Implementation" and outdoor exposure levels were set to 55 dB(A) during all hours while indoor exposure limits remained the same. The most recent MOE guidelines from 2013 (NPC-300) maintain these limits but provide more details on assessment methods and differentiate between land uses and sound sources. For reference, normal conversation is disturbed with background noise levels above 50 dB(A).

Until relatively recently, exposure assessment for noise was limited by technology much the same as for ambient air pollution, and estimates were often based on aggregating populations around monitoring sites. With respect to traffic noise, modeling was challenged by the fact that emissions for different vehicles differ greatly and are influenced by a large number of variables. These include vehicular features such as exterior design, weight, tires, engine and exhaust systems, and environmental factors such as road surface type, road network (e.g., traffic signals, speed limits), topography, and perhaps most importantly, physical features of the environment (e.g., buildings) that reflect and redirect sound pressure waves. The US Department of Transportation compiled the first vehicle noise emission database, and other countries followed suit during the 1980s, which led to numerous emission standards for different regions characterized by different vehicle fleets. Throughout the 1990s the use of dispersion models gained prominence and became required for environmental assessments in Ontario. The 2002 European Union Environmental Noise Directive and the mandatory assessment of noise for entire cities with 250,000 or more inhabitants encouraged the development of noise modeling software for more general applications.

The physical characteristics of noise differ significantly from air pollution, one consequence being more localized health risks of noise, which do not lend themselves to critical examinations of the risk governance process in the same way as air pollution. Perhaps for this reason, geographers have paid relatively little attention to noise since contributing to early work on subjective responses to noise (Hall and Taylor, 1977; Taylor and Hall, 1977). Although recent research on wind turbine citing has ‘reintroduced’ environmental noise to geographic inquiries (e.g., Baxter et al., 2013;

Walker et al., 2014) the dominating concerns surrounding noise and health relate to cognitive processing and the physiological perspective on stress, therefore much of the current knowledge in this field comes from environmental psychology and epidemiology.

1.2.2 *Biological hazards or ambient stressors?*

The physiological perspective on stress refers to acute (i.e. fight-or-flight) or chronic stimulation of the sympathetic nervous system and the activation of the hypothalamus-pituitary-adrenal 'stress' axis, which results in the release of catecholamines (e.g., adrenaline) and corticosteroids (e.g. cortisol). The most common health effects associated with environmental noise exposure are cardiovascular disease (CVD) outcomes of this generalized psychophysiological stress response, which can categorized as the result of direct or indirect effects (Babisch, 2011; Münzel et al., 2014). Direct effects of noise are conceptualized as 'objective' responses to noise exposure (i.e., sound level), and do not require the involvement of cortical structures to active the fight-or-flight response. Involuntary sympathetic arousals during sleep, for example, can lead to alterations in blood pressure and lipids and eventually manifest as chronic CVDs (Münzel et al., 2014). Indirect effects, or 'subjective' responses (e.g., noise annoyance), are the result of cognitive and emotional appraisals (i.e., psychological stress), which may also lead to physiological stress and the manifestation of CVDs under chronic exposure (Münzel et al., 2014).

Biological mechanisms also link air pollution to CVDs. These mechanisms are activated by pollutants crossing the blood-gas barrier and leading to acute effects from short-term exposure (e.g., myocardial infarction), or through pulmonary and systemic oxidative stress and inflammation, which may lead to chronic disease in individuals with long term exposure (e.g., atherosclerosis) (Brook et al., 2004). Therefore, the most challenging issues in epidemiological research on the effects of vehicular traffic is the relative effect of air pollution versus noise on CVD outcomes linked to both types of exposure with high biological plausibility (Babisch, 2011; Brook et al., 2004). Although subjective responses to air pollution such as odour annoyance can cause psychological and physiological stress (Amundsen et al., 2008; Claeson et al., 2013), it is difficult to separate effects of biological mechanisms and physiological stress effects of subjective responses because clinical outcomes are the same as for direct effects of inhalation and ingestion. Arguably, this becomes intractable when considering responses to traffic noise, which also have the same cardiovascular disease endpoints.

Research on the cumulative effects of noise and air pollution provides mixed results. For example, Gan et al. (2012) concluded that there were independent effects of noise and air pollution on coronary heart disease mortality, while Fuks et al. (2011) found no independent effect of noise on arterial blood pressure in a cohort exposed to particulate matter. Tetreault et al. (2013) conclude that the confounding effects are low and that the level of correlation between noise and air pollution does not influence the relative effects on CVD. Conversely, Foraster (2013) argues that attempts to control for the confounding effect of noise in studies on air pollution or vice versa to disentangle direct exposure effects are inconclusive because of inconsistent exposure assessments and different study outcomes. Although the aforementioned studies did not attempt to evaluate the confounding effect of psychological stress, disentangling health effects of stress from direct effects of air pollution has been a topic of discussion for decades without much progress, though recent work has reinvigorated such efforts (Clougherty and Kubzansky, 2009; Clougherty et al., 2010; Evans and Cohen, 1987). Likewise, recent research has examined the relative effects of objective versus subjective responses to noise on CVD outcomes, but there is insufficient evidence to make any conclusions (Babisch et al., 2013; Fyhri and Klaeboe, 2009).

The uncertainty surrounding cumulative effects of noise and air pollution on cardiovascular diseases and other clinical outcomes highlights the shortcomings of using merely biomedical endpoints of the health-illness continuum. To this end, indicators of subjective responses such as noise annoyance are normally considered mediators or risk factors, but there are three main reasons for the growing support of considering annoyance to noise and odours as health outcomes (Michaud et al., 2008; Nicell, 2009). Firstly, residual confounding and population heterogeneities in epidemiological studies may inhibit generalization on the cumulative effects of air pollution and noise on clinical outcomes in perpetuity. Research by geographers on the effect of place on ambient stressors certainly suggests that this may be the case. Secondly, the World Health Organization (1948) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” While this may be an ideal more so than something attainable in practice, chronic psychological stress caused by annoyance undoubtedly detracts from such a complete state of well-being. Thirdly, and from a health interventionist perspective, annoyance represents an upstream health indicator for potential clinical outcomes. This is supported by the precautionary framework for research and action on environmental health effects of multiple stressors, which suggests that the evidence-burden for environmental health outcomes should be relaxed to protect vulnerable populations in cases of uncertainty (Wakefield and Baxter, 2010).

The effects of noise as a psychological stressor were identified early on, and much of the recent literature has simply confirmed such findings (Evans and Cohen, 1987). These include effects on cognitive functions such as memory and concentration; affect and interpersonal behaviours by diminished altruistic behavior and sensitivity to others; stress induced aggression, and annoyance. The effects of odours from air pollution as an ambient stressor has received less attention, perhaps due to the more concerning effects on respiratory and cardiovascular outcomes along with cancer, reproductive and developmental effects. However, previous research nonetheless suggests that odour annoyance should also be considered an indicator of health (Atari et al, 2012; Parr, 2006). Dose-dependent responses to noise and air pollution have been established for numerous clinical outcomes, as well as noise and odour annoyances (Brook, 2008; Davies and Van Kamp, 2012; Klaeboe et al., 2008).

1.2.3 *A proposed framework for environmental health and stress*

The above discussion demonstrates that the systemic health risks posed by cumulative exposures to noise and air pollution are complex. A complete assessment of systemic health risks requires consideration of multiple exposures along with individual and social influences that characterize those exposures; multiple pathways to embodiment and health through psychological and physiological stress responses, and; the effects of individual, cultural and structural resources on perceptions of the exposures. Although it is not exhaustive, Figure 1.1 proposes a framework for the relationship between these major factors that structure systemic risks from an environmental health and stress perspective. No single study, except perhaps a comprehensive environmental assessment, can address such a complex framework in its entirety, but as outlined above, previous research has addressed many of the individual relationships that make up this framework. The dotted lines in Figure 1.1 represent knowledge gaps on environmental health effects of multiple exposures addressed by this thesis, while dashed lines represent potential implications of research on multiple exposures for addressing systemic health risks. The solid lines represent relationships that are fairly well understood based on previous research. Pathways from left to right represent exposure to embodiment and health, while other pathways moderate environmental health effects of multiple exposures.

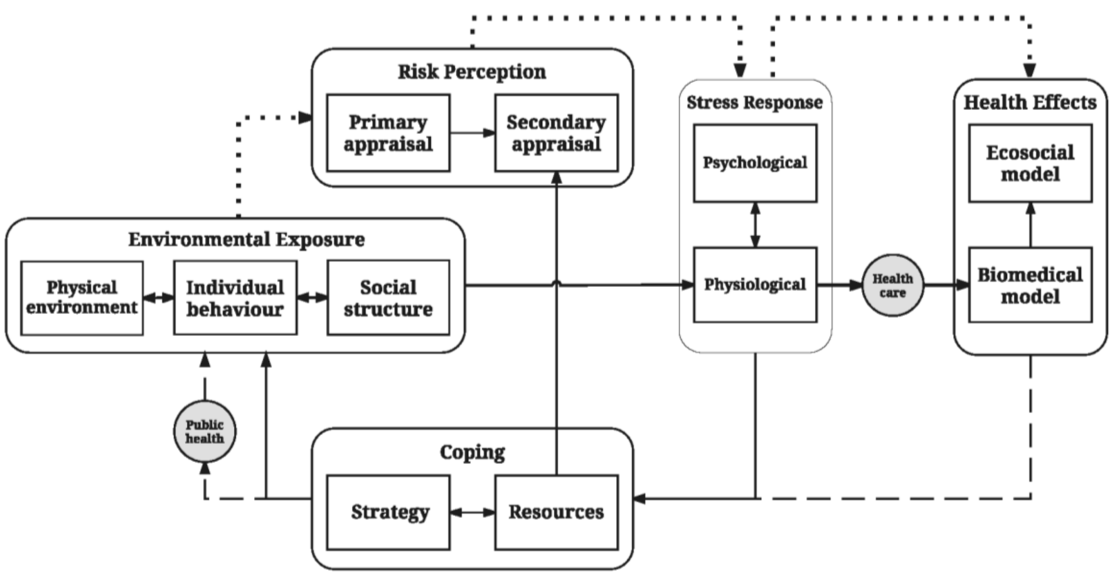

Figure 1.1 - Proposed systemic environmental health and stress framework

The solid line from exposure through physiological stress to biomedical health effects acknowledges the relevance of objective responses to sound and direct effects of air pollution as identified by previous epidemiological studies. The physiological stress response in this case does not only refer the ‘stress axis,’ but any effect of air pollution or noise that disrupts homeostasis, or the natural balance of physiological systems. This pathway represents the challenge that exists in disentangling the effects of psychological stress from biomedical health effects of noise and air pollution. One crucial step in disentangling these effects is to understand the relative or synergistic effects of co-exposure on subjective responses, which is represented by the pathway from environmental exposure to stress responses. Understanding the influence of the urban physical environment on cumulative exposure is also important to this end, and this thesis addresses both of these issues.

The circles for health care and public health represent the points of intervention for these approaches to improving environmental health. Health care strategies to manage or alleviate biomedical health outcomes of environmental exposure are well established, but little is known about the ecosocial health benefits of reducing exposures as a public health strategy. This is in part due to a lack of health indicators for subjective exposure responses that can be used to compare biomedical and ecosocial health effects and this thesis attempts to address this shortage. Finally, the framework in Figure 1.1 suggests that there may be a feedback between environmental health and stress effects of multiple exposures and coping, which corresponds to the characterization of environmental health risks as systemic, and this thesis aims to add support for this concept.

1.3 Objectives

1.3.1 *Objective 1: Demonstrate the impact of high volume traffic facilities on the noise annoyance dose-response*

Vehicles are a significant, and often the dominant source of both environmental noise and air pollution in urban environments (Hoek et al., 2008; Allen et al., 2009). Studies that assess the spatial distributions of noise and air pollution over large areas such as entire cities commonly observe a modest and significant correlation (0.3-0.5) between the two exposures (Allen and Adar, 2011). However, previous research shows that urban form can affect the correlation between traffic noise and air pollution (Foraster et al., 2011). Given the same traffic volumes within different urban forms, the level of emitted air pollution will remain constant, but noise levels will change drastically depending on vehicle speeds and sound reflections from the built environment (Tang and Wang, 2007). Conversely, varying traffic volumes within similar urban forms has a much stronger effect on exhaust emission levels, while traffic noise levels remain relatively constant. Research on cumulative exposure effects on annoyances as well as cardiovascular disease outcomes suggest that there may be additive effects of noise and air pollution (Gan et al., 2012; Klæboe et al., 2000), but research findings are mixed. Foraster (2013) argues that inconsistent results (e.g., Tetreault et al., 2013) are due to not taking into account variations in the cumulative exposure to air pollution and noise in different areas. To this end, Allen and Adar (2011) suggest that neighbourhoods or urban areas with different levels of correlation between noise and air pollution should be leveraged to properly assess the effects of cumulative exposure. The noise annoyance dose-response is well established in the literature (Miedema, 2007), but the effect of varying cumulative exposures to noise and air pollution such as caused by high volume traffic facilities is not known.

1.3.2 *Objective 2: Evaluate the effect of cumulative exposures and odour annoyance on noise annoyance*

As described for Objective 1, traffic noise and air pollution exposures are normally correlated in urban environments. Klaeboe et al. (2000) showed that noise annoyance increases with levels of noise and air pollution exposure when either is held constant, and they also demonstrated this effect on odour annoyance. Hence, odour annoyance and noise annoyance may be dependent. However, the authors did not test if this additive effect of co-exposure on annoyances depended on the correlation between noise and air pollution. It is conceivable that the additive effect on noise annoyance can be confounded by odour annoyance if the presence of odorous air pollutants is not highly correlated with noise. Furthermore, their study was conducted in Oslo, Norway and as such in an urban environment representative of large cities. Schomer et al. (2013) argue that a nuanced understanding of how community context affects noise responses is missing because almost all noise research to date has been conducted in large cities and therefore relatively noisy environments. This raises questions about noise sensitivity and its relation to environmental context. To address the aforementioned knowledge gaps, Objective 2 seeks to answer two questions: (1) Do cumulative effects of noise and air pollution on noise annoyance depend on odour annoyance? (2) Does environmental context influence noise sensitivity and consequently the effect of noise on noise annoyance?

1.3.3 *Objective 3: Formulate and test a model for environmental health effects of multiple exposures*

The above discussion on noise and air pollution as biological hazards versus ambient stressors makes a case for considering noise and odour annoyances as health outcomes based on shortcomings of research on clinical outcomes, an ecosocial perspective on health, and the precautionary framework for environmental health research. However, if reducing annoyance is to be a useful tool for improving or protecting public health through environmental management, a clearer understanding of potential health benefits is needed. Health indicators are frequently used to assess quality of life (QoL), and a number of measurement instruments that include health as well as environmental indicators have been created (e.g., Coons et al., 2000; Fleury-Bahi et al., 2013; Kristofferzon and Ternesten-Hasseus, 2013). The World Health Organization Quality of Life (WHOQOL) assessment and SF-12/SF-36 short form surveys are perhaps the most utilized QoL instruments (Harper et al., 1998; Hays et al., 1993; Wareet al., 1996). The WHOQOL assessment is a comprehensive instrument for measuring all dimensions of QoL, including the environment, and therefore cannot measure its effect on other dimensions such as health. The SF-12 instrument was designed to assess the impact of clinical health care (e.g., asthma management) on health related QoL (HRQoL), which is measured by two factors, functional mental and physical health. While previous research has used some or all of the domains that make up the instrument to measure effects of noise, air pollution and annoyance (e.g, Dratva et al., 2010; Nitschke et al., 2014; Yamazaki et al., 2005), no previous research has evaluated the sensitivity of the SF-12 mental and physical health factors to annoyance from multiple environmental exposures.

1.3.4 *Objective Four: Critically appraise the capacity of environmental impact assessment to address environmental health in megaproject planning*

Environmental assessment frameworks in Canada do not require the assessment of systemic health risks from multiple exposures, alternatively referred to as cumulative effects of exposure. Briggs (2008) proposes the integrated environmental health impact (IEHI) assessment framework when systemic health risks are present. Previous research demonstrating the interacting effects of air pollution and noise on health, as well as place effects on environmental health and risk perception, suggests that systemic risks are present when poor air quality and high levels of noise characterize the environmental context of a project. Using a recent environmental assessment for a transportation megaproject as a case study, this thesis seeks to demonstrate that the IEHI assessment framework can alleviate challenges posed by current environmental assessment frameworks in Ontario and Canada in terms of accommodating stakeholder participation and addressing environmental health risks.

1.4 Organization of the thesis

The thesis consists of six chapters including this introductory chapter. Chapter Two describes the historical and geographical context of the thesis, which details the history of Windsor from its founding up to the initiation of the cross-border partnership to modernize the infrastructure of the Windsor-Detroit Gateway. While this chapter does not make specific reference to environmental health effects of traffic noise and air pollution, and as such does not draw on the environmental health and stress framework outlined above, the chapter was included to inform the reader about the sociocultural environment that informs public perceptions of transportation and its health risks in Windsor. It was beyond the scope of this thesis to address specific links between sociocultural context and secondary appraisals of risks posed by air pollution and noise in the community, but previous research suggests that this played an important role in the confounding effects of place on environmental annoyances observed in Chapter Three (e.g., Bickerstaff 2004; Day, 2007).

Chapter Three describes the research to meet Objectives One and Two; Chapter Four addresses Objective Three, and; Chapter Five addresses Objective Four. More generally, Chapter Three seeks to understand how physical and social environments can interact to influence health outcomes of exposure to traffic noise and air pollution, and furthermore how environmental perceptions can moderate the effects of these interactions. This draws on pathways between exposure, perception and stress responses in the environmental health and stress framework, and is theoretically grounded by the physiological and psychological stress perspectives, relational geographies of health as well as sociocultural perspectives on risk perception. Chapter Four draws on the same theoretical perspectives, but focuses more specifically on evolving the analytical framework for understanding physiological versus psychological stress responses to ambient stressors. In so doing, the chapter proposes and tests a structural equation model for the relationship between annoyances and health related quality of life. Chapter Five provides a detailed analysis of the public input to the planning and environmental assessment process for the Detroit

River International Crossing. With respect to the environmental health and stress framework, findings in this chapter provide support for the effect of socio-culturally informed risk perceptions on coping resources as determined by agency in environmental management. Chapter Six provides an assessment of the thesis in terms of meeting the objectives and discusses the contributions of the results to the field of environmental health research and to address environmental impact assessment challenges, as well as opportunities for future research to build on the outcomes of the thesis.

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CHAPTER TWO

2. RESEARCH CONTEXT

This chapter describes the historical development of the study area and provides a background on the more recent developments that influenced government agencies in the United States and Canada to plan and construct a new border access road in Windsor, Ontario as well as plan the construction of a new border crossing between Windsor and Detroit, Michigan. This chapter is a modified version of a paper currently under review for publication (Oiamo, T.H., Lafreniere D., and Parr, J. *The Making of a Key North American Environment of Mobility: the Windsor-Detroit Borderland*. Forthcoming in: Coates, C., Young, J., and Bradley, B. (Eds.). *Moving Natures: Environment and Mobility in Canadian History.* Calgary: University of Calgary Press and NiCHE series, Energy, Ecology, and the Environment).

2.1 **Introduction**

The Windsor-Detroit borderland is a quintessential twentieth-century environment of mobility, where contemporary technologies, trans-boundary politics and globally forged liminal spaces converge. Grounded in particular landscape forms, and made within local, regional and international relations, here incompatible choices collide. On the Canadian side of the Detroit River the effects of the collision are most grave for the cultural landscapes in two historic neighbourhoods, Sandwich and Brighton Beach. Until relatively recently, these were places of mixed industrial, residential and recreational use. Now they are being transformed by the construction of the approach to a new bridge

Americans refer to as the New International Trade Crossing (NITC) and, to Canadians, the Detroit River International Crossing (DRIC). Sandwich (1797) was the original urban settlement that later became part of the City of Windsor. Once the regional capital, this now historic neighbourhood sits immediately to the north and east of a reclaimed industrial district known as Brighton Beach, the point from which the new bridge will be anchored. The new bridge and the Rt. Hon. Herb Gray Parkway will be the most costly road development project in Canadian history. How this area came to be the site of a significant yet excluding environment of mobility in early twenty-first century North America is our focus here (Figure 2.1).

For the past two centuries, these neighbourhoods experienced the effects of globalization on a local environment as well as changing personal and commercial mobilities. Transportation engineering works imposed transient effects on these spaces and reordered them as a conduit for international trade. Manufacturing, processing and power generation enterprises cleaved to the borderlands along the river in order to minimize the transportation costs for their production inputs and finished products, activities with worrisome environmental legacies. Within this landscape, the Ambassador Bridge persists not only as an emblem of international cooperation, but also as a representation of how mobility and its infrastructure can both link and divide a space. The world’s longest suspension bridge when it opened in 1929, its technological legacy still epitomizes the acquisitiveness of private capital. Today, it is a roadblock for contemporary mobility needs. This chapter examines how Brighton Beach and Sandwich became the products of diverse and contending colonial, technological and entrepreneurial forces.

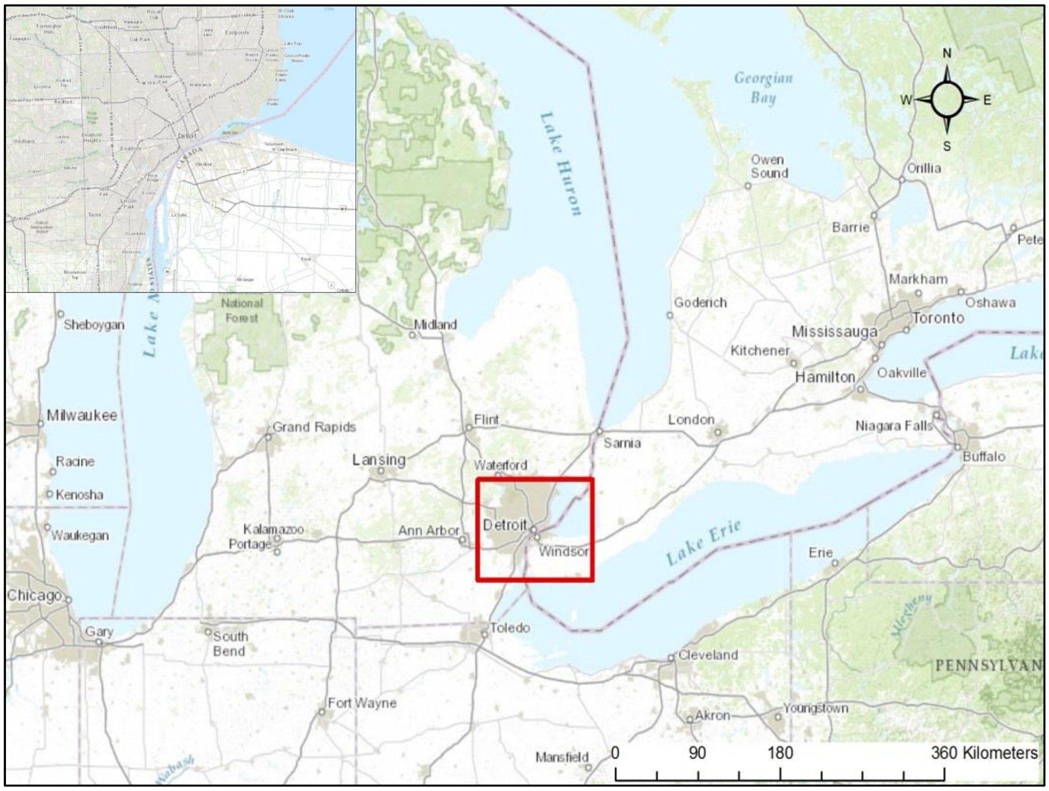

Figure 2.1 Highway and railway transportation networks surrounding the Windsor-Detroit Gateway

2.2 From frontier to borderland: Settling the banks of the Detroit River

Ever since the first settlement of French merchants and military in 1701, mobility technology and culture have shaped the Detroit frontier. The Detroit River crossing has been a busy conduit, useful in avoiding the longer land route around the Great Lakes, under Erie or over Superior. Antoine Laument, Sieur de Lamothe Cadillac, a French commandant and merchant, recognized this situational advantage, when he and his flotilla of twenty-five canoes first arrived at the future site of Detroit (Lajeunesse, 1960; Teasdale, 2010). Shortly following the establishment of the fort on the river, French families from the St. Lawrence Valley began to arrive in the region and establish farms on the south side, opposite the fort.[1] The clearing of the black oak savanna, a light forest cover rising on the rich soils of tall grass prairie, yielded rich nourishment for bison, elk, and white-tailed deer. In the early eighteenth century, it became a welcome habitat for this new cohort of Europeans. The initial settlement of French farms in the familiar 'long lot' system, gave each farm access to the waterfront for irrigation, navigation, and trade. Among the farms, at the point where the river turns south towards Lake Erie, was a reserve of the Huron Nation. In the eyes of Europeans, native land was 'unsettled,' fit to be appropriated for the townsite of Sandwich. Sandwich soon became the capital of the Western District of Upper Canada, inaugurating a long history as an entrepôt of important cross-border trade and traffic (Harris, 1997).[2]

Until the founding of Sandwich, communication between the two shores of the river was relatively infrequent. With the movement of British Loyalists from Detroit to Sandwich, ties of kinship and business increased traffic across the river. The earliest ferry service, established in 1798, was nothing more than a large flat-bottom canoe that operated between the foot of Mill Street in Sandwich and the town of Detroit. Timber, market crops and furs were among the items traded across the river, between the two border towns and onward. Throughout the nineteenth century, industrial innovation and rapid urbanization spread across the continent. These changes transformed the border

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[1] An infrequently recognized geographic curiosity is that the present day City of Windsor, the area of interest in this paper, is in fact south of Detroit.

[2] From 1797 to 1850, Sandwich was the capital of the Western District of Upper Canada, a region that spanned from the Detroit River to the outskirts of the present city of Hamilton.

communities of Sandwich and Windsor. International relations between the United States and British North America matured. In January 1854, the rail head of the Great Western Railroad reached Windsor, then a small hamlet directly opposite Detroit, revolutionizing how the region communicated with the rest of the continent. Windsor subsequently became the principal settlement of the region. No longer the seat of government, the nucleus of development, or the economic engine of the region, Sandwich lost its prominent merchants and lawyers to Windsor and became a distant suburb, a part of the periphery.[3]

Later the same year, the Reciprocity Treaty reduced regulatory barriers to commerce between the United States and British North America. This important ancestor to the 1988 Canada-U.S Free Trade Agreement removed the American 21 percent tariff on natural resource imports (Ankli, 1971; Officer and Smith, 1968). The treaty consolidated Windsor's newly acquired position as an entrepôt for the trans-national railroad network for wheat, market crops and timber now were carried easily across the border to the American Midwest. This critical relationship to the continental market created a boom in Windsor. Sandwich was pushed further to the margins.

Throughout the remainder of the nineteenth century, prosperity in Sandwich rose and fell in response to the differentially conferred advantages of a succession of transportation technologies. In the summer of 1886, North America's first electric streetcar began to serve the border communities of Windsor and Sandwich, the start of a long regional

[3] The importance of the event was encapsulated by the *Detroit Daily Free Press*: "To-day the ice fetters will be broken, for the last link [Niagara to Windsor] in the great chain of communication between the east and the west is finished." *Detroit Daily Free Press*, 18 January 1854.

history of innovation in transportation provision and manufacturing (Schramm, 1984). The arrival of the electric streetcar also helped to develop the burgeoning tourist industry centred on the town's famous sulphur springs. New sources of power provided the electricity needed to expand the grid and helped illuminate and develop recently established local salt mines. With reliable electricity, other manufacturers opened shops around the region, including two pharmaceutical companies (Sterns and Parke Davis) and two transport start-ups (the Evans and Dodge Bicycle factory and the Milner-Walker wagon works). A few years later the Dodge family became famous in the new automobile industry (Roberts, 2006).[4]

In the last decades of the nineteenth century, the shoreline of the Detroit River became a place of transnational economic prosperity. Ferries shuttled thousands of passenger and freight railway cars across the river in the late nineteenth century, but the logistical and technological frictions of this ferry operation began to impede growth. Windsor and Detroit authorities in 1871 approved plans to bore a railway tunnel under the river. Construction began the following year but was soon abandoned. A ventilation failure caused a deadly accident. Existing tunnelling technologies were not up to the engineering challenge. With 1600 feet remaining untunnelled the aborted tunnel became part of a history fraught by technological shortcomings and defeat (Mason, 1987).

Diverse interests defended technologies that competed for space along the river. Ships carrying grains and minerals from Lake Superior needed clearance under bridges and safe

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[4] The Milner-Walker Wagon Works, founded in 1897 in part by the famous distiller Hiram Walker, was located in his eastern suburb of Walkerville. This company, led by its industrious manager, Gordon McGregor, and its owner, Henry Ford, became the Ford Motor Company of Canada.

passage past piers (Morrison, 1930). Expansion of marine shipping terminals was thwarted by the pre-existing railway, because trains, which carried people, a variety of agricultural and, increasingly, manufactured products, also needed access to the riverbanks. As the proponents of contending transportation technologies vied for space, civic and business leaders in Windsor and Detroit competed for shares of population and labour force growth. Both urban centres focused on building ever greater infrastructure to accommodate increased trans-boundary and local traffic.

The Detroit River railroad tunnel, also called the Michigan Central Railway Tunnel, opened for passenger and freight operation in 1910. The completion of the rail tunnel enhanced the region’s position as a principal place of cross-border trade. The Lake Carriers Association, which represented the interests of hundreds of seafaring vessels with economic stakes in the Detroit River, successfully lobbied for a tunnel rather than a bridge (Mason, 1987). The tunnel was positioned in an undeveloped space between the urban fringes of Sandwich and Windsor, across from an equally advantageous position on the Detroit side where a rail route could easily reach the river’s edge. Still in use as a freight tunnel today, it was a technological feat serving the transportation needs of the region. It also reduced Sandwich and Brighton Beach into marginal border spaces in the broader global trading network. Windsor, with its spatial and economic advantages, augmented by its proximity to the railroad ferries and tunnel, had secured local commercial primacy.

With the railway overland link to Detroit complete, the topography and geology of Windsor and its hinterland continued to encourage complementary manufacturing, agricultural, transportation pursuits. In the early days of roofless vehicles, the flat topography and mild climate as well as the ready supplies of gravel for the road system enticed residents to take up motoring. Well-suited to many contending uses for space, these boundary lands, both historically and today, remained good places for growing food. A Jesuit travelling with the explorer René Robert Cavelier, Sieur de La Salle, wrote in 1679 of the abundant fruit along the Detroit River, and in the twentieth century the region still produced prodigious supplies of vegetables, fruit and grain for market (Mason, 1987; Morrison, 1954). The County of Essex encompassed the border towns, and its elected officials were still promoting farming and gardening as land uses in “The Sun Parlour of Canada” in 1912 (Essex County, 1912). Market gardening and soft fruit production were sufficiently remunerative in the climate and soils of Essex to support such contemporary Canadian countryside rarities as free rural mail delivery service and municipal telephones. Sandwich East, West and South Townships, where ‘peaches grow to perfection,’ ‘among garden lands, which grow radishes, potatoes, sweet corn, tomatoes, and all kinds of vegetables,’ surrounded the towns of Sandwich, Windsor and Walkerville. The central part of Sandwich West, stretching from the Town of Sandwich southward, was ’noted for the quantities of melons marketed every year, and the balance of the township for its fine corn land and other field grains’ (Essex County, 1912). In what was a conduit elsewhere for some people, these sedentary pursuits provided an anchor in place for generations of others.

2.3 A new geopolitical era takes form

While the ease of shipping and proximity to markets made agriculture a significant force of economic development in Essex County throughout the nineteenth century, new and profitable industries were also beginning to recognize the area's locational advantage. Among these industries were automobile manufacturing and steel production. Building connections to nearby Detroit and the desire to circumvent restrictive Canadian trade tariffs, automobile production soon became a leading industry in the border municipalities of Sandwich, Windsor, Walkerville, Ojibway and Ford City (Figure 2.2)

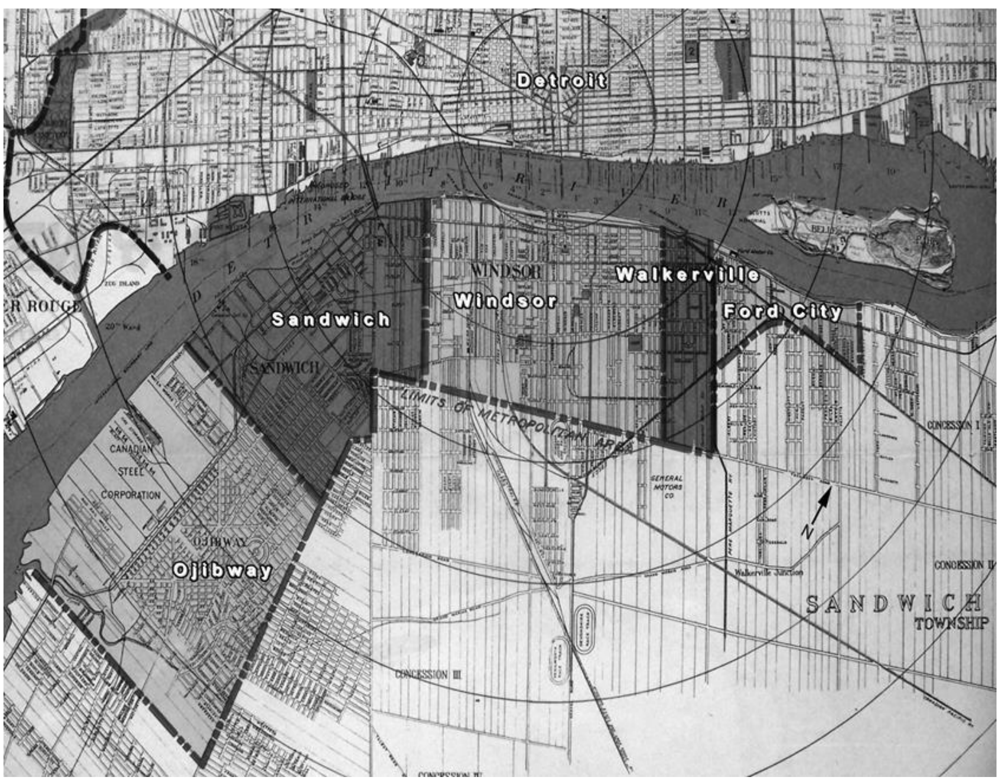

Figure 2.2 - Map showing the Border Cities, including the proposed developments of Ojibway (Federal Lithograph Co., c1920)

Recognizing an emerging bi-national market, the United States Steel Corporation planned a large-scale foundry on 6.6 square kilometres of land along the fertile banks of Detroit

River in Brighton Beach, immediately south of Sandwich. US Steel expected this operation to grow prodigiously, for this location with the river for shipping and production could access a huge distribution area (The Evening Record, 1913a). Both Gary, Indiana, at the southern tip of Lake Michigan, and Hamilton, Ontario, at the western reaches of Lake Ontario had exploited similar advantages. The Town of Ojibway, a creature of US Steel, was incorporated in 1913 by a special act of Parliament. Advertisements in local newspapers called on ‘the man with a little money’ to buy lots in ‘The Gary of Canada’ (Figure 2.3; The Evening Record, 1913b). The lots, on fertile soils and priced from $200 to $500, were to house the steel giant’s sixteen thousand workers and their families. The town only grew to one hundred and sixty residents before the world-wide depression of the 1930s slowed trade and stalled the domestic automobile and steel industries. The town never materialized, the only remnant being an old blast furnace and a couple of lengths of sewer piping that lay beneath an underdeveloped road bed. An unintended and fortuitous consequence was that the significant oak savannah of the area remained in its natural state, exempted from the influence of the rising contemporary global network privileging environmentally noxious heavy industry.

Twentieth-century industrialization and urban development in the Canadian border cities were as much the result of political forces as locational advantages. The Conservatives defeated Sir Wilfrid Laurier’s Liberals in 1911 on a platform of resistance to a new Canada-United States Reciprocity Agreement, already ratified in the United States (Beaulieu and Emery, 2001).

Figure 2.3 - Advertisement for Town of Ojibway, proposed by US Steel (The Evening Record, 1918).

The protectionist sentiments of the new Conservative government, led by Sir Robert Borden, echoed the Canadian Manufacturers' Association's (CMA) resistance to free trade in favour of local branch-plant industry (The Evening Record. 1913c). The push and pull of advancing technologies and the burgeoning global marketplace drew labour and capital east and north of Sandwich and Brighton Beach to the growing City of Windsor.

The marginalisation of the southern reach of Windsor was further secured when the Ford Motor Company of Canada, established in 1904, located in Ford City, east of the city's central business district. By 1922, Ford employed 40 percent of the population of the Windsor area. Rates of population growth in Windsor during the 1910s and 1920s surpassed Detroit and even more so nearby London, Ontario (Roberts, 2006). This growth depended on a permeable border for labour. In 1912, Canadian commuters constituted 16 percent of the Detroit labour force. In 1913, cross-border pay rates in the auto sector were harmonised. Soon 25 percent of the workforce at Ford's Detroit plant was Canadian-born, and by the late 1920s, fifteen thousand residents crossed the border daily to work (Roberts, 2006). The Ford Motor Company of Canada employed eight thousand workers in 1928, and other carmakers including General Motors of Canada, the Chrysler Corporation of Canada, and the Studebaker Corporation of Canada had operations in Windsor (Roberts, 2006). By the late 1920s, Windsor-Detroit was the busiest border crossing in North America, serviced primarily by a fleet of steam-powered ferries. Workers and freight operators experienced significant delays, often many hours long as they attempted to make their daily commutes, threatening the economic prosperity of the region (The Border Cities Star, 1925). Both public officials and private interests responded to the need for a more efficient crossing, and a bridge became the central plan.

Through the early twentieth century the growing automotive industry was the key driver of Windsor's economy, and the need for a new crossing preoccupied civic leaders on both sides of the river. Pressures from the owners of the growing fleet of personal and commercial automobiles, automobile manufacturers and a new breed of freighting, transport trucks, initiated plans for a second permanent river crossing. When the original suspension bridge design was developed in 1920, it called for two decks, one for automobiles and trams, the other for railcars and utilities. The railway companies' unwillingness to endorse the project, combined with a tainted fundraising campaign, caused its eventual failure (Mason, 1987). It took another five years of political and financial manoeuvring to secure the future of the Ambassador Bridge. By this time, the design was solely based on use by automobiles and trucks. Although mayors on both sides of the Detroit River opposed private ownership, the premier of Ontario, G. Howard Ferguson, announced in early 1927 that the British North America Act prevented the province from guaranteeing bonds for the bridge (Mason, 1987). Efforts to secure funding from the national level of government were thwarted by an election in 1926 and general opposition to funding a privately owned bridge. Seeking support for his adamant opposition to private ownership, Mayor John W. Smith of Detroit agreed to hold a referendum to let his constituents vote on the issue. They overwhelmingly supported the existing private arrangement because further delays to promised jobs were intolerable, and the need for the crossing had become unquestionable. Prominent public figures, such as Henry Ford, also strongly supported the bridge. Thus the Ambassador Bridge would be privately financed and owned, a precedent with formidable implications both for future residents and commercial users seeking a less congested crossing.

The placement of the Ambassador Bridge and its regulatory foundation, built upon the transnational policy mechanisms of the 1920s, had profound effects on the natural, urban, and cultural landscapes of the Windsor area. The first site planned for a new bridge promised to consolidate the position of Windsor as the vital centre of the growing conurbation on the Canadian side. However, when the approach in Detroit proved too costly and cumbersome to construct, the plan shifted to a more southerly location nearer the narrowest point on the river, from 19th Street in Detroit to Huron Church Road in Sandwich, where fewer high value uses of land contended for the space. Although these sites were some distance away from the centres of Detroit and Windsor, they offered lower construction costs and proximity to the planned industrial areas in Ojibway, Brighton Beach and Sandwich.

Within Sandwich, support for this location of the bridge was decisive. A referendum on 5 January 1926 resulted in 1,556 votes in favour of the location along Huron Church Line to a mere 104 opposed (The Border Cities Star, 1925b). What many in Sandwich did not realize was that the bridge, although good for the growing automobile industry and a sign of progress and friendship between the two nations, would divide the town. The bridge, running down Huron Church Road and alongside the Assumption Church, both physically and psychologically, separated Sandwich from the church and the City of Windsor (Lafreniere and Rivet, 2010). It also solidified the marginality of Sandwich in this new environment of mobility.

The economic boom prior to the Depression led to urban and suburban development throughout the border cities and their hinterlands. Sandwich had become a place of modest housing for industrial labourers. Urban transit and rising municipal taxes had pushed development to the periphery of the border cities, and settlement along the highways outside the urban centres intensified. With the exception of a few new streets, however, residential settlement in Sandwich remained unchanged during the 1930s and 1940s. Some of the urban workers who had lost their jobs during the Depression resorted to small-scale farming. This eclectic mix of modest residential neighbourhoods surrounding the old Sandwich town centre, commercial and industrial land uses, failed developments, and not-quite-rural landscapes survives today and testifies to the area's subservient role. In the presence of mobility as the dominant land use, people make do.

The Great Depression and political forces beyond Canadian borders had detrimental impacts on the region. The US Congress passed the Smoot-Hawley Tariff Act in 1930, a result of US protectionism. Facing a gloomy economic future, the US also put restrictions on the employment of Canadians and other non-Americans within its borders. Nearly thirteen thousand people left the Canadian border cities between 1930 and 1933 (Morrison, 1930). During the following two decades, Windsor's population only grew by 20 percent. Advocates for the Ambassador Bridge and the Detroit-Windsor tunnel had argued that Windsor would become a residential suburb of Detroit. They did not foresee the vulnerabilities of border towns to domestic political concerns. At the start of the Second World War, many square miles of undeveloped subdivided suburban property and vacant lots within the city limits of Windsor remained (Robinson, 1942).

Following the decline in international trade during the Depression, motor vehicle exports had diminished, but as local manufacturing diversified into armed vehicle production, economic prosperity returned. When World War II began, the Ford plant at Windsor employed eleven thousand workers; this increased to seventeen thousand by the end of the conflict. Windsor became the largest source of military transport vehicles for the British army and its Commonwealth Allies. With the boom that followed, the roads to the Ambassador Bridge became busier and land development intensified. Windsor was fourth among Canadian cities in 1953 in the gross value of manufactured products.

2.4 Urban effects of a changing borderland

All the settlements adjacent to Windsor along the Detroit River have been disrupted and disordered by the relative advantage their location afforded international trade. H.W. Gardner speculated in 1913 that Windsor and its hinterland would grow and prosper because of their "unsurpassed transportation facilities by rail and by water and unique advantages with respect to the exchange of products between Canada and the United States" (Gardner, 1913, p. 1). Indeed, in succeeding years, corporations such as The Dominion Steel and Coal Company, which had purchased US Steel property, had begun smelting, and the Canadian Salt Company forever turned the once-fertile agricultural lands of the black oak savannah into sites for mining salts. Brighton Beach, located southwest of Sandwich, was a place of modest but serviceable wood-frame bungalows and interspersed with gardens. By the 1950s, its residents looked at and smelled Zug Island across the Detroit River, described as "a nightmare of steel mills and foundries" (Figure 2.3; Vasey, 1997, p. 1). Brighton Beach also became a dumping ground for toxic refuse from all over Windsor: “so far down it’s almost out of town” and “insult piled on injury,” a contemporary observer has written (Vasey, 1997, p. 2). A place out of sight and out of mind for the well-established citizens of Windsor, many characterised Brighton Beach as a ‘dog-patch,’ a marginal and abused place. The predicament of Sandwich paled beside the accumulating neglect of this location. In different ways, both communities were caught in a process of developing underdevelopment, lingering on the periphery of the rising City of Windsor to the east, where many were eager for more fabulous routes to the river and the border and the international markets beyond.

Figure 2.4 - View of Zug Island from vantage point at old ferry terminal in Sandwich (photograph by authors)

Wartime industrial growth in the border communities was accompanied not by urban development within the city limits of Windsor, but by the sprawl characteristic of contemporary North America. The population of the City of Windsor barely rose between 1941 and 1956, while its suburban population increased threefold on 2700 acres of newly developed land (Faludi et al., 1959). Windsor put significant efforts into curtailing this trend of sporadic, extensive, unplanned development and looked for ways to renew many of its urban neighbourhoods. Consultants authoring an urban renewal report concluded that the city of 5700 acres had 1800 acres of declining industrial, commercial and residential lands, and an additional 300 acres that were blighted (Faludi et al., 1959). Sandwich (annexed by Windsor in 1935) was declining, parts of Windsor and Walkerville (also annexed in 1935) were not prospering, but first in need of attention was the downtown core of Windsor, claimed the consultants (Faludi et al., 1959).

As the city government prioritized other areas of Windsor for redevelopment, the designation of the Malden Road Landfill in Sandwich in 1956 forcefully re-affirmed this part of Windsor as a municipal reserve of indiscriminate use. The landfill covered 180 acres of land, wedged between well-kept residential neighbourhoods in southern Sandwich and the Town of Ojibway. The Division of Industrial Wastes of the Ontario Ministry of the Environment surveyed the landfill in 1968 and reported that every month 365,000 gallons of liquid wastes were dumped into open pits in the porous marsh (Ministry of Environment, 1968). The dominant auto industry was undoubtedly a major contributor of this pollution. Near-equal parts septic tank wastes, spent oils and water, paint wastes, detergent and alkaline cleaners from domestic and industrial sources, these pools were simply 'covered up' with dirt and rubble, the leachates directed via peripheral ditches to McKee Drain, through Sandwich and Brighton Beach and into the Detroit River. The landfill stopped accepting industrial wastes five years after the survey, when it had become clear that it lacked facilities required to properly dispose of these toxic materials. The health impacts of this site have not been documented, but evidence from studies of other hazardous waste landfills suggests that its presence burdened the residents of Sandwich long after the facility closed (Goldberg et al., 1999; Lambert and Lane, 2004).

The Sandwich and Brighton Beach communities embodied the negative externalities of producing mobility. The people of Windsor and their surroundings became disposable assets in a borderland where the community, the municipality, the province and the nation were invested more in industrial growth than local well-being. A number of actors with different stakes in the game shaped the local environment. The City of Windsor and the Canadian Salt Company began acquiring property in the Town of Ojibway from the Dominion Steel and Coal Company in the late 1930s. Rising private automobile ownership increased the demand for road salt. The Canadian Salt Company grew considerably following World War II, occupying the majority of land along the Detroit River in Brighton Beach. In exchange for granting mining rights under the Malden Landfill to the Canadian Salt Company, the city took ownership of the lands to the south of Brighton Beach and preserved them in perpetuity as an urban nature preserve named Ojibway Park. The remaining Town of Ojibway was sold to the City of Windsor in 1951. The neglect of this land has had the benign consequence that Ojibway Park, the Ojibway Prairie Complex and Ojibway Prairie Provincial Nature Reserve exist today for recreational and research uses, immediately south of the planned super-highway and border crossing.

Sandwich and Brighton Beach preceded the growth of automobile dependence, and were therefore not serviced by extensive road networks. When the age of automobility and suburbia arrived, redefining how cities were planned across North America, the greater Windsor area was ill prepared for the change, particularly the attendant increase in traffic. Most pressing was the lack of an east-west thoroughfare linking the eastern facilities of Ford, General Motors and Chrysler ('the Big Three') with industry and regional transportation networks to the west. The solution was a two-lane highway along the Third Concession and E.C. Row Avenue (named after Edgar Charles Row, president of Chrysler Canada between 1951 and 1956), which linked provincial highways no. 39 in the east end and no. 18 in the west end of the Windsor Area. In 1963, the Windsor Area Transportation Study (WATS) proposed the expansion of this highway into the four-lane E.C. Row Expressway (Tofflemire, 2009). However, the expressway's western leg between Huron Line and Ojibway was not completed until 1983.

By then traffic and land use demands in Windsor had changed significantly. The Engineering and Traffic Staff at the City of Windsor and a representative of the Ontario Department of Highways worked together on WATS, but the result set an unfortunate precedent for downloading provincial highways to local jurisdictions. The authors noted that "a causal glance at the area map will quickly indicate that Windsor is served by an abundance of Provincial highways" (Tofflemire, 2009, p. 2). Although some highways were downloaded or consolidated immediately, provincial control over other local highways ended when Windsor subsequently annexed more land. Problematically, highways met municipally-managed streets. Overlooking the complications associated with increased cross-border traffic, the city focused on the border-crossing plazas and the tunnel, rather than on the bridge, to ease congestion in the downtown area of Windsor.

Antipathies between the province and the municipality jeopardized the accommodation of cross-border traffic through the city. Most significantly impaired were the connections between Highway 401 and the border crossings. The 401 'super-highway,' completed through Essex County in 1957, terminated well outside the urban area of the border cities. The province wanted the highway to transect the Sandwich South and Sandwich West Townships and terminate at Provincial Highway 18 near the Town of Ojibway. This would have brought Highway 401 near the shores of the Detroit River, southwest of the Ambassador Bridge. In contrast, the City of Windsor wanted a highway terminus that would funnel traffic from Highway 401 through their downtown and the Windsor-Detroit Tunnel. The Sandwich Townships strongly opposed these plans, both of which would take car drivers around -- rather than through -- their municipalities (The Windsor Daily Star, 1953). Thus did the 'super-highway' terminate at Provincial Highway 3, which led to Huron Church Road and the Ambassador Bridge, with a small branch of Highway 401 added to a link with Provincial Highway 3B towards the Detroit-Windsor tunnel. These provincial highways terminated at the Windsor city limits of the day, only two kilometres from the bridge plaza and three kilometres from the tunnel plaza. However, by the late 1990s, only segments of Highway 3 were retained as a Provincial Connecting Link, which, combined with Highway 401, left only two of seven provincial highways in the road network connecting one of the world's busiest highways to North America's busiest border crossing.

As the postwar boom was coming to an end in the late 1950s, the urban renewal consultants advised city planners that Windsor had “no special attraction to particular industry types that would make it competitive against the industrial region of south central Ontario” (Faludi et al., 1959, p. 2). City officials worked hard against long odds. Industrial centres exist at the mercy of their markets. The locational advantages of Windsor were disappearing, as the dynamic and flexible logistics of the trucking and air transport industries surpassed the efficiency of water and rail transportation systems. In a maturing, globalizing economy, distant business and political spheres determined demands on the highway system differently. The City of Windsor and its residents were forced to cope with the environmental footprints of policies at the federal levels of government in the United States and Canada, in particular those aimed at mobilizing resources and capital.

The rise of the postwar automobile industry reduced Canadian dependence on natural resource extraction, but protectionism in the US threatened to destabilize this new industrial base. The Big Three automakers were crucial to the new economy yet hampered by old tariff agreements incompatible with the new global economies of scale. Consumer preferences for all makes and models with different options for powertrains and frills fragmented demand. This meant that the Big Three needed to centralize their operations to serve the entire North American market and increase world export capacity. Separate auto production systems in Canada and the US were unsustainable. During the recession of the late 1950s, six thousand employees in the Canadian automobile and parts industry lost their jobs as Canada fell into a debilitating trade deficit. The Canada-US Automotive Products Agreement, or Auto Pact, signed into effect in January 1965, guaranteed that future ratios of automobile production to sales in Canada would never drop below a baseline from 1963-64, and allowed for tight control of the North American auto industry in favour of the Big Three. The agreement enabled corporate globalization, allowing transnational companies to act autonomously and direct international trade policies (Anastakis, 2005).

The creation of a borderless auto industry brought prosperity but also challenges. As the border became more permeable, Windsor's role in facilitating mobility and the advantages of a border location receded. Although Ford and Chrysler expanded their operations in Windsor, Ford Canada previously had located its head offices in Oakville, and the Big Three opened new plants and facilities in St. Thomas, St. Catharines, Oakville, Oshawa and Montreal. Car production in Canada doubled between 1965 and 1970, which led the industry to radically reorganize. The Ford engine plant in Windsor, which previously produced nine different engines in eighty-six different versions for cars sold in Canada, now produced only one engine in fifteen versions for shipment to plants in both the US and Canada. Independent parts makers followed suit, and shipments across the border increased (Anastakis, 2005). Highway 401 became the primary trading corridor between the Big Three in Detroit and their Canadian branches. Total volumes of cross-border traffic through Windsor rose steadily throughout the 1970s, overloading the approach to the border built in 1957. The only large change in infrastructure was the widening of Huron Church Road -- the primary corridor through the city for trucks bound travelling Highway 401 to the US -- from two to six lanes from the city limits to the Ambassador Bridge in the early 1980s. This configuration remained unchanged until 2011.

In the decades following the Auto Pact, the Canada-US Free Trade Agreement (1988) and the superseding North American Free Trade Agreement (NAFTA; 1994) increased levels of trade in all goods and services, and accordingly added pressure on the cross-border traffic infrastructure. However, a World Trade Organization ruling in 2001, deeming the Auto Pact an illegal restriction on international competition, placed even greater demands on Windsor as an acquiescent participant in a globalizing economy. This decision released the automakers from the obligation to meet production-to-sales ratios in Canada. The Big Three almost immediately announced plant closures in Canada, several of which were in Windsor.

Since 2000, the contending plans for an improved Detroit River crossing have revealed starkly the different political economies, public cultures and policy preferences of these neighbouring nations. Projects to facilitate mobility, when they arise at international borders, as they often do, illuminate national differences, for the creation of these environments of mobility draw heavily on national treasuries. Such is now the case at Windsor-Detroit. Improved connections between Canada and the US at this most important North American trade corridor are sorely needed. The Ambassador Bridge of 1929 is now a costly bottleneck to commerce, industry and labour. This is a key border crossing so clogged as to impede trade, since 9/11 further constricted by heightened security concerns in the US. Moreover, lines of idling heavy vehicles have created an environment of 24-hour immobility, toxic to the health and well-being of the tens of thousands who live nearby. More fluid connections are required to accommodate the increased flows of goods and people. The contemporary international crises of rising unemployment and diminished production make the trading relationship even more welcome and urgent. These issues are felt acutely in the automobile sector, the material lifeblood of the surrounding region.

The Ambassador Bridge was owned and operated by the Bower family until Manuel Moroun became the majority shareholder in 1979 when the Detroit International Bridge Company (DIBC) was offered on the New York Stock Exchange (Mason, 1987). Audible rumblings on a new bridge, or at least a new ownership scheme, began at this point in time. The DIBC made several attempts to sell the Ambassador Bridge before the initial public offering, but the Government of Canada blocked these (HMQ (Canada) v. Canadian Transit Company, 2012 ONSC 1219). Meanwhile, the Canadian Government passed the Sharp Policy, which stated that the Canadian portion of all international bridges would ultimately revert to public ownership. The Canadian government attempted to use this policy to force the Canadian Transit Company, the wholly owned Canadian subsidiary of the Detroit International Bridge Company, to sell their Canadian assets under auspices of foreign ownership laws. The Canadian government settled the case a decade later in return for upgrades to the Canadian customs plaza. Subsequent discussions to purchase the bridge by the Windsor Harbor Commission and the Government of Canada subsided without any results. The DIBC and the Canadian Transit Company have been involved in litigation with governments on both sides of the border almost continuously since 1979 and the cases have covered the gamut, including racketeering, contempt of government, land use disputes and NAFTA claims.

The first significant effort to build a new crossing was initiated in the early 1990s by The Mich-Can International Bridge Company, which was headed by past presidents of the

Detroit Canada Tunnel Corporation and the Canadian Transit Company. They determined that the only suitable sites for anchoring a new crossing was Brighton Beach, a derelict suburb turned industrial site in Windsor, and land across the Detroit River owned by the Detroit Coke Company, the principal supplier of coke to the Ford Motor Company (Clarke, 2013). This point of the river is narrow and provides relatively easy access to the US interstate highway system as well as Canada's 400-series highway system. The proposal had strong momentum, but a legislative barrier to financing the bridge motivated by Moroun's political influence brought the project to a halt in 1994. However, increased trade and traffic during the 1990s made a new crossing seem inevitable.

The effects of NAFTA on cross-border trade were substantial. NAFTA coincided with the introduction of just-in-time delivery systems for manufacturing processes during the 1990s, which increased the pressure on commercial transportation networks in the heavily industrialized regions surrounding the Windsor-Detroit Gateway (Tofflemire, 2009). The infamous 'NAFTA Superhighway' never materialized, but as traffic volumes increased along with wait times at the Windsor-Detroit border throughout the late 1990s, it became clear that additional capacity would be needed.

Canadian and American authorities have considered several alternatives to improve the Windsor-Detroit crossing. The Canadian government's proposal for a new bridge contends with the idea of twinning the privately held Ambassador Bridge. These projects draw on foundational differences between the two neighbours. Whether Liberal, Conservative or New Democratic parties govern, federally or provincially, Canadian administrations turn readily to Keynesian instruments for infrastructure improvements and stimulus to employment. In the US, such policies are more problematic historically, particularly when Republicans govern. The owner of the Ambassador Bridge, a financial backer of agreeable legislators on both sides of the aisle in Michigan, has proceeded aggressively to protect his private interests. On the Canadian side of the Detroit River, this includes assembling property in Sandwich and adjacent to the bridge for a twin bridge without the necessary permits from the Canadian government (Bennett, 2011). Ground to create a new access ramp for truck traffic on the Canadian side of the Ambassador Bridge has already been broken, and ramps on the American side for a twinned bridge are waiting for a span that will never come. Millions of dollars were spent on media campaigns in Michigan against the new, publicly owned bridge. Lawsuits have been filed against different levels of governments on both sides of the border (Battagello, 2013).

Hazarding the possibility that their Detroit River International Crossing through Brighton Beach might be a ‘bridge to nowhere,’ Canadian governments have pursued their preferred alternative to a privately owned bridge, using the rights of the Crown to expropriate lands required for their preferred access route to the crossing (Figure 2.4). While the City of Windsor, along with community groups and private interests such as the automakers, have also been important players in debates over a new crossing, it is difficult to tell if contemporary strides of globalization are continuing to leave Windsor behind. Windsor’s exclusion from the DRIC ‘Partnership,’ which included Transport Canada, Ministry of Transportation Ontario, US Federal Highway Administration and the Michigan Department of Transportation, certainly suggests its reduced prominence as a stakeholder in this crucial node of the North American trade and transportation network.

The City of Windsor's proposal of an outrageously expensive alternative to the Partnership plans, known as 'GreenLink Windsor,' casts suspicion on the balance of power and the ability of the city to guide the form of its own local environment (Stang, 2007).

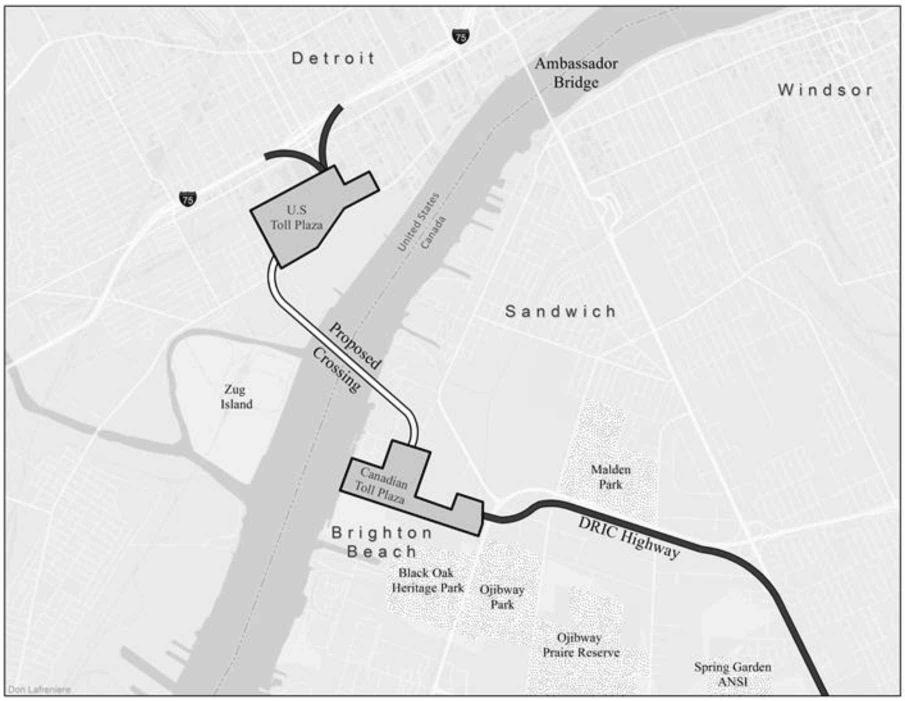

Figure 2.5 - Map showing proposed location of new crossing and parkway through Windsor

2.5 Conclusion

This front line of trade, once a national frontier, has persistently felt the pain and gain of being an environment of mobility. First, prospering from its situational advantage as the primary trading post for the emerging markets of the British North American colonies and the needs of its growing American neighbour, the communities of Sandwich and

Brighton Beach are now at the mercy of trans-boundary politics. While Brighton Beach will almost certainly be all but paved over for the new bridge plaza, Sandwich will find itself cleaved, once again, by the need to facilitate exchanges between society and nature. In so far as Windsor grew and thrived because it was on an international border, this formerly advantageous geopolitical locale has now, perhaps, become a destructive burden – a borderland where a borderless economy takes precedence over the land. As the city was trying to adjust and cope with the local influences of changing trans-national tariffs and political agendas, the world started moving through, rather than in and out of, Windsor. The impending border crossing megaproject may further intensify this marginal position, as well as reshape the boundaries of Sandwich, an already socially, political and economically fragile community. Undoubtedly, Windsor will continue to be defined as a borderland, but as international boundaries take on different meanings, so will the future of this Canadian environment of mobility.

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CHAPTER THREE

3. COMBINED EFFECTS OF AIR POLLUTION AND TRAFFIC NOISE ON NOISE ANNOYANCE AND THE MEDIATING ROLE OF ODOURS AND NOISE SENSITIVITY

The health risks of traffic noise and air pollution in urban environments are cumulative. Motor vehicles are a significant and often the dominant source of both types of pollution, which have been linked to health outcomes of physiological and psychological stress. This study addresses three significant knowledge gaps on these issues in environmental health. Firstly, previous research suggests that there may be cumulative effects of air pollution and traffic noise on environmental annoyances as well as cardiovascular disease outcomes, and there is uncertainty in how particular characteristics of the physical environment can moderate these effects. Secondly, psychological effects of ambient stressors include noise annoyance, which can confound cumulative exposure effects on disease outcomes, and there is uncertainty in how co-exposure and subjective responses to both traffic noise and air pollution affect levels of noise annoyance. Lastly, annoyance can be conceptualized as an outcome of appraising environmental stressors, and previous research shows that this is a sociocultural process. Noise sensitivity is an important determinant of appraisal, but previous research has not investigated the effects of sociocultural and environmental context on noise sensitivity.

3.1 Introduction

There are different definitions of noise annoyance and odour annoyance, but the most common view of both is that they are indicators of nuisance, disturbance or disruption to intended or actual activities (Griffiths, 2014; Guski et al., 1999). Previous research has identified dose-dependent and cumulative effects of air pollution and traffic noise on annoyances as well as cardiovascular disease (CVD) outcomes (e.g., Gan et al., 2012; Klaeboe et al., 2000); therefore it is important to gain a clear understanding of potential interaction effects of cumulative exposures. One particular uncertainty that impedes a clear understanding on this topic is the potentially moderating effects of air pollution and associated levels of odour annoyance on the dose-response relationship between traffic noise and noise annoyance. Previous research shows that there are additive effects of exposure to traffic noise and outdoor air pollution on noise and odour annoyances (Klaeboe et al., 2000), but it is not known how additive effects are influenced by environmental context, or place, or if there are multiplicative effects of co-exposure. Place and environmental context in this instance refers to the unique combination of physical characteristics that influence exposure and sociocultural characteristics that may influence environmental perceptions in different communities.

Understanding how the physical environment influences cumulative exposures and consequently health can aid environmental management to reduce health risks. Noise annoyance is of particular concern because it is associated with a number of health related outcomes such as cognitive impairment, sleep disturbance and behavioural change, and may also moderate CVD outcomes (Moudon, 2009; Babisch et al., 2013). If higher levels of odour annoyance increase noise annoyance, such health effects may also be exacerbated when people are exposed to high levels of both traffic noise and air pollution. Furthermore, the moderating effects of noise annoyance on CVD may be confounded when people are also exposed to high levels of malodorous air pollutants. Figure 3.1 provides a conceptual model for the cumulative effects of air pollution and traffic noise, drawing attention to the influence of the physical environment on cumulative exposures. The model distinguishes physiological responses (e.g., effects of air pollution respiratory and cardiovascular system) from psychological responses (e.g., disturbance to activities and nuisance) to multiple exposures to highlight the challenges of estimating health risks. The conceptual model in Figure 3.1 is put in the perspective of this study, which seeks to understand how environmental perceptions and annoyance are affected by combined exposure to ambient air pollution and traffic noise.

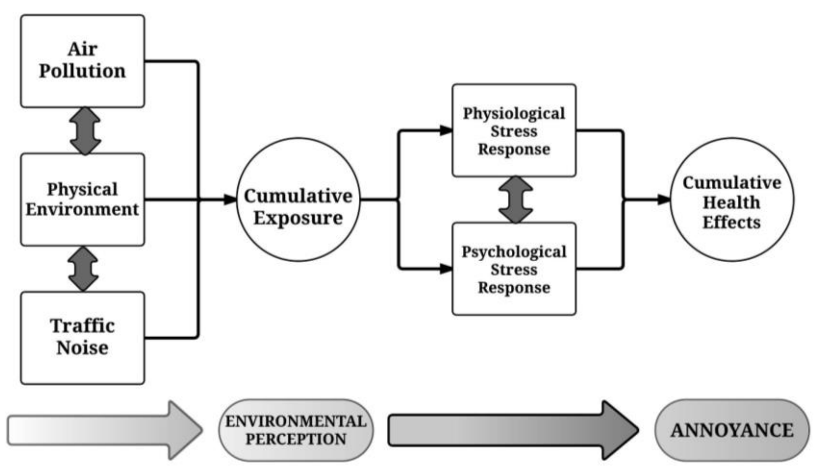


Figure 3.1 - Theoretical model of health effects of cumulative exposure to traffic noise and air pollution

Understanding cumulative health effects of multiple exposures requires a better understanding of the relationship between physiological and psychological responses to ambient stressors. No research to date has examined how physiological and psychological responses interact while controlling for both traffic noise and air quality, and previous research on this relationship provides mixed results. Ndrepepa and Twardella (2011) found a significant effect of noise annoyance on arterial hypertension, but not ischemic heart disease, in a meta-analysis of nine studies with various research designs that did not control for noise level. Babisch et al. (2013) observed a significant interaction between aircraft noise level and annoyance in predicting hypertension prevalence, but did not observe an interaction effect from traffic noise and annoyance. The authors conclude that because the effect of objective noise responses (i.e., involuntary arousals of the sympathetic nervous system) is stronger than the subjective noise response, annoyance may function as an effect modifier. However, Fyhri et al. (2009) argue that the association between noise exposure, noise annoyance and hypertension may be a spurious relationship mediated by noise sensitivity.

Noise sensitivity is predominantly conceptualized as an invariant personality trait based on empirical research linking self-reported levels of sensitivity to other emotional traits, and its apparent stability over time and place (Miedema and Vos, 2003). Reactions to noise are stronger among noise sensitive individuals and levels of sensitivity are not associated with perceived loudness or noise exposure. However, there is no clear conceptual definition as sensitivity is not a unitary concept (Job, 1999). For example, people can have different sensitivities to loud and quiet noises. Miedema and Vos (2003) suggest that sensitivity is related to a general dissatisfaction with the environment and the perceived existence of a wide range of local environmental problems. Job (1999) proposes a definition of noise sensitivity as an outcome of ‘internal states’ that increase the degree of reactivity to noise in general. Such ‘internal states’ are then linked to numerous components that include risk perception of the noise source, the existence of other ambient stressors, coping resources, hearing acuity, all of which are distinguished as a physiological or psychological reactivity.

Consequently, noise sensitivity may be more usefully conceptualized as a compositional indicator of multiple factors that moderate that relationship between ambient stressors and annoyance, and as such dependent on community and individual contexts. To our knowledge no research to date has demonstrated that environmental context can influence noise sensitivity. However, Job’s definition of noise sensitivity and demonstrable effects of environmental contexts such as proximity to green areas on noise annoyance suggest that this is plausible (Gidlof-Gunnarsson and Ohrstrom, 2007; Li et al., 2012). Klaeboe (2005) showed that neighbourhood soundscapes (i.e., real-time perceptions of sound) can affect residential noise annoyance among people exposed to similar sound levels at home, which lends further support to noise sensitivity as a compositional indicator of community and individual determinants of annoyance (Figure 3.2). Therefore, the treatment of annoyance and sensitivity in community noise research and the conventional understanding of their relation to noise exposure deserve further examination (Schomer et al., 2013). While noise sensitivity remains a somewhat clouded concept, the current knowledge on noise annoyance is based on decades of meticulous research.

The noise annoyance dose-response curves estimated by Schultz (1978) and more recently Miedema et al. (2001) were based on comparing annoyance survey data and monitored noise levels from a multitude of cities. However, as their data suggests, noise annoyance varies considerably in different communities with similar noise levels (Fidell, 2003). As an alternative to fitting dose-response curves to data on annoyance and exposure, Fidell et al. (2011) proposed a first-principles model from a priori determinants of noise annoyance for estimating its prevalence by fitting noise survey data to an exponential function. The 'effective loudness function' estimates the community tolerance level (CTL) to noise based on a hypothesized relationship between noise exposure, its perceived loudness, and the percentage of people highly annoyed (%HA) at different levels of noise (described in more detail in Methods).

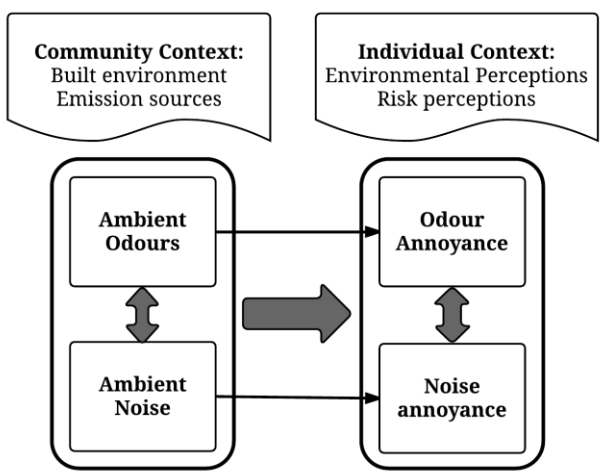


Figure 3.2 - Conceptual model of noise sensitivity as a compositional indicator of the ability to cope with ambient stressors

The CTL is determined by minimizing the difference between the observed %HA and the %HA predicted by the effective loudness function at different levels of noise exposure. This is accomplished iteratively by moving the effective loudness function along the noise exposure axis to a point where differences between observed and predicted levels of annoyance are minimal. The CTL is represented by the noise level at which 50 percent of the sample is highly annoyed. Schomer et al. (2012) found that the average day-night level (DNL) of traffic noise at which 50 percent of people are highly annoyed is 78 dB(A), and that this CTL can differ notably between communities. They attribute this difference to non-acoustic factors, or what we refer to as place effects. Therefore, the CTL can be interpreted as a measure of place effects on noise sensitivity and consequently annoyance.

Other variables that relate to place and are well documented as influential on annoyance include fear of danger from the noise source and importance attributed to the noise source (Fields, 1993; Fyhri et al., 2009; Miedema and Vos, 1999). Acknowledging the influence of environmental context on human reactions to environmental noise is central to the soundscape perspective. This can help advance the field of noise research from a traditional framework concerned with unwanted sound and minimally acceptable health risks to a research agenda framed around the promotion of health and quality of life (Schomer et al., 2013). The soundscape perspective considers noise exposure as one of many influences on noise perception, or the individual soundscape, which is a person's real-time perception of their sonic environment. With respect to environmental health it is important to understand how soundscapes are affected by exposures to other ambient stressors such as air pollution. To this end, previous research has also demonstrated dose-response relationships between common air pollutants and odour annoyance that includes concentrations well below most regulatory guidelines (Atari et al., 2012; Forsberg et al., 1997; Klaeboe et al., 2008). Taken together with the soundscape perspective and previously demonstrated noise annoyance dose-responses, this suggests that there may be an interaction effect between noise and odours on noise annoyance and that the absolute level of noise annoyance depend on environmental context.

3.2 Methods

3.2.1 *Objectives and study context*

This study investigated how environmental context can influence the association between traffic noise and noise annoyance. Of particular interest were how characteristics of the physical environment can confound cumulative effects of multiple exposures to noise and air pollution on noise annoyance and the role of odour annoyance and noise sensitivity in mediating such effects. For this purpose, two areas in Windsor, Ontario, Canada were sampled for a community survey, which was complemented by exposure assessment for air pollution and traffic noise. These areas included residential areas surrounding a border crossing and access infrastructure (the corridor area) and a ‘control area’ that was also located in Windsor, but not in the vicinity of the border access and crossing infrastructure (Figure 3.3). The two areas we compared provided an opportunity to study annoyance in an unconventional setting as most environmental noise research is conducted in large cities with high levels of noise (Schomer et al., 2013).

Windsor, Ontario, Canada is located on the United States – Canada border and along the Detroit River. The city covers approximately 146 km^2 and has a population of 210, 891 (Statistics Canada, 2012). It is ranked 23rd in Canada by population and as such is a medium sized city characterized by urban forms commonly observed in cities throughout North America with the exception of a major traffic corridor that provides access to the main border crossing. Medium- and low-density residential and commercial areas surround the central business district and commercial arteries transect the urban area. The E.C. Row Expressway is a busy east-west corridor for commercial transportation to industrial facilities in the city's east end and passenger traffic across the city. The Expressway also provides an important access route within the city to the Ambassador Bridge in the western neighbourhood of Sandwich, which along with the Detroit-Windsor Tunnel crossing in central Windsor provide vehicle access to the international border and Detroit, Michigan.

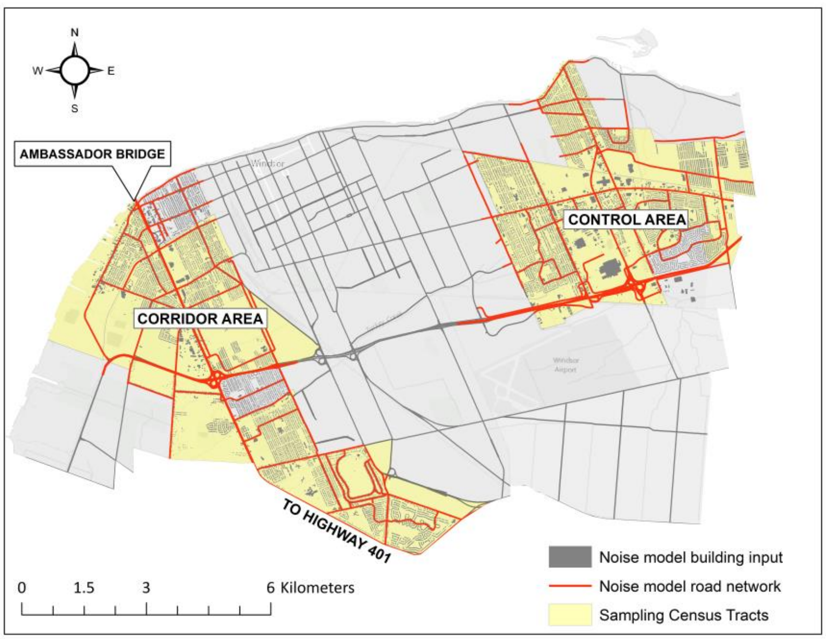


Figure 3.3 - Sampling areas, road network and buildings for noise model in Windsor, Ontario

The Ambassador Bridge is the busiest border crossing in North America. High volumes of truck traffic during the day and night characterize the main access route from Highway 401 along Highway 3 and Huron Church Road. The majority of commercial trips through this corridor and across the border originate outside Windsor, while most of the passenger border traffic originates in the city (DRIC Study, 2004).

Work to upgrade the access route from Highway 401 to the Ambassador Bridge is underway, but at the time of this study border traffic originating outside Windsor passed through the city on a signal-controlled thoroughfare in the immediate vicinity of residential and commercial areas. Stop-and-go traffic and slower speeds due to the traffic signals leads to high noise and air emissions in this area of Windsor and the busy border crossing results in a pollution hotspot near the Ambassador Bridge. Previous land use regression (LUR) analyses of pollution distributions in Windsor found that the distance to the Ambassador Bridge was a strong predictor of NO_2 and sulphur dioxide (Luginaah et al., 2006; Wheeler et al., 2008). Additionally, previous noise mapping of the border corridor showed that traffic along Huron Church Road, which is the main access road to the bridge crossing, has a significant impact on noise levels in the surrounding neighbourhoods (Novak et al., 2009). Effects of air pollution on health have also been observed, with increased rates of cardiac hospitalization from short-term increases in ambient concentrations, and increased levels of respiratory hospitalizations in the months following 9/11 when heightened security measures resulted in exceptionally long crossing queues (Fung et al., 2005; Luginaah et al., 2006a).

3.2.2 *Data collection and analysis*

The overall analytical strategy was to model the cumulative effects of residential traffic noise and air pollution on noise annoyance, and furthermore determine if the steeper gradient of poor air quality towards the Ambassador Bridge pollution hotspot in the corridor area influenced the cumulative effect of traffic noise and air pollution on noise annoyance. An additional goal was to test if odour annoyance and noise sensitivity confound the effects of ambient exposures on noise annoyance, and if this confounding could be attributed to place effects. This required the use of multiple methods to collect and analyze joint spatial and survey data.

3.2.2.1 *Traffic noise assessment*

Average 24-hour (DNL), daytime ($L_{eq,\ Day}$) and nighttime ($L_{eq,\ Night}$) residential traffic noise levels were estimated on the most exposed façade for all buildings including the residences of study participants in the study areas (SoundPLAN GmbH, Backnang, Germany). Traffic noise emissions, attenuation and propagation were based on the United States Federal Highway Administration Traffic Noise Model (TNM 2.5) and the International Organization for Standardization calculation method (ISO 9613-2). Traffic volume data on passenger and commercial vehicles for the border access route from Highway 401 to the Ambassador Bridge were weighted by weekday to weekend ratios and based on City of Windsor intersection counts, the US Bureau of Transportation Statistics, Transport Canada, the Detroit River International Crossing Study and hourly counts from video cameras provided by the Ontario Ministry of Transportation in 2009 (Nameghi et al., 2013). Traffic counts for the remainder of the modeling system were Average Daily Traffic (ADT) counts conducted by the City of Windsor between 2005 and 2013. Traffic was categorized according to light, medium and heavy vehicles as required for TNM2.5 and by volumes during the day (0700-2200) and night. Other inputs to the noise model included a standard ground attenuation coefficient, road width and surface material as well as speed limits.

Environmental inputs were prepared in ArcGIS 10.2 (Esri, Redlands, USA) and included building footprints with estimated heights from the City of Windsor and a Digital Ground Model (Ontario Ministry of Natural Resources) for road gradients (Figure 3.1). Screening and elevation effects for the Ambassador Bridge were manually input to noise model. Road network and data files were prepared from DMTI *CanMap* Streetfiles (2012; DMTI Spatial Inc., Markham, Canada). The final noise model was validated by comparison to previous noise mapping in the area based on monitoring and modeling (Novak et al., 2009). Finally, the assessed DNL on the most exposed façade of participant residences was categorized according to previous research findings and regulatory guidelines. Participants with assessed DNL below 45 dB(A) were used as the reference group as this is generally considered the level of background noise in urban areas. The ordinal variable allowed comparison of this group to residents exposed to low (45-55), medium (55-65) and high (65+) DNL. The World Health Organization recommends that noise exposure be limited to a DNL of 55, which corresponds to regulatory guidelines in Ontario, and significant effects on cardiovascular health are observed above 65 dB(A) (Babisch, 2008).

3.2.2.2 *Air pollution assessment*

Residential exposures to NO_2 were estimated with a land use regression model and the general methodology is described in detail elsewhere (Hoek et al., 2008; Oiamo et al., 2012). This method has been employed to estimate air pollution exposure in other studies on the effects of noise and air pollution (Beelen et al., 2009; Gan et al., 2012). Previous LUR analyses on the spatial distribution of NO_2 in Windsor, based on a single monitoring campaign during the winter of 2004 showed a strong and positive concentration gradient towards the Ambassador Bridge, as well as higher concentrations in proximity to arterial roads, industrial land uses and population density (Luginaah et al., 2006). Subsequent studies included monitoring data for all four seasons in 2005 (February, May, August and October) and showed that annual average NO_2 concentrations from 54 sites were also predicted by distance to the Ambassador Bridge as well as industrial point sources and proximity to highways and major roads. Furthermore, the aspatial distribution of NO_2 was significantly correlated to sulphur dioxide, benzene and toluene (Wheeler et al. 2008).

3.2.2.3 *Community survey*

Eight census tracts in the control area were chosen for sampling based on similar population and building densities found in eight census tracts surrounding the border access corridor (Figure 1). Survey samples were drawn at random from these census tracts and questionnaires were administered through a web-based system and by phone interviews, which had a 34% response rate during the spring and early summer of 2013 (n=610). The study received ethical approval from the University of Western Ontario and the University of Windsor. Levels of noise and odour annoyance were assessed and compared on an 11-point rating scale to the questions “what number from 0 (no disturbance) to 10 (intolerable disturbance) best represents how much you are bothered, disturbed or annoyed by road traffic noise at home?” and “on a scale of 0-10 how much are you annoyed by odours from traffic or industry at home?" (Fields et al., 2001). An additional question asked participants to rate traffic noise as not annoying, somewhat annoying or highly annoying outside their dwelling, and responses to this item were used as the dependent variable for the multivariate analysis (Klaeboe et al., 2004). Participants were asked if they were highly, somewhat or not sensitive to noise. Previous research also suggests that both noise sensitivity and noise annoyance are influenced by perceptions of risk associated with the noise source (Miedema and Vos 2003; Job, 1999), therefore we included a dichotomous response (yes/no) question "do you believe that air pollution from traffic is causing health problems in your community?" The survey collected demographic and socioeconomic information about the participants, including gender, age and area social and material deprivation, which was assigned to each participant based on their Dissemination Area (DA) of residence. The Canadian Institutes for Health Information created the deprivation index based on the 2006 Census and assigned DAs to quintiles of social and material deprivation measured at the Census Metropolitan Area level (CIHI, 2011).

3.2.2.4 *Statistical analyses*

A geographic information system was used to assign noise and air pollution exposure estimates to survey respondents based on their home address, and data were analyzed with IBM SPSS 20 (IBM Corporation, Armonk, NY, USA). A binary variable representing participants sampled from the corridor versus the control area was also used in the analyses. Descriptive statistics and bivariate analysis were utilized to analyze sample characteristics for the full sample and study areas. \

Potential differences in the noise annoyance dose-response between the two study areas were examined by fitting the survey data separately to the ‘effective loudness function’ ($e^{-(A/m)}$) (Schomer et al., 2012), where A and m are parameters representing non-acoustic effects on annoyance and the estimated noise dose, respectively. The loudness function is based on previous research demonstrating that the dose-response is represented well by the asymptotic exponential function, and the established model for perceived loudness as doubling with a 10 dB change in sound level [$(^{10L/10)0.3}$] is used to estimate the loudness dose from DNL [m= $(10^{DNL/10)0.3}$] (Schomer et al., 2012). The parameter A, hypothesized to be a community-specific constant, is determined iteratively by minimizing the least square difference (root mean square error [RMSE]) between the %HA predicted by the loudness function and the observed %HA at different noise levels. This parameter is expressed as DNL and termed the CTL, at which 50% of the community reports being highly annoyed (Fidell et al., 2011).

A series of heterogeneous choice, or location-scale ordinal regression models (SPSS PLUM procedure) were used to predict noise annoyance. The estimation of regression coefficients for the independent variables DNL, NO_2, odour annoyance, noise sensitivity and control variables is referred to as the location model. Ordinal regression is preferred over binary logistic regression since the noise annoyance dose-response is well established (Schultz, 1977; Miedema and Oudshoorn, 2001). Scale models estimate differences in the residual variance of generalized linear model (GLM) predictions for different groups within the sample (Williams, 2009). This provided an opportunity to assess if the error in predicting noise annoyance based on noise and air pollution differed in the study areas.

In this study then, the scale model was utilized to examine if differences in the physical environment of the corridor and control areas that affect cumulative exposures to air pollution and traffic noise had a significant effect on the prediction of noise annoyance. In other words, the scale model tested if the presence of the border infrastructure in the corridor area confounded the prediction of noise annoyance. The following models estimated the effects of location and scale parameters on noise annoyance in Windsor: Model 1 tested the direct effects of noise exposure; Model 2 tested the conditional and interacting effects of traffic noise and NO_2; Model 3 and 4 controlled for the confounding effects of odour annoyance and noise sensitivity, respectively, and Model 5 controlled for cumulative exposures, odour annoyance and noise sensitivity in a stratified sample based on place of residence in the corridor or control area. All models were adjusted for sex, age and area deprivation.

3.3 Results

3.3.1 *Residential traffic noise and NO_2 exposure assessment*

The average 24-hour sound level (DNL) on the most exposed facade for all residences in the study areas was 53.3 dB(A). However, sound levels in the corridor were notably affected by the border crossing and access facilities with an average residential DNL of 55.1 dB(A) (n=16360) compared to 50.9 dB(A) (n=12211) in the control area. The significant difference was primarily due to average night-time levels of 41.4 dB(A) in the control area compared to 46.6 dB(A) in the corridor, while the average day-time sound level was 49.6 dB(A) in the control area and 52.8 dB(A) in the corridor. Figure 3.4 shows that the higher levels of residential noise are concentrated along the border access and crossing infrastructure, the E.C. Row Expressway and busy thoroughfares. Although the E.C. Row Expressway appears to have a high impact on noise levels in the two study areas, very few residents in the study sample were in close proximity to this facility. Assessed residential exposures for study participants corresponded well to the overall study area noise levels. The only significant difference between area and participant levels of traffic noise was observed for Lnight facade exposures in the corridor, which was slightly higher at 47.6 dB(A).

Modeled DNL and NO_2 concentrations at participant residences were normally distributed with few outliers. Figure 3.5 shows that higher levels of NO_2 characterize areas near the Ambassador Bridge, as well as areas surrounding the major traffic arteries and industrial sources throughout the city. Correlations between residential levels of traffic noise (Day, Night, DNL) and NO_2 were statistically significant and the correlation coefficients ranged from 0.25 to 0.33 in the full sample and were higher for participants in the control area compared to the corridor area (Table 3.1). Estimated residential levels of air pollution and traffic noise for the study participants are described in Table 3.2, which shows that on average participants in the corridor area were exposed to significantly higher levels of both traffic noise and NO_2.

Table 3.1 - Correlation coefficients for DNL, NO2, and annoyances

	Control		**Corridor**		**Full Sample**	
	DNL	NO_2	DNL	NO_2	DNL	NO_2
DNL dB(A)	--	0.23**	--	0.16*	--	0.30**
Leq, Day (06-22)	--	0.21*	--	0.15*	--	0.25*
Leq, Night (22-06)	--	0.25**	--	0.17*	--	0.33**
Noise Annoyance	0.17**	0.07	0.12*	-0.15*	0.19**	0.06
Odour Annoyance	0.15**	0.14**	0.07	0.13*	0.12**	0.22**

*$p<0.05$, **$p<0.01$, ***$p<0.001$

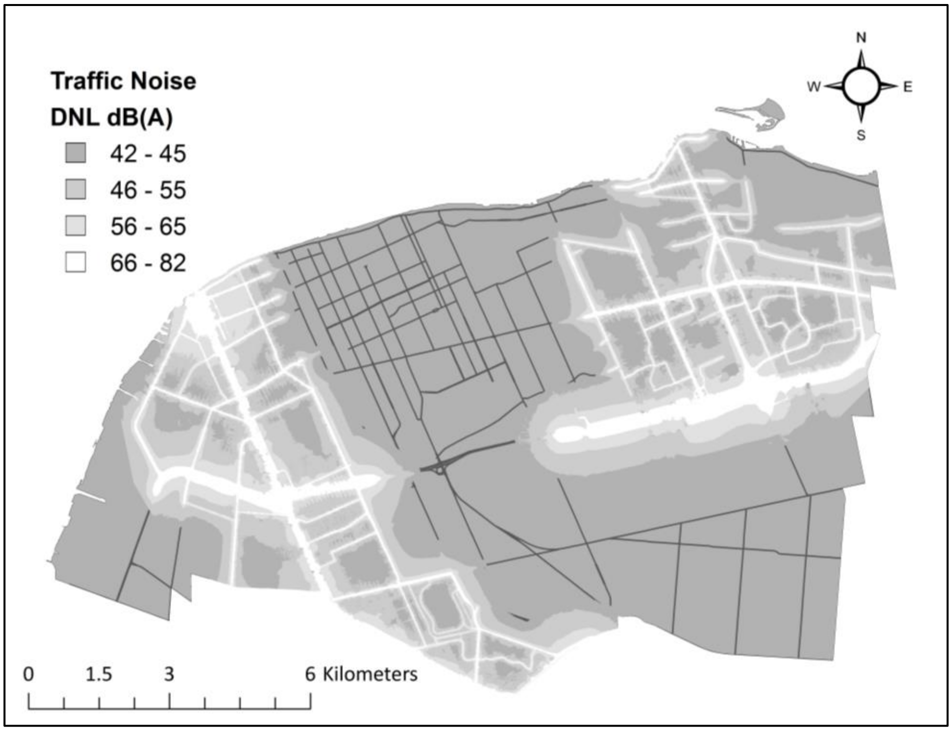


Figure 3.4 - Estimated spatial distribution of traffic noise based on emission and dispersion modelling

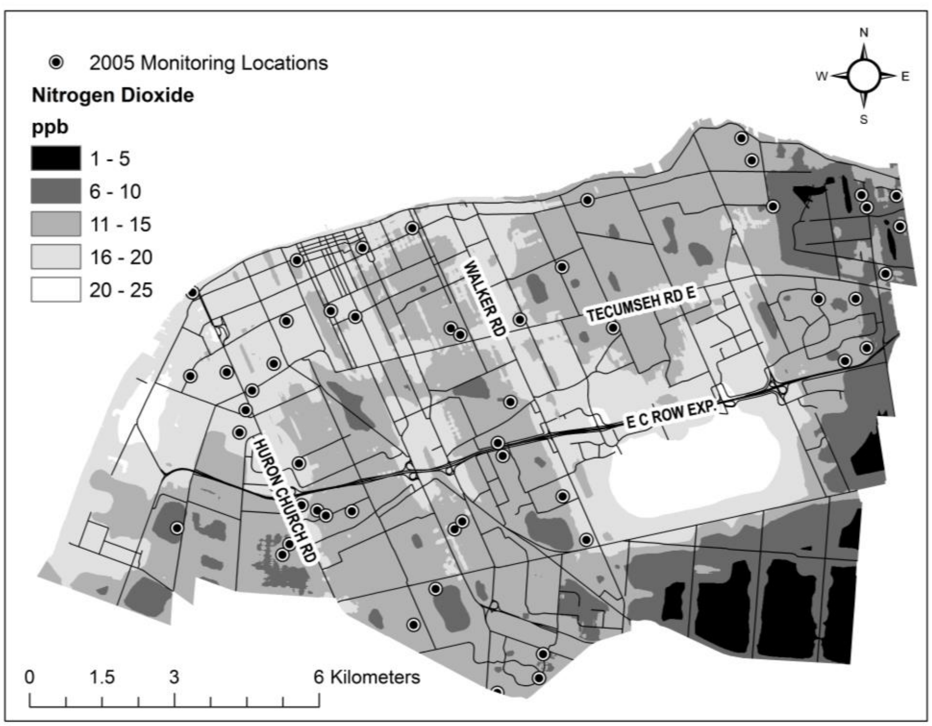


Figure 3.5 - Estimated spatial distribution of nitrogen dioxide based on land use regression modelling

Table 3.2 - Descriptive and bivariate statistics for survey responses

Variable	Response	**Control (n=267)**	**Corridor (n=343)**	**Full Sample (n=610)**
Noise Annoyance[a] (%)	Not annoying	62.7	46.8	55.7
	Somewhat annoying	30.0	37.1	33.1
	Highly annoying	7.3	16.1	11.1
Noise Annoyance (0-10)	Mean	3.0	4.0	3.5
	SD	2.6	2.9	2.8
	25th percentile	1	2	1
	75th percentile	5	7	5
Odour Annoyance [b] (0-10)	Mean	2.7	3.9	3.2
	SD	2.6	3.1	2.9
	25th percentile	1	1	1
	75th percentile	4	6	5
Noise Sensitivity (%)	Not sensitive	51.6	46.4	49.3
	Somewhat sensitive	37.6	45.7	41.1
	Highly sensitive	10.8	7.9	9.5
Pollution Risk (%)	Yes	62.7	72.7	67.0
	No	33.3	27.3	33.0
Sex	Male	39.7	40.8	40.2
	Female	60.3	59.2	59.8
Age (years) [c]	Mean	52.8	49.9	51.6
	SD	14.4	15.4	14.9
Area Deprivation[d] (%)	1st Quintile	10.2	20.6	14.8
	2nd Quintile	37.9	19.5	29.8
	3rd Quintile	14.6	13.9	14.3
	4th Quintile	18.7	16.9	17.9
	5th Quintile	18.7	29.2	23.3
DNL dB(A)[e] (%)	<= 45	33.5	3.4	20.3
	45 - 55	34.1	47.6	40.0
	55 - 65	21.9	31.1	25.9
	65 +	10.5	18.0	13.8
NO_2 (ppb)[f]	Mean	12.98	15.19	13.95
	SD	2.39	1.93	2.46
	25th percentile	11.50	13.65	12.36
	75th percentile	14.51	16.50	15.76

Test of difference between corridor and control areas:
[a](χ^2=19.50***); [b](U=35705.5***); [c](t=2.43*); [d](χ^2=35.59***); [e](χ^2=102.81***); [f](t=12.34***)
*$p<0.05$, **p<0.01, ***p<0.001

3.3.2 ***Survey results and subjective responses***

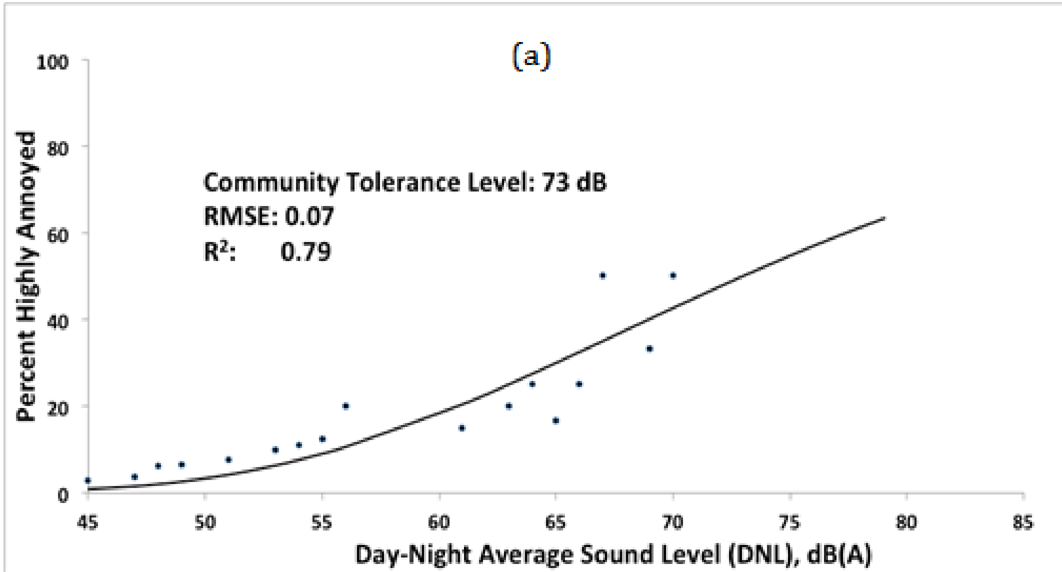
Table 3.2 shows the descriptive statistics for survey responses on levels of annoyance and noise sensitivity as well as *a priori* covariates. Females were slightly over-represented in the full sample, but no differences were observed between the study areas. The mean age of respondents in the control area was slightly but significantly higher at 52.8 compared to 49.9 in the corridor. The 2011 Census median age in Windsor was 40.1, compared to 51.0 for the study sample and as such the results should be interpreted with caution, although previous research has not observed a strong effect of age on noise annoyance (Klaeboe et al., 2004; Statistics Canada, 2012). Bivariate analyses showed that a significantly higher proportion of respondents in the corridor resided in DAs classified with higher levels of social and material deprivation.

Analysis of the survey data on subjective responses and their associations with noise and air quality also demonstrated differences between the corridor and control area. Levels of noise annoyance and odour annoyance were significantly higher in the corridor area, but there was no significant difference in noise sensitivity overall or pollution risk perception between the study areas. There was a stronger association between noise annoyance and odour annoyance in the corridor (Spearman $r = 0.45$, $p<0.01$) than the control area ($r = 0.37$, $p<0.01$) and these measures exhibited significant associations with risk perception and noise sensitivity in both areas. Higher noise levels and NO_2 concentrations were not associated with higher levels of noise sensitivity.

Correlations between annoyances and exposures were stronger in the control area (Table 1). Odour annoyance was positively correlated to estimates of residential NO_2

concentrations for all participants, and also with DNL in the control area and full sample. There was a significant positive correlation between noise annoyance and DNL in both study areas, but a significant negative correlation was observed with NO_2 in the corridor. This was due to a negative noise annoyance gradient and positive NO_2 gradient towards the Ambassador Bridge and along its access corridor. The correlation between noise annoyance and DNL was stronger in the control area and full sample.

Further analysis of the noise annoyance by estimation of CTLs suggested that different environmental contexts in the corridor and control areas influenced the dose-response relationship between traffic noise and annoyance. Fitting the survey data to the effective loudness function demonstrated consistency between the observed traffic noise and annoyance levels for the control sample and the dose-response curve proposed by Fiddell et al. (2011) (Figure 3.6a). The estimated CTL of 73 dB(A) based on the lowest RMSE (0.07) for the control sample had a R^2 value of 0.79. This implied that 50% of the control sample was highly annoyed by residential traffic noise levels at 73 dB(A). Conversely, the poor fit of the corridor survey data indicated that there was not a consistent dose-dependent relationship between %HA and traffic noise among residents living near the border access infrastructure (Figure 3.6b).



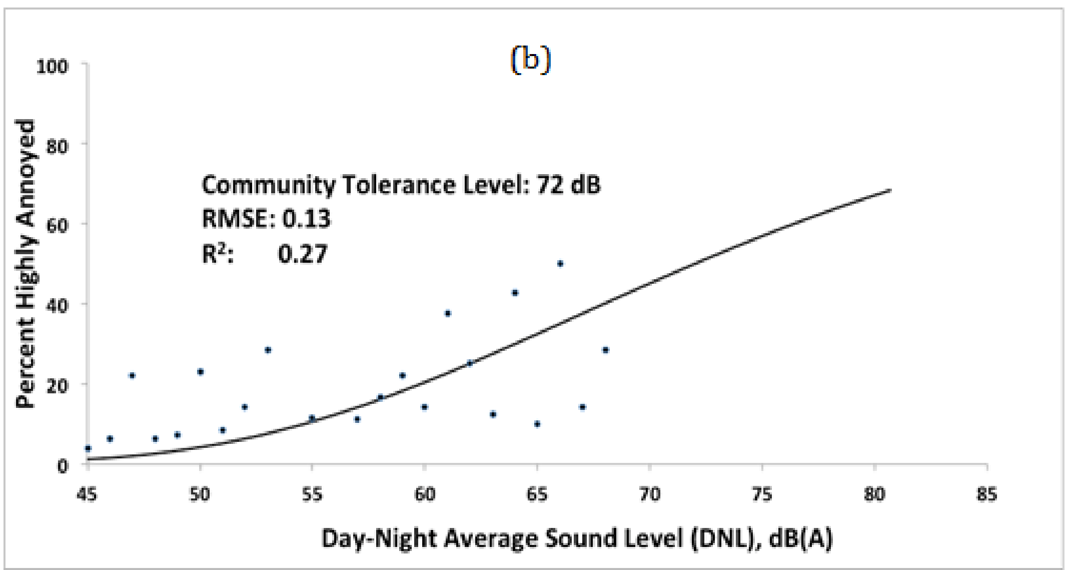


Figure 3.6 - Best fits for survey data on high annoyance to effective loudness function in control area (a) and corridor (b).

3.3.3 *Ordinal Regression Models for Noise Annoyance*

The ordinal logit model for effects of residential traffic noise levels on noise annoyance demonstrated a dose-response (Table 3; Model 1). Specifically, people exposed to low, medium and high levels of noise were 1.51 (*p=0.09)*, 1.91 ($p<0.05$) and 3.14 ($p<0.001$) times more likely to report higher levels of annoyance than residents exposed to background levels of noise, respectively. The scale parameter suggested that the residual variance of predicted levels of noise annoyance for respondents in the corridor area was 1.25 times higher, but the error in predicting noise annoyance with noise alone was not significant different in the two study areas ($p<0.056$). The estimates of location parameters without scaling them to the residual variance of predicted levels of noise annoyance in the two study areas are not shown, but the results showed a stronger effect of traffic noise. This corroborated the results of fitting levels of noise annoyance to the effective loudness function and a confounding effect of the environmental context in the corridor area. Model 2 demonstrated that the environmental context was related to air pollution.

Model 2 controlled for NO_2 and the interaction between NO_2 and traffic noise. Only respondents in the high noise category (DNL 65+) were significantly more likely (Odds Ratio [OR]: 2.22, $p<0.05$) to report higher levels of annoyance when effects of air pollution were controlled. The interaction term suggested that the effect of NO_2 on noise annoyance differed among respondents exposed to different levels of traffic noise. Specifically, the effect of NO_2 on noise annoyance was significantly lower for respondents exposed to medium (DNL 55-65) noise levels compared to respondents with background levels of noise (DNL <=45). Alternatively, the results of the interaction in Model 2 can be interpreted as a significantly stronger effect of NO_2 on noise annoyance for respondents in the reference (low) noise exposure group. The scale parameter in Model 2 shows that that the standard deviation of the residual variance in the corridor was 28% (p<0.05) higher for residents in the corridor. This confirms that the influence of the physical environment on cumulative exposures in the corridor area confounded the effect of noise exposure on noise annoyance.

Table 3.3 - Ordinal regression location-scale models for noise annoyance

	Model 1: DNL	Model 2: DNL + NO_2 +(DNL*NO_2)	Model 3: Model 2+Odour Annoyance	Model 4: model 3+ Noise sensitivity	
Parameter Estimates	**Exp(B)**	**Exp(B)**	**Exp(B)**	**Exp(B)**	**B (95%CI)**
Threshold					
Somewhat annoying	2.27*	1.90	2.59*	4.44**	
Highly Annoying	20.43***	17.90***	26.52***	49.55***	
Location					
DNL (Reference:DNL <45 dB(A))					
Low (45-55)	1.51	1.12	0.66	0.54	-0.62 (-1.45-0.22)
Medium (55-65)	1.91*	1.45	0.76	0.62	-0.47 (-1.36-0.42)
High (65+)	3.14***	2.22*	0.72	0.56	-0.58 (-1.61-0.45)
NO_2		1.19	1.17	1.23*	0.21 (0.12-0.41)
NO_2*DNL (Reference: <45 dB(A))					
NO_2*DNL 45-55		0.82	0.78*	0.74*	-0.30 (-0.53--0.07)
NO_2*DNL 55-65		0.71**	0.68**	0.64***	-0.45 (-0.69--0.19)
NO_2*DNL 65+		0.97	0.94	0.87	-0.14 (-0.41-0.13)
Odour Annoyance			1.13	1.10	0.09 (-0.07-0.25)
Odour Annoy*DNL (Reference: <45 dB(A))					
Odour Annoy*DNL 45-55			1.25*	1.25*	0.22 (0.04-0.41)
Odour Annoy*DNL 55-65			1.24*	1.25*	0.23 (0.03-0.42)
Odour Annoy*DNL 65+			1.26*	1.32**	0.28 (0.06-0.49)
Noise Sensitivity (Reference: Not sensitive)					
Somewhat sensitive				3.07***	1.12 (0.76-1.52)
Highly Sensitive				2.20**	0.79 (0.24-1.42)
Perceived Pollution Risk (Reference: No)				1.38	0.32 (-0.07-0.71)
Scale					
Study Area (Reference: Corridor sample) (p-value)	1.26 (0.056)	1.28 (0.044)	0.97 (0.79)	0.94 (0.61)	
Nagelkerke R^2	0.09	0.11	0.29	0.35	
Model X^2 (df)	50.67 (12)***	61.22 (16)***	170.45 (20)***	212.57 (23)***	
Goodness of fit X^2 (df)	1231.21 (1204)	1200.28 (1200)	1197.23 (1196)	1150.84 (1193)	
Test of Parallel lines X^2	12.89 (11)	14.32 (15)	17.34 (19)	19.02 (22)	

Adjusted for sex, age and area deprivation
Test of Parallel Lines based on location model only
^{t} p<0.1, *$p<0.05$, **p<0.01, ***p<0.001

Model 3 controlled for of the effects of odour annoyance and its interaction with traffic noise. We observed higher levels of odour annoyance in the corridor, along with higher levels of NO_2, while the strength of the association between NO_2 and odour annoyance was similar in the two study areas (Table 1). There were no direct effects of noise exposure or NO_2 when the effect of odour annoyance was controlled, however, the interaction effect of traffic noise and NO_2 was stronger (Model 3; Table 3.3). Controlling for odour annoyance demonstrated that the effect of NO_2 on noise annoyance decreased as noise exposure increased. Compared to the reference noise exposure group, the effect of NO_2 on noise annoyance was 0.78 times lower with low levels of noise exposure and 0.68 times lower with medium levels of noise exposure. Hence, higher exposure to air pollution caused noise annoyance in the absence of traffic noise and independently of odour annoyance. The confounding effects of odour annoyance on noise annoyance did not vary with NO_2 exposure, which confirms that there was a consistent effect of air pollution on odour responses in the two study areas (Table 3.1).

Conversely, the effect of odour annoyance depended on noise exposure. Odour annoyance had a stronger effect on noise annoyance among respondents exposed to low (OR: 1.25, $p<0.05$), medium (OR: 1.24, $p<0.05$), and high (OR: 1.26, $p<0.05$), levels of traffic noise compared to respondents with negligible levels of traffic noise exposure, confirming a cumulative effect of odours and traffic noise. Taken together, these results suggest that residents with relatively low levels of noise in the corridor area reported higher levels of noise annoyance because of higher levels of NO_2 and odour annoyance independently. The explained variance in noise annoyance increased substantially with odour annoyance as a predictor, from R^2=0.11 predicted by traffic noise and NO_2 alone to

R^2=0.29 with odour annoyance. The non-significant scale parameter in Model 3 indicated that the higher error produced by predicting cumulative effects of exposures alone in the corridor was due to odour annoyance.

Model 4 additionally controlled for noise sensitivity, which was a strong predictor of noise annoyance as expected. At average level of exposure to NO_2 and with background levels of noise, respondents who reported *some* noise sensitivity were 3.07 times more likely to report higher levels of noise annoyance (Table 3.3). Somewhat counterintuitive was the finding that people with *high* noise sensitivity had a lower likelihood of being annoyed by noise (OR: 2.20, p<0.01). There was not a significant difference in noise sensitivity overall in the corridor and control area, but a higher proportion of residents in the corridor reported being somewhat sensitive (Table 3.2). Combined with the fact that corridor respondents reported significantly higher levels of noise annoyance and were exposed to higher levels of traffic noise, this suggested that environmental context can influence the moderating effect of noise sensitivity on noise annoyance.

An interesting effect of adding noise sensitivity to the model was the significant effect of NO_2, which was absent in Model 2 and Model 3. It indicated that higher NO_2 exposure increased the likelihood of reporting high noise annoyance by 23%. Including noise sensitivity as a covariate resulted in the overall model explaining 34% of the variance in noise annoyance, although odour annoyance made the greatest contribution to the explained variance. Model 5 (Table 3.4) included the same variables as model 4, but the sample was stratified by residence in the corridor or control area. This model confirmed that the effect of noise sensitivity depends on environmental context. As expected in the control sample, respondents who reported high noise sensitivity were more likely to be annoyed by noise (OR: 2.99) than people who reported being somewhat sensitive (OR: 2.70).

Table 3.4 - Stratified ordinal regression location-scale models for noise annoyance (Model 5)

	CONTROL	CORRIDOR
Parameter Estimates	**Exp(B)**	**Exp(B))**
Threshold		
Somewhat annoying	109.04**	329665.56*
Highly Annoying	1316.06***	4665379.59*
Location		
DNL (Reference: DNL <45 dB(A))		
Low (45-55)	0.57	6.48
Medium (55-65)	0.90	5.67
High (65+)	1.44	7.39
NO_2	1.25	1.86
NO_2*DNL (Reference: <45 dB(A))		
NO_2*DNL 45-55	0.78	0.43
NO_2*DNL 55-65	0.63**	0.40*
NO_2*DNL 65+	0.92	0.55*
Odour Annoyance	1.23***	1.44***
Noise Sensitivity (Reference: Not sensitive)		
Somewhat sensitive	2.70***	3.81***
Highly Sensitive	2.99***	1.84
Perceived Pollution Risk (Reference: No)	1.56	1.24
Nagelkerke R^2	0.28	0.44
Model X^2 (df)	89.32 (19)***	129.84 (19)***
Goodness of fit X^2 (df)	639.86 (663)	484.08 (513)
Test of Parallel lines X^2	5.92 (19)	23.62 (19)

Adjusted for sex, age and area deprivation
Test of Parallel Lines based on location model only
^{t} p<0.1, *$p<0.05$, **p<0.01, ***p<0.001

There was no effect of high noise sensitivity on noise annoyance in the corridor sample, but respondents who reported being somewhat sensitive were 3.8 times more likely to report higher noise annoyance (Table 3.4). The effects of cumulative exposures also differed between the two samples, as NO_2 was less likely to have an effect on residents with higher levels of noise exposure in the corridor. Conversely, NO_2 had a stronger effect on people with background levels of noise exposure in the corridor, where NO_2 levels were higher. The effect of odour annoyance did not differ by level of noise exposure when the sample was stratified, which was explained by the stronger effect of odour annoyance in the corridor where noise levels were higher. All models controlled for sex, age, and area deprivation and there were no significant effects of these covariates on noise annoyance.

3.4 Discussion

This study investigated the effects of community and individual predictors on noise annoyance, and found that while modeled noise level had a significant effect on noise annoyance, individual predictors were more important than the effects of cumulative exposures alone. We observed that 11.1% of the full sample was highly annoyed by traffic noise, but this differed significantly in the corridor (16.1%) and control area (7.3%). In a survey of noise annoyance from road traffic noise throughout Canada, Michaud et al. (2008) found that 6.7% of respondents were highly annoyed. Though the corridor stands out as different, the levels of road traffic noise annoyance in the control area appeared consistent with the findings for Michaud et al.'s national sample.

Schomer et al. (2013) suggests that previous noise assessments were conducted in environments that are too noisy, which prevents a more nuanced understanding of individual and community soundscape determinants. The control area in our study is representative of commonly observed urban forms and building densities in North America, and therefore provides insight on the effects of noise in 'less-noisy' environments. The average DNL for study participants in control area was 51.2 dB(A), and 31% of respondents in this area were exposed to a DNL above 55 dB(A), which is the maximum level recommended by the Ontario Ministry of the Environment. The WHO also recommends that this level not be exceeded to protect the majority of people from being seriously annoyed (Berglund et al., 1999).

The effective loudness function showed that at 55 dB(A) less than 20% of our control sample was highly annoyed (Figure 3.6). Schomer et al. (2012) calculated the CTL for a number of road traffic annoyance surveys around the world, and found that the CTL was on average 78.3. Further research is required to determine if CTLs depend on the physical characteristics of urban environments, but our results imply that residents in communities with lower sound levels have a lower tolerance to noise. It makes tacit sense that noise-sensitive people seek out quieter neighbourhoods while those who are less sensitive to noise may not prioritize noise in their choice of living situation.

Individual and environmental predictors of soundscapes seemed to be codependent in our full sample. However, varying effects of odour annoyance by level of noise exposure were not present in the stratified samples. The stronger effect of odour annoyance in the corridor area explained the interaction with noise in the full sample, as levels of both NO_2 and noise exposures were higher in the corridor. Odour annoyance was significantly correlated with NO_2, which is representative of overall air quality in Windsor (Wheeler et al., 2008). This suggests that in the presence of high levels of air pollution and traffic noise, the olfactory sense dominates the response.

Our results support the findings of Klaeboe et al. (2000) by showing that higher levels of NO_2 lead to higher levels of odour annoyance, which increases noise annoyance.

However, we also demonstrated that this cumulative effect of air pollution and noise depends on a relatively high correlation between the two exposures, and that cumulative exposures have a multiplicative effect. The location-scale model for interaction effects of noise and air pollution on noise annoyance confirmed the hypothesis that influences of the high volume traffic facilities on cumulative exposures can confound the relationship between noise and noise annoyance. Specifically, the scale parameter in Model 2 shows that the residual variance for predicting noise annoyance based on co-exposure was significantly higher for respondents in the corridor area, where the association between noise and air pollution was lower.

Large study samples used to assess cumulative health effects of exposure invariably include participants from areas where correlations between noise and air pollution are confounded by air pollution hotspots. In such areas, we argue, levels of odour annoyance will increase levels of noise annoyance and confound its strength as a mediator between noise exposure and health outcomes such as CVD. It may be that above threshold levels there is a general annoyance effect. Studies commonly report a modest and significant correlation between noise and air quality (Allen et al., 2011). However, Tetreault et al. (2013) found widely differing methods for assessing noise and air pollution among 14 studies that included data on both exposures. Monitoring and/or different modeling approaches were used for both air pollution and noise, therefore it is difficult to determine whether variations in the cumulative exposure are due to methodological differences or environmental characteristics and local conditions in the study areas.

The influence of urban form and the physical environment on the spatial distribution of air pollution is well accounted for in land use regression models by predictor variables such as open space, dwelling density and road network characteristics. However, the effects of the physical environment on cumulative exposures and its implications for noise annoyance have received little attention. We recommend continuing this practice since traffic and the built environment can interact to moderate relative levels of air and noise pollution. Generally, if traffic volumes and vehicle types are similar, higher density urban areas with less space dedicated to roads such as found in central business districts and older cities yield lower noise and higher levels of air pollution. Suburban or modern residential/commercial areas with lower building densities and more space for transport infrastructure produce higher levels of noise and less air pollution (Tang and Wang, 2007).

This study complements this generalization by showing that similar urban forms with different traffic volumes should also be considered to influence cumulative exposures, as doubling the traffic volume results in an equivalent increase in air pollution and only a ~3 dB(A) increase in noise (Gan et al., 2012). Levels of NO_2 and traffic noise in the corridor and control areas of Windsor reflect this phenomenon, where absolute differences in exposure levels were more pronounced for NO_2. This indicates that the results of this study apply to other urban environments transected by road infrastructures that accommodate high volumes of traffic.

3.4.1 *Implications for environmental health research on cumulative exposures*

An important consideration in environmental health is the potential ‘triple jeopardy’ effect among disadvantaged groups, which can arise when social determinants of health and poor environmental quality interact to increase risk and severity for related health outcomes (Jerrett et al., 2001). We did not observe any effect of socioeconomic and demographic variables on noise annoyance, and previous research on their influence has produced mixed results. Michaud et al. (2008) found that females were more likely to be highly annoyed whereas Miedema and Vos (1999) and Klaeboe et al. (2004) did not see a significant effect of gender or marital status on noise annoyance. Michaud et al. (2008) also found that people with a low/modest gross annual salary between $20,000 and $50,000 were more likely to be highly annoyed than other income groups, which may represent a frustration with overall life circumstances. On the moderating effects of socioeconomic status, previous research found that higher income groups in small and medium sized cities can ‘buy’ themselves free from noise (Fyhri et al., 2006), while residents with less education are more likely to live in noisy neighbourhoods (Meline et al., 2013). However, effects of socioeconomic status on annoyance are inconsistent because of the strong influence of individual and contextual modifiers of perception (van Kamp et al., 2013).

Our results indicated that the effects of traffic noise on noise annoyance were confounded by noise sensitivity rather than socioeconomic status and demographic variables. The effect of noise did not change notably when noise sensitivity was included in Model 4, which supports previous research that suggests noise sensitivity is not related to noise exposure. Miedema et al. (2003) question the validity of ascribing noise sensitivity to a general negative affectivity among people, but maintain that it is an invariant personality trait that can be linked to neuroticisms and anxiety among other psychological disorders. The findings of this study contradict this assertion by way of two findings. We show that communities with relatively low levels of traffic noise such as the control area may have a lower tolerance to noise, and that the effect of noise sensitivity on noise annoyance differs with environmental context. These results demonstrate that noise sensitivity is a multidimensional concept, but further research is needed to examine if the anomalous effect of noise sensitivity in the corridor was an outcome of cumulative exposure, environmental perceptions or a combination thereof. It is possible that participants in the corridor area were desensitized to noise, but the strong effect of being somewhat sensitive suggests there was nonetheless an effect of noise sensitivity on annoyance.

Although linking noise sensitivity to individual characteristics may be useful to explain the seemingly heterogeneous distribution of noise annoyance, it does little to assist the promotion of public health through noise and air pollution control. Alternatively, noise sensitivity should be viewed as an indicator of the ability to cope with noise, which may be affected by invariant personality traits (e.g., general environmental sensitivities) or other health issues, but more importantly it appears to relate to environmental context. Within this framework, noise and odour annoyance can be considered as indicators for coping with cumulative exposures. Noise annoyance may be a proxy for coping with health effects caused or exaggerated by noise exposure and mediated by noise sensitivity or sensitivity to other negative aspects of the surrounding environment (i.e., cumulative effects). Therefore, clarifying the relationship between annoyance and coping should be prioritized in environmental health research. This will contribute to reducing uncertainties on cumulative health effects and aid policy making for environmental management (Michaud et al., 2008).

3.4.2 *Conclusion*

Air pollution hotspots such as freeways and industrial areas are common features of cities, and this study shows that these can distort the relationship between noise and air pollution. The location-scale modeling approach used in the current paper can be used for binary and ordinal outcomes and shows promise with respect to identifying areas where differences in cumulative exposures may affect the noise annoyance dose-response. Multilevel modeling with random intercepts for exposure variables is another approach that could determine with more certainty how variations in the level of co-exposure affect environmental annoyance. The current study demonstrates that there is a strong association between different types of environmental annoyance and that accounting for levels of noise and air pollution exposure independently does not suffice.

This study demonstrates that sampling and analysis for future studies on noise annoyance should account for the potential moderators of cumulative exposures in the physical environment. Allen and Adar (2011) argue that study samples with spatial variations in levels of correlation between noise and air quality should be leveraged to more precisely assess independent effects of each variable on health. Our results strongly support this claim. Nonetheless, this study is consistent with others, which suggest a multiplier reduction in annoyance with decreases in both odour and noise. Since these two forms of pollution seem to be synergistic, those considering efforts to reduce either noise or odour at any initial level should be heartened to know that the reductions might have a multiplier effect on annoyance reduction and hence overall well-being (Berglund et al., 1999).

3.5 References

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CHAPTER FOUR

4. CUMULATIVE EFFECTS OF NOISE AND ODOUR ANNOYANCES ON ENVIRONMENTAL AND HEALTH RELATED QUALITY OF LIFE

The effects of noise on noise annoyance and odorous air pollutants on odour annoyance are well established. For these reasons annoyances are an important consideration in research on cumulative exposures and cumulative health effects of exposures. Cumulative exposures are defined by several chemical hazards or a combination of chemical and stressor-based hazards, for which health outcomes can be generalized as the effect of physiological and psychological stress responses. Cumulative health effects can therefore be the result of different types of stress responses to the same hazard, and an analytical framework to disentangle the health effects of such stress responses is currently lacking. The current study conceptualized and tested such a framework for its sensitivity to psychological stress effects of ambient exposures as measured by noise annoyance and odour annoyance. The SF-12 health related quality of life instrument was used to assess annoyance impacts on functional health and a structural equation model was used to test the validity of the framework. The structural model indicated a significant effect of cumulative exposures, therefore the methodology shows promise with respect to disentangling the health effects of physiological and psychological responses to stressor-based and chemical hazards posed by outdoor air pollution and traffic noise.

4.1 Introduction

No research to date has examined how cumulative exposures to noise and air pollution, noise annoyance and odour annoyance may interact to affect health related quality of life (HRQoL). The separate effects of air pollution and environmental noise on cardiovascular disease and other health outcomes are well documented (Brook et al., 2004; Münzel et al., 2014). Previous studies also demonstrate dose-responses between odour annoyance and air pollution, as well as noise annoyance and environmental noise (Atari et al., 2012; Klaeboe et al., 2000a). Furthermore, there is evidence for an interaction effect of noise and air pollution on both types of annoyance (Klaeboe et al., 2000a; Meline et al., 2013). Although work examining cumulative exposure effects on cardiovascular disease outcomes has only appeared recently (e.g., Beelen et al., 2009; Ganet al., 2012), Brook et al. (2011) argue that the evidence base is strong enough to include environmental exposures to noise and air pollution as modifiable risk factors for hypertension in clinical practice. However, this evidence is based predominantly on direct effects, such as effects of air pollution through inhalation and effects of noise through involuntary arousals during sleep as the potential health effects of subjective responses have received less attention.

Noise annoyance is most commonly operationalized as a disturbance or disruption to intended activities, either measured on a general adjectival scale or by reference to specific activities (Fields et al., 2001; Michaud et al., 2008a). However, there are several conceptual definitions of noise annoyance, which have different implications for environmental health research. The implications are that noise annoyance is either conceptualized as a mediator or moderator of health outcomes (e.g., (Babisch et al., 2013) or as a health outcome of the psychological stress response to noise exposure (Evans and Cohen, 1982). This leads to an ambiguity in terms of implications for health promotion (Figure 1). For example, measureable effects on disease outcomes do not need to be present for annoyance to affect health as defined by the World Health Organization (WHO, 1948): "A complete state of physical, mental and social well-being and not merely the absence of disease or infirmity." However, The WHO Guidelines for Community Noise defines annoyance as "[…] a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them," which still implies that annoyance is cognitive evaluation contingent on perceptions of risk (Berglund et al., 1999). To this end, annoyance serves as a general term for a range of negative emotions such as anger, depression anxiety and exhaustion, but their subclinical severities evade the biomedical definition of health. The equivocal conceptualization of noise annoyance as a health outcome or health mediator is therefore, at least in part, due to different definitions of health.

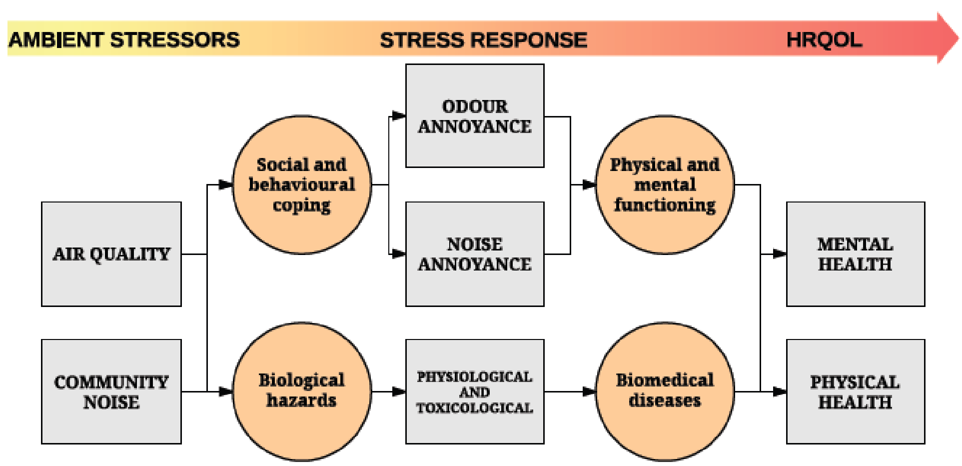

Figure 4.1- Conceptual diagram of odour and noise annoyances as mediators or moderators of health

A similar definitional problem exists for odour annoyance. Most research conceptualizes odour annoyance as dependent on hedonic tone (i.e., level of unpleasantness or pleasantness of odour) and a subjective nuisance that may be associated with levels of air pollution exposure (Forsberg et al., 1997; Williams & McCrae, 1995), or a consequence of odour and air pollution impacts on health through its irritant properties, cardiovascular, respiratory and psychobiological effects (Claeson et al., 2013; Jacquemin et al., 2007; Schiffman & Williams, 2005). Similar to noise annoyance, research on health symptoms associated with odour annoyance provide mixed results, suggesting that it may be more appropriate to instead consider annoyance as an indicator of coping with ambient stressors, which implies the activation of a potentially chronic stress response (Stenlund et al., 2009; Sucker et al., 2001; Winneke et al., 1996).

Shusterman (1992) argues that the distinction of annoyance as a subjective response or health outcome is irrelevant for scientific purposes and a matter of legal interpretation for regulation. Conversely, we argue that the distinction for scientific purposes is crucial to support legal interpretations for regulation. Research to date does not offer a clear picture of the potential health benefits of regulating annoyance to reduce social and behavioural effects on HRQoL. Instead, research has demonstrated that annoyances relate to subtle and complex interactions between risk perceptions, coping, physical surroundings and sociocultural circumstances (Berglund et al., 1999; Luginaah, et al., 2002; Parr, 2006b). In this sense both odour and noise annoyance may be considered more than merely mediators of something more serious, but the lack of current regulation suggests that additional evidence is needed to demonstrate that annoyance is something that requires mitigation in its own right. In this respect, alternatives to the biomedical perspective on health provide a theoretical and conceptual foundation.

Embodiment of the ecological context is a central construct in the ecosocial perspective on social epidemiology and recognizes that human biology cannot be fully understood without knowledge of individual and societal ways of living (Krieger, 2001). A rich body of literature relevant to environmental and HRQoL has demonstrated how embodiment is situated in place and is the outcome of interactions between environment and society. For example, Parr (2010) used community case studies of environmental change throughout Canada to illustrate how responses to environmental stimuli depend on senses tuned to local context and its environmental and sociocultural histories. Coping with ambient stressors can be emotion- or problem-oriented, and Cavalini et al. (1991) argue that passive resignation is the modal response to emotion-oriented coping with the malodourous.

Botteldooren and Lercher (2004) distinguish between three styles of problem-oriented coping with odours and noise that seek to mitigate the ambient stressor by attempting to reduce exposure, which are active coping through changing individual behaviours, social coping by seeking social or administrative support, and political coping by way of mobilizing citizen power. Social and political coping depend on the context of place, which can influence the experience of air pollution and furthermore public perceptions of its health risks (Bickerstaff, 2004; Day, 2007). However, it can be argued that active coping depends more on characteristics of the physical environment than the context of place as such. This study attempts to demonstrate that coping with cumulative exposures can affect health. This is predicated on the conceptualization of annoyance as an indicator of coping with the ambient stressors traffic noise and outdoor air pollution. The concept of HRQoL is utilized to demonstrate that mitigating annoyance can have public health benefits.

4.1.1 *Environmental and Health Related Quality of Life*

Health related quality of life is a holistic measure of health status composed of several dimensions, generally categorized as physical, mental and social wellbeing. Health related quality of life is therefore well suited to measure the multidimensional outcomes of annoyance and its associated effects. Two of the most utilized scales to measure HRQoL are the World Health Organization Quality of Life (WGOQOL) instruments and the Medical Outcomes Study 36-item short-form health survey (SF-36) (Harper, Power, & WHOQOL Grp, 1998; Ware & Sherbourne, 1992). Both scales register the physical, mental and social dimensions that determine quality of life, but they were designed for different purposes. The WHOQOL provides a broad measure of health that is useful to characterize HRQoL in populations of interest, while the SF-36 was designed primarily to measure health care outcomes for use in clinical practice and research as well as health policy evaluation (Ware & Sherbourne, 1992). Along with several other HRQoL instruments (e.g., Nottingham Health Profile, Sickness Impact Profile, Health Utilities Index), the SF-36 survey is used predominantly to evaluate the effectiveness of health care interventions for specific health outcomes (Coons et al., 2000).

Rogerson (1995) argues that there are two fundamental sets of processes that guide QoL concepts in different fields related to both environment and health, and these processes relate to psychological and physiological mechanisms and the external factors that trigger such mechanisms. The WHOQOL group similarly refers to QoL as "[…] a subjective evaluation that is embedded in a cultural, social and environmental context" (Harper et al., 1998). Within these frameworks there are striking similarities between environmental and HRQoL, and it can be argued that established HRQoL instruments such as the SF-36 externalize environmental influences (e.g., health care access and utilization) while more comprehensive instruments such as the WHOQOL measure the influence of environmental and social factors together with mental and physical wellbeing. Lercher (2003) points to few indicators of social functioning and the complete lack of items addressing the environment as drawbacks of the SF-36 instrument in studies on environmental and HRQoL. Conversely, we argue that this instrument is well suited to measure and demonstrate effects of annoyance as a health outcome of coping on QoL because it was designed to measure the effects of interventions on functional health.

The eight domains of the SF-36 and SF-12 instruments are general health [GH]; vitality [VT]; mental health [MH]; role emotional [RE]; social functioning [SF]; physical functioning [PF]; role physical [RP], and; bodily pain [BP]. The instrument has undergone extensive validation and reliability analysis to demonstrate its psychometric properties. This suggests that PF, RP, and BP are indicators of a physical health factor, while MH, RE and SF are indicators of a mental health factor. The GH and VT domains are indicators of both mental and physical health.

Few studies have utilized HRQoL instruments or the SF-36 family of instruments to study noise annoyance or odour annoyance specifically. Dratva et al. (2010) found in a

Swiss cohort that traffic noise annoyance exposure had a significant and negative effect on all SF-36 domains except general health, after controlling for potential confounding by chronic disease, population and sex variables. Nitschke et al. (2014) found a negative association between all health domains and noise annoyance among study participants in Australia. Luginaah et al. (2002) found a significant relationship between three mental health domains of the SF-36 (RE, SF and MH), cardinal symptoms of air pollution exposure and odour annoyance surrounding an oil refinery in Oakville, Canada. No previous research has investigated the interacting effects of noise annoyance and odour annoyance on the SF-12/36 domains, or examined the effects of either type of annoyance on the mental and physical health factors. According to Klaeboe et al. (2000) noise annoyance and odour annoyance are codependent, and therefore research is needed to understand how they interact to affect HRQoL.

4.1.2 *Research Objectives and Study Area*

The main objectives of this study were to conceptualize a framework for measuring the effects of annoyance on HRQoL and consequently test the hypothesis that annoyance is a health outcome of coping with ambient stressors. Furthermore, quantifying the impacts of ambient stressors on functional health as measured by the SF-12 or SF-36 surveys will provide an important contribution to the literature on behavioral and emotional coping with environmental stressors, because the methodology can be applied in different environmental contexts for comparative purposes. While acknowledging that previous research on environmental QoL and HRQoL frequently conceptualizes environmental influences broadly to include factors such as the built environment and urban form, green space and other amenities (e.g., Fleury-Bahi et al., 2013; Rogerson, 1995), this study focused specifically on how environmental embodiment through the auditory and olfactory senses can affect HRQoL.

Windsor, Ontario is located along the Canadian border with the Unites States and four border crossings are located within the city. Among them is the Ambassador Bridge, which is the busiest border crossing in North America and anchored in the west end of Windsor. Road infrastructure that provides access to the bridge from Highway 401, the main transportation corridor in southwestern Ontario, transects several west and southwest neighbourhoods of the city. However, the general form of the built environment, apart from the crossing infrastructure, is largely similar to the east end of the city. Both areas can be characterized as low to medium density urban environments, with a mixture of new residential developments, older neighbourhoods and a range of socioeconomic conditions. Conversely, the two areas have different levels of environmental quality in terms of air pollution and environmental noise. Levels of air pollution are significantly higher in the corridor area as a result of high border traffic volumes and the number of Canadian and US industrial facilities in close proximity, while 24-hour average levels of traffic noise are also significantly higher in large part due to high volumes of heavy trucks. It is in this context that we examine the impacts of annoyances and co-exposure on HRQoL.

4.2 **Methods**

The research approach relied on obtaining self-reported levels of HRQoL, odour and noise annoyances along with data on background variables from representative population survey samples that exhibited sufficient variance in terms of traffic noise and ambient air pollution exposure. This variance was offered by sampling in residential areas near and at a distance from the border crossing corridor in Windsor. These data were combined with spatial data on residential location and estimated exposures to traffic noise and nitrogen dioxide (NO_2) as an indicator of air quality.

4.2.1 *Spatial Data*

The samples were selected from eight census tracts each in the border crossing corridor and the ‘control’ area. A binary variable indicating place of residence in one these areas was used to assess the influence of environmental context beyond the air quality and traffic noise variables we actually measured. Residential levels of traffic noise were modeled in SoundPLAN 7.3 (SoundPLAN GmbH, Backnang, Germany) from traffic data on the road network within the 16 census tracts. The standard environmental noise metric DNL (day-night level), which adds a 10 dB(A) penalty to night time levels for average sound level estimates was utilized (Miedema and Oudshoorn, 2001; Schultz, 1978). Residential levels of air pollution were estimated with a land use regression (LUR) model for the annual average of NO_2. Nitrogen dixide is significantly correlated with sulphur dioxide, benzene and toluene in Windsor, and therefore provides a good estimate of overall air quality (Wheeler et al., 2008). Finally, census dissemination area (DA) levels of socioeconomic deprivation were assigned to participants. The Canadian Deprivation Index developed by the Canadian Institute for Health Information categorizes DAs within quintiles of material (education; employment; income) and social (single parent households; single resident households; separated, divorced or widowed) deprivation relative to the Windsor Census Metropolitan Area (CIHI, 2011). The residential addresses of each respondent were geocoded using the 2011 Census Road Network File from Statistics Canada in ArcMap 10.2 (Esri, Redlands, USA).

4.2.2 *Environmental Health Survey*

Residents in the study areas were administered a survey (n=603) by phone (53%) and a web-based system (47%) during the spring of 2013. Random samples were drawn from each census tract and mailed an information letter that included an invitation to complete the survey online. The online system was accessible for two weeks, after which residents were contacted by phone to reach the desired number of participants (~30) in each census tract. The duration of the phone survey was approximately 25 minutes while the online survey duration varied as respondents had the option to suspend and return to the survey at a later point. The survey collected information on sex and age, and included a number of items for environmental perceptions in addition to the SF-12™ (version 2) functional health and well-being survey (QualityMetric, Lincoln, USA). The study received ethical approval from the Research Ethics Boards at relevant institutions.

The SF-12 health survey measures the same eight health domains as the SF-36 survey (http://www.sf-36.org/demos/sf-12v2.html) and is a validated and reliable alternative with fewer survey items (Ware et al, 1996). The 12-item version was utilized in this study to minimize the time required to complete the questionnaire and maximize the response rate. The scales are coded such that higher scores indicate better health. The SF-12 uses the same standard loading factors from the SF-36 to compute Mental Component Summary (MCS) scores and Physical Component Summary (PCS) scores, which have been identified as latent constructs by psychometric analyses, and provide general measures of HRQoL in a population (Mchorney et al., 1993). Therefore, the MCS and PCS are mental and physical health factors that can be computed from standardized scores on all eight domains. The instrument was not designed to measure environmental and HRQoL. However, it can be argued that environmental annoyances should be considered health outcomes on their own, and within this framework it was hypothesized that the mental and physical health factors are both affected directly by annoyance and indirectly by cumulative exposures to traffic noise and air pollution.

Questions on noise and odour annoyances were based on previous research that shows there are different dimensions of annoyance. The International Commission on the Biological Effects of Noise recommends that two questions measuring general, non-specific reactions to noise are included in noise annoyance surveys (Fields et al., 2001). These questions are [“Thinking about the last 12 months or so…”] “when you are at home, how much does noise from traffic bother, disturb or annoy you; Extremely, Very, Moderately, Slightly, or Not at all?” and “what number from zero to ten best shows how much you are bothered, disturbed or annoyance by traffic noise?” Previous research has also demonstrated that the magnitude of annoyance is related to the extent to which noise interferes with regular activities (Fields, 1993; Michaud et al., 2008). Therefore, the following items were included in the survey: “Over the past 12 months or so, while you were at home, did road traffic noise never, seldom, sometimes, often or always interfere with your ability to…” sleep; hear other people or the TV and radio inside your home; concentrate on tasks such as reading and writing; feel relaxed and peaceful at home. Noise sensitivity is an important moderator of noise annoyance, therefore respondents were also asked if they were highly, somewhat or not sensitive to noise (Miedema & Vos, 2003).

Previous research has also identified different dimensions of odour responses. Luginaah et al. (2002) found that odours induce action-oriented responses such as staying indoors; therefore respondents were asked if they never, seldom, occasionally, or often closed their windows due to odours in the past 12 months. More general impacts of odour arise from interactions between several variables collectively known as FIDOL: frequency, intensity, duration, offensiveness, and location (Nicell, 2009). To represent these interactions the survey included items on how often people noticed odours at home, and how annoyed they were by these odours (Likert scale 0-10). Finally, respondents were asked if they strongly disbelieve, disbelieve, are neutral, believe or strongly believe that air pollution is a health risk to people who live in Windsor. Previous research shows that responses to both odour and noise are associated with risk perceptions of their source (Parr, 2006; Schomer et al., 2013).

4.2.3 *Analysis*

Spatial data on noise, air pollution and deprivation were joined to survey data in ArcMap 10.2 and the complete set of data was analyzed with IBM SPSS 20 (IBM Corporation, Armonk, NY, USA) and Mplus 7.2 (Los Angeles, CA, USA). Descriptive statistics and bivariate analyses were used to compare the survey sample characteristics to 2011 Census data and to examine differences between the two sampling areas (Statistics Canada, 2012). Raw scores from the eight SF-12 domains were standardized and transformed to *t*-scores with normative data for the Canadian population (Hopman et al., 2000). Previous research has identified significant effects of sex and age on the domain and summary scores (Hopman et al., 2000). Therefore, all data were standardized to the 1991 standard population of Canada for comparison with normative SF-36 data produced by Hopman et al. (2000) and to get a representative estimate of mental and physical health for the general population in Windsor as depicted by our sample.

Mental and physical summary scores can be computed using the factor scoring coefficients originally developed for the SF-36 (Ware et al., 1994). However, the scoring coefficients used to compute the MCS and PCS were determined with orthogonal rotation, and Fleishman et al. (2010) argue based on empirical and conceptual grounds that factor scores based on oblique rotation, which allows factors to correlate, are preferable. We therefore utilized confirmatory factor analysis (CFA) and the resulting mental and physical health factors were used for consequent analyses (Byrne, 2012). A CFA was also used to create factors for odour and noise annoyance based on the multiple determinants of noise and odour responses discussed above. All factors were evaluated for construct validity and indicator reliability by computing the Cronbach's alpha coefficient. The robust maximum likelihood estimator was used to reduce the influence of non-normality on parameter estimates.

Previous research has shown that place and socioeconomic status can have a significant influence on environmental risk perception, and can therefore moderate responses to odours and noise (Bickerstaff, 2004). Furthermore, previous research has demonstrated that exposure to air pollution can be associated with socioeconomic deprivation, while the evidence is mixed for traffic noise (Crouse et al., 2009; Havard et al., 2011).

Therefore, the effects of a variable indicating residence in the corridor area as well social and material deprivation on the annoyance and health factors were assessed. A structural equation model (SEM) was used to test the hypothesized effects of noise annoyance and odour annoyance on mental and physical HRQoL, as well as the relationship between annoyances, multiple ambient exposures, risk perception and noise sensitivity.

4.3 Results

4.3.1 *Sample Characteristics*

The phone survey had a response rate of 32% (n=603), while 3% of residents that received the informational letter followed the invitation to complete the survey online. The mean age of the sample was 51.6 (standard deviation [SD] 14.8) years. Females were overrepresented in the sample at 59.9%, and this proportion was slightly but not significantly higher in the control area (Table 4.1). Broad categories of the age distribution indicated that the older age group (65+) was also overrepresented compared to the 2011 census. Conversely, the age groups below the age of 35 were underrepresented. Overall, the sex and age distributions were similar across the two study areas.

Table 4.1 also describes the distribution of covariates in the full sample and corridor and control areas. A significantly higher number of respondents in the corridor resided in DAs with higher levels of social and material deprivation. Respondents in both areas reported similar levels of noise sensitivity, with the majority of people not sensitive to noise. The questions on risk perceptions of air pollution showed that in general, study respondents were highly concerned with community health impacts. On the binary scale

67% of the full sample reported that air pollution posed a community health risk, for which the proportion was significantly higher in the corridor area. On the ordinal scale 35% believed and 52 % strongly believed that air pollution was a health risk.

Tests of means showed that respondents in the corridor were exposed to significantly higher day-night levels (DNL) of traffic noise measured by A-weighted decibels [dB(A)] as well as air pollution measured by parts per billion [ppb] of $NO_{2.}$ Survey data on subjective responses to noise and air pollution corroborated this. As expected, there were significantly higher levels of odour and noise annoyance in the corridor (Table 4.2).

The proportions of respondents reporting high levels of odour and noise annoyance were more than doubled in the corridor. Respondents in the corridor also noticed odours and closed their windows more often because of odours, and reported that noise interrupted their ability to relax and concentrate more frequently. There were no significant differences in the reported frequencies of sleep and communication disturbances from traffic noise. Between 62.9 and 76.0% of respondents reported that sleep, concentration, communication and relaxation were never affected by traffic noise.

Table 4.1 - - Age- and sex-standardized descriptive statistics and bivariate analysis

		Control (n=336)	Corridor (n=267)	Full Sample (n=603)	Area test of difference
Sex (%)	Male	39.5	40.9	40.1	Pearson X^2= 0.15
	Female	60.5	59.1	59.9	
Age Groups (%)	<= 24	3.5	5.3	4.3	Pearson X^2=12.2
	25 - 34	7.4	13.6	10.1	
	35 - 44	17.7	15.9	16.9	
	45 - 54	22.7	21.6	22.2	
	55 - 64	24.5	27.7	25.9	
	65 - 74	19.5	11.4	15.9	
	75+	4.7	4.5	4.6	
Area Social and Material Deprivation (%)	1st Quintile	10.3	20.8	14.9	Pearson X^2=28.5***
	2nd Quintile	38.1	19.7	30.0	
	3rd Quintile	14.7	13.3	14.1	
	4th Quintile	18.0	16.7	17.4	
	5th Quintile	18.9	29.5	23.5	
Noise Sensitivity (%)	Not sensitive	51.6	46.2	49.3	Pearson X^2=5.8
	Somewhat sensitive	37.5	45.8	41.1	
	Highly sensitive	10.9	8.0	9.6	
a. Pollution Health Risk (%)	No	37.2	26.9	32.7	Pearson X^2=5.7*
	Yes	62.8	73.1	67.3	
b. Pollution Health Risk (%)	Strongly disbelieve	2.7	2.3	2.5	Pearson X^2=10.1*
	Disbelieve	2.9	1.1	2.2	
	Neutral	8.0	8.3	8.1	
	Believe	38.9	29.9	35.0	
	Strongly believe	47.5	58.3	52.2	
DNL dB(A)	Mean	51.32	56.06	53.40	*t*-test=6.4***
	Standard Deviation	9.68	7.70	9.17	
NO_2	Mean	12.99	15.21	13.96	*t*-test=11.9***
	Standard Deviation	2.40	1.92	2.46	

* Significant at the 0.05 level (2-tailed)
*** Significant at the 0.001 level (2-tailed).

Table 4.2 - Age- and sex-standardized descriptive statistics and bivariate analysis for noise and odour responses

		Control (n=336)	Corridor (n=267)	Full Sample (n=603)	Area test of difference
Noticed odours (%)	Never	45.4	30.3	37.9	Pearson X^2=23.4***
	Seldom	27.1	25.8	26.4	
	Sometimes	20.1	27.3	23.7	
	Often	5.6	14.8	10.2	
	Always	1.8	1.9	1.8	
Closed windows b/o odours (%)	Never	49.6	35.6	42.6	Pearson X^2=12.9**
	Occasionally	44.8	53.8	49.3	
	Often	5.6	10.6	8.1	
Odour annoyance (0-10) (%)	0	54.6	36.7	45.7	Pearson X^2=23.2***
	1-3	24.5	27.3	25.9	
	4-6	13.6	19.3	16.4	
	7-10	7.4	16.7	12.0	
Noise annoyance (0-10) (%)	0	19.5	15.9	17.7	Pearson X^2=25.2***
	1-3	42.8	33.3	38.1	
	4-6	27.1	25.0	26.1	
	7-10	10.6	25.8	18.2	
Noise - Concentration (%)	Never	80.8	71.2	76.0	Pearson X^2=11.6**
	Seldom	11.8	12.5	12.1	
	Sometimes	5.6	12.1	8.9	
	Often/always	1.8	4.2	3.0	
Noise - Sleep (%)	Never	65.5	60.2	62.9	Pearson X^2=4.7
	Seldom	17.4	16.3	16.8	
	Sometimes	14.2	17.8	16.0	
	Often/always	2.9	5.7	4.3	
Noise - Hear (%)	Never	74.0	68.6	71.3	Pearson X^2=4.7
	Seldom	14.7	14.0	14.4	
	Sometimes	9.1	14.4	11.8	
	Often/always	2.1	3.0	2.5	
Noise - Relax (%)	Never	70.5	58.3	64.4	Pearson X^2=12.9**
	Seldom	15.6	18.6	17.1	
	Sometimes	9.4	16.3	12.9%	
	Often/always	4.4	6.8	5.6	

* Significant at the 0.05 level (2-tailed)
** Significant at the 0.01 level (2-tailed).
*** Significant at the 0.001 level (2-tailed).

4.3.2 *Functional Quality of Life Domains and Factors*

Table 4.3 shows the mean domain scores and summary scores within each age category and for all ages. For domains that load positively onto the PCS score (physical functioning, role physical and bodily pain, based on the standard model by developers of the SF-12 instrument) there was a general trend towards lower scores and functional health for older age groups. For domains that only load positively onto the MCS score in the standard model (social functioning, role emotional, and mental health) there was no consistent trend. Mental health and role emotional increased with age, while the middle age groups scored higher on social functioning. General health and vitality load onto both factors of the standard model and we observed a clear trend towards lower scores for older age groups for these domains. The physical summary scores declined with age while the mental summary scores were higher for middle age groups (55-74 years). There were notable differences in domain and summary scores between sexes (Table 4.4). The trend towards lower scores on functional physical health with age was consistent for men and women, but men had higher levels of functional health within individual age groups and for all ages combined.

Table 4.3 - Mean age- and sex-standardized SF-12v2 scores for full sample

Age Groups (n)		PF	RP	BP	GH	VT	SF	RE	MH	PCS	MCS
<= 24	**Mean**	**91.3**	**80.8**	**88.0**	**81.9**	**67.2**	**74.7**	**75.6**	**65.9**	**58.0**	**43.1**
(109)	SD	14.4	25.8	27.0	18.5	30.6	25.8	23.9	24.4	6.1	11.6
25 - 34	**Mean**	**90.9**	**88.4**	**85.9**	**74.6**	**63.9**	**87.4**	**88.6**	**71.9**	**56.0**	**47.7**
(139)	SD	21.1	18.7	18.9	23.8	23.2	20.0	18.2	19.0	7.0	8.3
35 - 44	**Mean**	**81.9**	**78.4**	**77.0**	**69.7**	**59.6**	**81.3**	**82.7**	**68.3**	**52.8**	**46.1**
(121)	SD	30.7	27.7	27.9	23.2	26.2	25.6	23.6	22.2	9.2	10.3
45 - 54	**Mean**	**85.2**	**77.4**	**75.2**	**67.9**	**59.2**	**78.4**	**81.1**	**70.2**	**52.7**	**45.9**
(82)	SD	27.2	32.3	31.1	28.5	28.3	27.8	27.8	23.9	10.4	11.5
55 - 64	**Mean**	**74.0**	**72.8**	**69.5**	**65.2**	**59.9**	**79.4**	**86.0**	**72.5**	**49.0**	**48.7**
(66)	SD	33.6	30.9	29.6	27.0	24.7	29.0	22.1	20.0	11.6	9.4
65 - 74	**Mean**	**70.5**	**71.6**	**72.3**	**65.3**	**63.6**	**84.1**	**86.2**	**77.3**	**48.2**	**50.8**
(52)	SD	34.2	32.1	27.9	28.7	25.8	27.1	23.8	19.3	10.8	9.2
75+	**Mean**	**48.5**	**59.8**	**65.3**	**41.9**	**44.4**	**71.7**	**91.8**	**75.9**	**39.8**	**51.1**
(33)	SD	38.7	28.5	30.3	28.1	24.3	32.8	16.8	18.5	11.1	7.7
All	**Mean**	**82.4**	**78.8**	**78.9**	**70.4**	**61.5**	**80.6**	**83.7**	**70.6**	**52.9**	**46.8**
Ages (601)	SD	29.0	27.9	27.6	26.0	26.8	26.1	23.1	21.7	10.0	10.2

GH - general health; VT - vitality; MH - mental health; RE - role emotional; SF - social functioning; PF - physical functioning; RP - role physical; BP - bodily pain.

Table 4.4 - Mean age- and sex-standardized SF-12v2 scores for males and females

Age groups (n)			PF	RP	BP	GH	VT	SF	RE	MH	PCS	MCS
Males - Means	<= 24 (56)		91.4	78.9	100.0	87.1	86.2	74.2	76.4	66.9	59.8	44.7
	25 - 34 (70)		95.6	89.7	88.5	78.1	65.0	87.1	89.7	67.8	57.8	46.5
	35 - 44 (61)		83.4	82.1	79.3	69.1	60.4	84.2	84.3	68.9	53.5	46.6
	45 - 54 (41)		83.7	72.1	70.7	62.4	56.8	74.9	76.8	68.6	51.2	44.6
	55 - 64 (32)		76.3	75.3	72.7	65.2	63.8	83.5	87.8	74.6	49.6	49.9
	65 - 74 (23)		74.8	80.2	73.1	68.7	67.8	88.3	87.8	82.0	49.7	52.3
	75+ (13)		61.0	62.8	70.7	38.1	45.5	73.7	92.3	75.7	42.0	50.2
	All Ages (296)	Mean	85.4	80.1	82.6	71.8	66.1	81.5	84.1	70.2	54.2	46.9
		SD	26.5	28.9	26.1	25.2	25.7	24.8	23.1	22.0	9.5	9.7
Females - Means	<= 24 (54)		91.2	82.7	75.5	76.5	47.6	75.1	74.8	64.9	56.1	41.3
	25 - 34 (68)		86.0	87.1	83.2	71.1	62.7	87.7	87.4	76.1	54.1	48.9
	35 - 44 (60)		80.3	74.7	74.7	70.3	58.9	78.3	81.1	67.6	52.2	45.7
	45 - 54 (40)		86.6	82.9	79.8	73.5	61.6	82.0	85.5	71.9	54.2	47.1
	55 - 64 (33)		71.8	70.4	66.3	65.2	56.0	75.4	84.2	70.5	48.4	47.5
	65 - 74 (29)		67.1	64.6	71.6	62.5	60.1	80.6	84.8	73.4	47.0	49.6
	75+ (20)		40.3	57.8	61.7	44.4	43.7	70.3	91.4	76.0	38.3	51.6
	All Ages (273)	Mean	79.6	77.5	75.4	69.0	56.9	79.7	83.4	71.0	51.8	46.8
		SD	31.1	26.8	28.5	26.8	27.1	27.3	23.1	21.4	10.4	10.7

GH - general health; VT - vitality; MH - mental health; RE - role emotional; SF - social functioning; PF - physical functioning; RP - role physical; BP - bodily pain.

Compared to the normative data for Canada the sample scored significantly lower on all domains except BP and RE (Figure 4.2). Scores for bodily pain were significantly higher for the sample population, while role emotional scores were almost identical. The difference between sample scores and normative data was particularly pronounced for MH, GH, SF and VT, which all load onto the mental component summary in the standard model. The standardized and transformed *t*-scores are interpreted as 10 points below or above 50 being equivalent to a standard deviation of one from the mean, and none of the sample scores were outside this range for the Canadian normative data. Nonetheless, the results suggested that functional mental health in Windsor was poorer than the Canadian national average (Hopman et al., 2000). Table 4.5 shows that the mental health factor was lower in the corridor area at 45.9 compared to 47.6 for the control area. This was due to lower scores on all mental health domains (GH, VT, SF, RE, MH). The difference was most pronounced for vitality, which was influenced by lower scores among young respondents in the corridor compared to the control area.

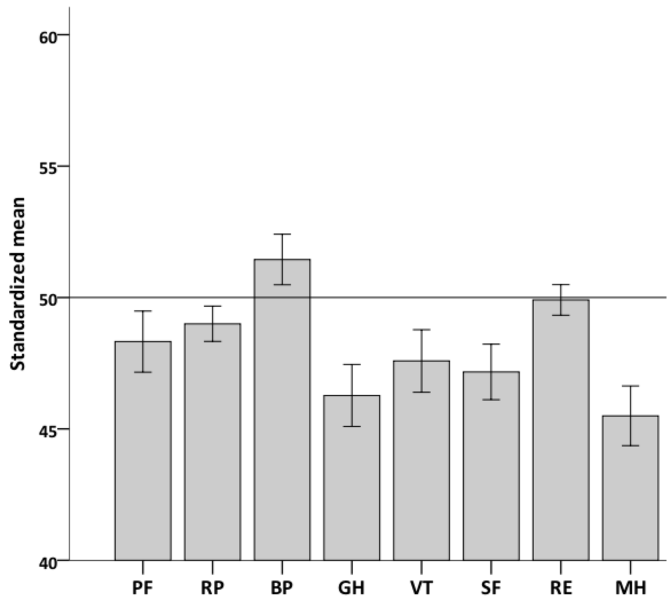

Figure 4.2 - Domain scores standardized and transformed to t-scores with Canadian normative data (Hopman et al., 2000). Summary scores calculated from standardized and transformed sample domain scores and US population standard loading factors (Fleishman et al., 2010). Error bars represent 95% confidence intervals. Line at mean=50 represents normative scores for the Canadian population.

All standard domain scores for the SF-12 were significantly correlated (Table 4.6). Physical health domains were highly correlated with each other (0.48-0.62), as were mental health domains (0.53-0.58). General health had a higher correlation with physical health domains than mental health domains, while vitality had higher correlations with mental health and general health. The lowest correlations were observed between mental health domains and the physical health domains. The Cronbach's alpha coefficients for mental health domains (0.83) and physical health domains (0.81) of the standard model indicated reliability of the measures. The domain score covariance matrix was used to estimate the regression coefficients for the standard model, which confirmed the presence of latent physical and mental QoL constructs. Similar to the standard model, mental (SF, RE, MH) and physical (PF, RP, BP) domain scores located onto separate factors. However, the overall poor fit of the model suggested that measurement errors were present and influential (Table 4.7). Therefore, modification indices from the model results were used to guide improvement of the model.

Table 4.5 - Mean age- and sex-standardized SF-12v2 scores for respondents in control and corridor areas

	Age groups (n)		PF	RP	BP	GH	VT	SF	RE	MH	PCS	MCS
Control	<= 24 (58)		91.0	78.1	97.6	87.2	82.5	79.4	74.9	70.0	59.1	45.5
	25 - 34 (62)		92.7	85.3	82.3	74.4	68.9	87.9	90.9	71.7	55.3	48.7
	35 - 44 (73)		81.5	79.4	79.2	69.5	60.6	81.8	83.2	67.9	53.1	46.2
	45 - 54 (47)		82.0	78.4	75.3	68.0	60.6	81.8	82.2	70.5	52.3	46.8
	55 - 64 (36)		76.8	73.7	70.8	63.5	60.7	77.8	85.2	71.4	49.6	47.9
	65 - 74 (35)		65.7	69.3	70.0	64.5	62.6	82.9	87.2	77.2	46.9	51.3
	75+ (17)		44.6	54.8	64.6	42.2	40.3	69.3	91.6	77.9	38.4	51.4
	All Ages (328)	Mean	81.2	77.1	79.8	70.7	65.2	81.6	84.1	71.3	52.7	47.6
		SD	29.9	28.7	26.4	26.5	26.1	24.8	22.5	21.8	10.2	10.0
Corridor	<= 24 (51)		91.7	83.8	77.2	75.9	50.1	69.3	76.4	61.3	56.7	40.3
	25 - 34 (77)		89.4	90.9	88.8	74.8	59.8	87.0	86.6	72.1	56.5	46.8
	35 - 44 (48)		82.4	76.9	73.7	69.9	58.3	80.4	82.0	68.8	52.4	46.1
	45 - 54 (35)		89.4	76.1	75.1	67.8	57.3	73.9	79.7	69.9	53.2	44.6
	55 - 64 (30)		70.6	71.8	67.9	67.3	58.8	81.3	86.9	74.0	48.3	49.6
	65 - 74 (17)		80.9	76.6	77.1	67.0	65.5	86.6	83.8	77.5	51.2	49.7
	75+ (16)		52.6	65.1	66.0	41.5	48.8	74.2	91.9	73.7	41.2	50.7
	All Ages (273)	Mean	83.9	80.7	77.9	70.0	57.0	79.4	83.2	69.8	53.3	45.9
		SD	28.0	26.8	29.0	25.5	27.0	27.6	23.8	21.6	9.8	10.4

GH - general health; VT - vitality; MH - mental health; RE - role emotional; SF - social functioning; PF - physical functioning; RP - role physical; BP - bodily pain.

Table 4.6 - Correlations among sex- and age-adjusted SF-12 scales

	PF	RP	BP	GH	VT	SF	RE
RP	0.622**						
BP	0.478**	0.586**					
GH	0.451**	0.426**	0.460**				
VT	0.294**	0.269**	0.410**	0.450**			
SF	0.450**	0.508**	0.417**	0.412**	0.355**		
RE	0.257**	0.413**	0.281**	0.232**	0.272**	0.581**	
MH	0.154**	0.255**	0.269**	0.298**	0.456**	0.528**	0.583**

** Correlation is significant at the 0.01 level (2-tailed).
GH - general health; VT - vitality; MH - mental health; RE - role emotional; SF - social functioning; PF - physical functioning; RP - role physical; BP - bodily pain

Table 4.7 - Confirmatory factor analysis and structural equation model fit indices

	SF12 CFA	SF12 CFA modified	CFA Annoyance	MIMIC Model	EHQoL SEM
Model X^2 (*df;* *p*-value)	78.79 (17;0.00)	22.34 (13;0.05)	40.02 (13;0.00)	199.46 (100, 0.00)	188.01 (130;0.00)
RMSEA	0.078	0.035	0.059	0.041	0.023
CFI	0.906	0.986	0.997	0.962	0.975
TLI	0.846	0.969	0.995	0.949	0.968

Figure 4.3 shows the modified SF-12 mental and physical health factor model for HRQoL. The results of the model modifications showed that the mental health factor did not predict levels of general health and vitality and furthermore that both factors were associated with social functioning. The modified model indicated that there was a residual covariance between the role physical domain, which measures the extent to which physical health affects regular activities, and the role emotional domain, which probed the extent to which emotional problems affect regular activities. A significant residual covariance between two factor indicators is interpreted as measurement error, because previous validations of the SF-12 instrument have demonstrated that the physical

and mental health factors account for the covariance between indicators in the general population. Hence, another factor beyond physical or mental health influenced how people scored on these domains. The model was also modified to include a residual covariance between the role physical and vitality domains, as well as the mental health and vitality domains. The fit indices for the modified measurement model were notably better than the standard model (Table 4.7).

4.3.3 *Noise and Odour Annoyance Factors*

The measurement model for odour and noise annoyance factors produced a good fit with the sample covariance matrix for the individual indicators. Tests for construct validity and indicator reliability showed that the general noise annoyance questions was a compositional variable based on responses to the four questions on noise interference with daily activities, and therefore removed from the model. This resulted in high a Cronbach's alpha coefficient for the noise (0.87) annoyance factor, which was similar to the odour annoyance factor (0.88). There was a significant correlation between the two factors (0.61) and the fit indices for the CFA were acceptable (Table 4.7). There was no significant effect of social and material deprivation on annoyance, and no significant effect of living in the corridor on levels of mental and physical health. Living in areas with higher levels of deprivation had a negative effect on physical health. Both annoyance factors were negatively and significantly correlated with both health factors, but the associations were stronger for the physical health factor. There were no significant direct effects of living in the corridor area or deprivation on the annoyance and health factor indicators.

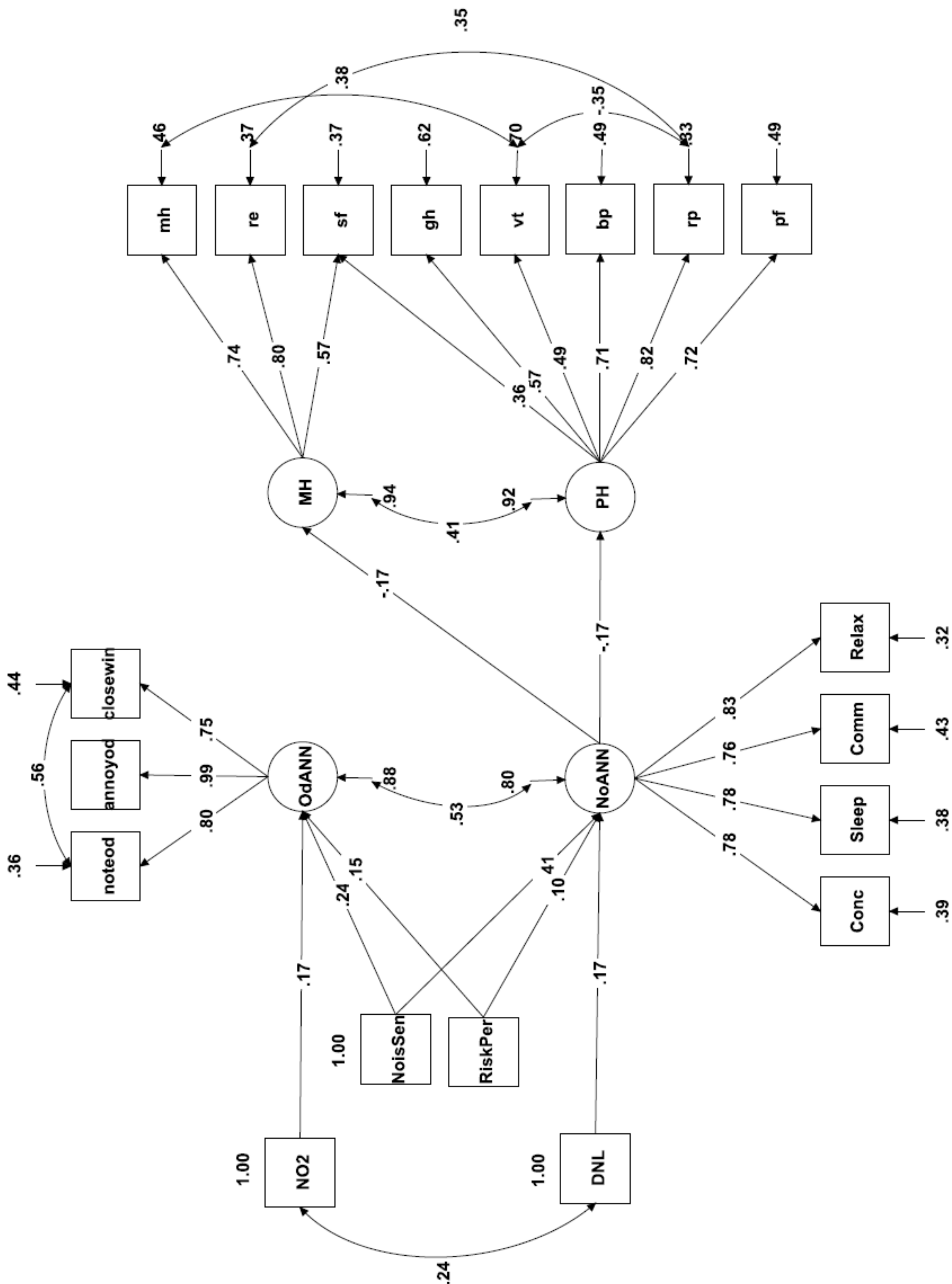

Figure 4.3- Structural equation model for effects of annoyance on health related quality of life. Only significant and standardized regression paths, correlations and latent variable residuals are shown. The DNL variable and residual is scaled to 10 dB increments. Fit indices are provided in Table 4.7.

4.3.4 *Environmental Effects on Health Related Quality of Life*

The structural equation model (SEM) tested the hypothesis that odour and noise annoyances affect HRQoL as measured by functional mental and physical health (Figure 4.3). The model demonstrated that noise annoyance had a significant and negative effect on HRQoL trough mental and physical health factors. There was no direct effect of odour annoyance on HRQoL, but the high covariance between odour and noise annoyance indicated that subjective responses to odours moderate the effect of noise. The background variables noise sensitivity, risk perception and residential exposure to traffic noise and NO_2 also contributed significantly to the model. Noise sensitivity had a strong effect on noise annoyance and a weaker effect on odour annoyance. Conversely, risk perceptions of air pollution had a stronger effect on odour annoyance than noise annoyance. Subjective responses to noise and air pollution were related to respective exposures and the significant residual covariance between exposures reflected the confounding effect of cumulative exposures on annoyance as demonstrated in Chapter Three.

Several other background variables were tested for contributions to the final. The study area indicator and area deprivation did not have a significant effect on annoyance when NO_2 and traffic noise were included in the model. The effects of sex and age on annoyances were not significant and therefore not included in the final model. Previous research has demonstrated the effects of these variables on HRQoL so it was not necessary to estimate these path coefficients in the current study. Model fit indices indicated that the SEM estimated the sample covariance matrix well, and factor determinancies for mental health (0.967), physical health (0.961), odour annoyance (0.962) and noise annoyance (0.938) indicated that the factors estimated by the measurement models were similar to the sample factors.

Table 4.8 shows the correlations between estimated factor distributions and SF-12 domains. There were significant and negative correlations between both types of annoyance and all health domains, except for odour annoyance and mental health. Generally, higher correlations were observed between physical health domains and annoyance, while mental health domains were more highly correlated with noise annoyance. Also, significant negative correlations were observed between residential traffic noise and RP, RE and MH, and between NO_2, SF and RE. The reliability of the estimates for dependent variables in SEM model is provided as R-square values. The results showed that the estimates for all dependent variables in the final model were reliable, and that the regression of the mental and physical health factors on SF-12 domains explained most of their variance. Noise sensitivity, risk perception and exposure to traffic noise and air pollution explained 12 % of the variance in odour annoyance and 20 % of the variance in noise annoyance. Noise annoyance explained 6 % and 8 % of the overall variance in functional mental health and physical health, respectively.

Table 4.8 - Sex- and age-adjusted Pearson correlation coefficients for factor scores and SF12 domains and R2 values for dependent variables in the final model

	MCS	PCS	OdPer	NoPer	DNL	NO2	R-Square[a]
MCS	1						0.055
PCS	0.487**						0.076
OdPer	-0.132**	-0.245**					0.119
NoPer	-0.221**	-0.282**	0.614**				0.204
DNL dB(A)	-0.153**	-0.092**	0.106**	0.172**			
NO_2	-0.129**	-0.072	0.194**	0.079	0.242**		
PF	0.332**	0.765**	-0.180**	-0.189**	-0.058	-0.074	0.512
RP	0.399**	0.874**	-0.180**	-0.200**	-0.124**	-0.037	0.666
BP	0.371**	0.761**	-0.206**	-0.227**	-0.068	-0.051	0.507
GH	0.379**	0.652**	-0.087*	-0.169**	-0.050	-0.059	0.379
VT	0.362**	0.571**	-0.103*	-0.164**	-0.010	-0.031	0.299
SF	0.803**	0.651**	-0.167**	-0.203**	-0.052	-0.107**	0.628
RE	0.882**	0.383**	-0.097*	-0.179**	-0.134**	-0.085*	0.632
MH	0.815**	0.338**	-0.061	-0.124**	-0.133**	-0.064	0.540

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

[a] All R-square values significant at $p<0.000$

4.4 Discussion

This study demonstrated that odour and noise annoyances conceptualized as health outcomes have a significant effect on physical and mental factors of HRQoL. Although the explained variation in HRQoL by annoyance was relatively small, this must be considered in the context of dominant predictors of HRQoL such as age and disease. The results support the dichotomous conceptualization of annoyance as both a health mediator and a health outcome, and corroborate assertions that environmental annoyances are a public health issue irrespective of clinical health outcomes of noise and air pollution. Related research on associations between life satisfaction, QoL and ambient exposures in different geographic settings are consistent with this conclusion (MacKerron and Mourato, 2009; Nitschke et al., 2014; Yamazaki et al., 2005).

The current study found that HRQoL in Windsor was generally poorer than the Canadian average, and that this was in part due to ambient stressors. To our knowledge this is the first study to estimate environmental effects on SF-12 scores in Canada, hence these findings should be interpreted with caution until further research corroborates these results. In fact, few studies have utilized this instrument to evaluate environmental HRQoL anywhere. However, Yamazaki et al. (2005) observed significantly lower vitality scores among groups exposed to higher levels of air pollution after adjusting for demographic and geographic variables in addition to disease status in Japan. They also observed a trend of lower scores on the PF, GH and MH domains for higher NO_x exposure groups.

In a study of environmental and health related quality of life in Switzerland, Dratva et al. (2010) observed lower scores on all domains except GH for people highly annoyed by noise. Their observed effect size for annoyance on HRQoL was higher for mental health domains among women especially, and higher for men on all domains except BP. The current study found that differences between Canadian normative scores and sample scores were higher for mental health domains than physical health domains. Taken together, these findings and the current study support the hypotheses that annoyances and ambient exposure to noise and air pollution affect HRQoL. Unlike previous research on environmental and HRQoL, however, the current study utilized confirmatory factor analysis to test the presence of latent mental and health factors of HRQoL and their role as mediators between annoyance and specific dimensions of HRQoL (i.e., SF-12 domains).

With respect to environmental and HRQoL the most relevant difference between computing the mental and physical health factors based on the standard principal component factor (PCA) loadings for the SF-36 and loadings based on confirmatory factor analysis is that the former method assumes that there is no correlation between mental and physical factors (Fleishman et al., 2010). Although this may be a useful feature to determine whether medical interventions improve physical or mental HRQoL, it presents a conceptual problem for assessing how environmental context affects HRQoL. This was illustrated in our study and was the reason CFA was utilized to estimate mental and physical health factors. The results indicated that the effects of annoyance on mental and physical health constructs were very similar (Figure 6). However, the significant effect of annoyance on both mental and physical health, along with the reduced covariance between these constructs in the final SEM model compared to the modified CFA model, implied that annoyances affect HRQoL through a combination of physical and mental coping mechanisms.

The demonstration of annoyance as a health outcome of coping in this study depended on a strong contribution of noise sensitivity to the model. Consistent with earlier research, noise sensitivity was a significant predictor of both noise and odour annoyances (Miedema and Vos, 2003). Chapter Three shows that noise sensitivity can be observed on the community level by estimating community tolerance levels, which suggests that noise sensitivity is a more than just merely an invariant personality trait. Furthermore, noise sensitivity is related to different measures of health (e.g., physical health anxiety, depression) and the noise annoyance dose-response is steeper for noise sensitive individuals (Hill et al., 2014; Miedema and Vos, 2003; Schreckenberg et al., 2010). Taken together, these studies and the results of this study suggest that noise sensitivity also functions as an indicator for coping ability that is influenced by environmental context, physical and mental health.

Therefore, the conceptualization of sensitivity as an individual trait that modifies noise effects on health may be too simplistic and require teasing out in future research. Rather, the relationship between health status and sensitivity, or alternatively HRQoL and coping ability may be recursive. In this formulation annoyance depends on the ability to cope with ambient stressors (i.e., noise sensitivity), while coping mechanisms mediate the relationship between ambient stressors and annoyance. This study demonstrated that annoyance is a health outcome of coping that affects HRQoL, which may in turn influence noise sensitivity. Future research on annoyance and HRQoL should therefore consider more carefully which coping mechanisms may be relevant in the given ecological context, because they can provide an indication of effective environmental management strategies to reduce sensitivity and cumulative effects of exposure.

The modeling framework in this study could not accommodate for a recursive effect of coping ability (i.e., noise sensitivity), coping mechanisms and strategies, health outcomes (i.e., annoyance) and HRQoL, but it did demonstrate why distinguishing between coping mechanisms and coping ability is an important consideration when assessing environmental health (Baum, Singer, & Baum, 1981). For example, our analysis showed that physical functioning as a factor of HRQoL depended on area deprivation. However, area deprivation did not contribute to the model when noise and air pollution exposure were included. This corroborates previous research on the double burden of socioeconomic deprivation and pollution in urban settings (Crouse et al., 2009) in the sense that social and active coping styles are affected by this burden.

With respect to social coping, Bickerstaff and Walker (2001) show that lower socioeconomic status can increase environmental concerns about air pollution because a lack of financial resources to escape the situation leads to a sense of powerlessness. A similar situation may exist for noise (Fyhri & Klaeboe, 2006). Others have demonstrated that perceptions of the physical environment, neighborhood satisfaction and income profiles predict low levels of self-rated health (Collins et al., 2004), and annoyance influences neighbourhood satisfaction (Botteldooren, Dekoninck, & Gillis, 2011). Interestingly, the measure of the extent to which physical health or emotional problems interfered with social activities (e.g., visiting friends, relatives) was only associated with the physical health factor in this study (Figure 4.3). It is doubtful that the negative effects of coping with cumulative exposures on functional physical health were strong enough to physically inhibit people from social activities, but it is plausible that annoyance also represented coping with physiological effects of cumulative exposure.

Irritant properties, or cardinal symptoms of odour exposure include eye irritation, coughs, sinus congestion, wheezing/breathing problems and nausea, while general symptoms result from stress-mediated mechanisms related to odour annoyance, which include headaches, dizzy spells, tiredness and sleeping problems (Aatamila et al., 2011; Luginaah et al., 2002). Table 4.8 shows that odour annoyance was associated more strongly with the physical HRQoL factor and related domains, which measure bodily pain, physical functioning and role physical. This shows that odour annoyance as an outcome of physical symptoms of odour and air pollution exposure can have a significant effect on HRQoL. The current study found that the odour annoyance factor was a strong predictor of closing windows, which is also a coping mechanism to reduce noise exposure. High levels of association between odour and noise annoyance observed in this study and by others may therefore be due to similar coping mechanisms that alleviate annoyance and reduce co-exposure to noise and air pollution, (Klaeboe et al., 2000b; Lercher et al., 1995).

The final model in this study indicates that overall, noise annoyance has a stronger effect on HRQoL than odour annoyance. This may be due to the higher temporal consistency of traffic noise and the transient nature of malodours due to effects of weather and climate on their distributions and strengths. Nonetheless, these details need not overshadow one of our main contributions, that the interacting effects of noise and odour annoyance have a significant effect on HRQoL. The results of this study supported the conceptualization of annoyance as a health outcome with significant effects on quality of life. Further analysis is needed to determine if the difference between the SF-12 measurement model for HRQoL in this study and the CFA model presented by Fleishman et al. (2010) were due to high levels of environmental annoyances in the study population. Place of residence in the vicinity of the border crossing corridor alone did not affect HRQoL, but the association between levels of annoyance and environmental exposures suggested lower levels of mental and physical health among residents living in the vicinity of the Ambassador Bridge and consequently high levels of traffic noise and air pollution.

4.5 Conclusion

The significant effects of traffic noise and air pollution on annoyances demonstrated in this study substantiate the benefits of reducing exposures to mitigate annoyances for public health purposes, particularly in areas of high exposure such as the corridor area in this study. There are also implications of this study for environmental assessment, in particular health impact assessment, of proposed developments and infrastructure projects. The results clearly support including noise annoyance as an indicator to assess potential health impacts of projects that have the potential to change the environmental context on a relatively large scale (Michaud et al., 2008b). To this end, the work also contributes to current efforts to advance methods and concepts for cumulative risk assessment (Sexton, 2012). That is, potential effects of noise and pollution resulting from a project should be assessed together to predict cumulative impacts on health. While the current study provides strong support for using annoyance as a health indicator, further validation of the SF-12 or SF-36 instrument as a measure of annoyance effects on health related quality of life can facilitate more in-depth evaluations of long-term impacts and public health risks.

4.6 References

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CHAPTER FIVE

5. ENVIRONMENTAL HEALTH IMPACT ASSESSMENT: A MISSED OPPORTUNITY FOR THE DETROIT RIVER INTERNATIONAL CROSSING STUDY?

Health impact assessments (HIA) are increasingly utilized for projects with a substantial impact on the physical environment. The goal of HIA varies considerably within different regulatory frameworks. The dominant model of HIA focuses on quantification, while some applications utilize HIA to facilitate stakeholder participation. The integrated environmental health impact (IEHI) assessment framework promotes the use of HIA to facilitate stakeholder participation by prioritizing a collaborative process for issue-framing and assessment design. This study evaluates the IEHI assessment framework's potential to alleviate tension points and sources of uncertainty surrounding environmental health during a megaproject planning process.

5.1 **Introduction**

Megaprojects provide a wide lens to observe how regulatory frameworks situate the built environment as a determinant of health within broader socioeconomic narratives. Gellert and Lynch (2003) define megaprojects as "[…] those which transform landscapes rapidly, intentionally, and profoundly in very visible ways" (p. 16). Flyvbjerg et al. (2003) characterize megaprojects as major programs costing more than 1 billion USD and attracting a lot of public attention due to potential impacts on communities, the environment and public coffers. Despite the enormity of such projects and deviation from normal or everyday governance processes, the significance of megaprojects as expressions of normativity for development processes has garnered relatively little attention from scholars.

Much of the recent research on megaproject decision-making is based on a methodology that engages critically and explicitly with the atypical sociopolitical arrangements necessitated by the physical magnitude of megaprojects. This type of analysis prescribes to *phronesis*, or what Flyvbjerg (2001) describes as social science aimed at describing how values, truths and power are negotiated in particular contexts and how these negotiations influence policy making. According to Aristotle, phronesis is 'reason capable of action' (Flyvbjerg, 2012b). Phronetic studies of megaprojects focus on analyses of stakeholder communication, political motives or agendas, and the different media through which truth and democracy are constantly challenged.

There are few, if any, case studies on the exposition of environmental health in megaproject planning, although a rich body of research on risk communication, stakeholder engagement and risk perceptions of environmental hazards informs this research area (e.g., Abelson et al., 2007; Bickerstaff, 2004; Elliot et al., 1999b; Flyvbjerg, 2012; Renn, 2008; Wakefield & Elliott, 2003). However, the effects of environmental change on health and wellbeing in the context of megaprojects have been explored (Gellert and Lynch, 2003; Parr, 2010). Complementing such scholarship, this study seeks to demonstrate how the environmental assessment (EA) process for the Detroit River International Crossing (DRIC) operationalized environmental health risks and formulated messages for risk communication.

This study utilizes the Integrated Environmental Health Impact (IEHI) assessment framework to illustrate why sources of uncertainty on environmental health impacts became tension points between the developers and community stakeholders during the DRIC Study. This is exemplified by critical examination of the assessment and planning process used to determine the location and design of the forthcoming border crossing and the Right Honorable Herb Gray Parkway in Windsor, Ontario. The DRIC Study included a study on the needs and feasibility of new border infrastructure between the United States and Canada as well as the environmental assessment for the Herb Gray Parkway.

5.1.1 *Environmental Health and Megaprojects*

In general, determinants of health can be categorized on a spectrum from the fundamental (macro level), such as the distribution of wealth and political order, through intermediate (meso/community level) and proximate (micro/interpersonal level) determinants (Schulz and Northridge, 2004). The built environment and social context constitute the intermediate level, where social variables (e.g., governance processes) can interact with physical characteristics such as land use and transportation systems to influence proximate determinants of health. Acknowledging that megaprojects can differ greatly with respect to their impact on landscapes and society, their location and consequent impacts on environmental health is of particular concern here. There are many examples of research that demonstrate how health is influenced by intermediate level determinants that differ from place to place, and theoretical developments in environmental health research illustrate the importance of context for understanding place effects on health in megaproject planning (Cummins et al., 2007; Macintyre et al., 2002).

The ecosocial perspective on health conceptualizes the interplay between societal arrangements and human biology as pathways to embodiment of a person's environment, which can manifest as health outcomes, and these pathways are of particular interest for megaproject planning when impacted communities can have large populations (Krieger, 2001). Embodiment here can be broadly defined as the expression of the environment in health and wellbeing. For example, public stakeholder participation in megaproject planning is a form of coping with health risks and constitutes a pathway to embodiment through psychological stress responses. Increasingly, yet perhaps implicitly, planning practitioners recognize the theoretical and practical importance of these pathways to embodiment and their relational health geographies, but the biomedical interventionist models of public health still dominates environmental regulation (Fehr et al., 2012; Kwiatkowski & Ooi, 2003; Spruijt et al., 2013).

Nonetheless, current trends in project planning suggest that there is sufficient structural capacity for governments to integrate the ecosocial perspective on health. Both practitioners and scholars are promoting the application of Health Impact Assessments (HIA) to complement traditional EAs as a tool in project development, though a challenge remains in terms of defining and measuring health impacts (Dannenberg et al., 2005; Negev et al., 2012)). Social Impact Assessment (SIA) is also being integrated into planning and development frameworks more frequently, but conducting HIA and SIA separately does not accommodate for the fact that public health cannot be explained in insolation from social processes and structures.

5.1.2 ***Integrated environmental health impact assessment***

Briggs (2008) argues that traditional methods of risk assessment are not capable of assessing complex or systemic risks that are strongly influenced by their social, economic and environmental contexts. Environmental health risks in megaproject development are arguably systemic because of their position within all of these contexts. Briggs (2008) defines integrated environmental health impact (IEHI) assessment as "a means of assessing health-related problems deriving from the environment, and health-related impacts of policies and other interventions that affect the environment, in ways that take account of the complexities, interdependencies and uncertainties of the real world" (p. 4). The central and defining tenets of IEHI assessment are broad and inclusive concepts of environment and health, and the prioritization of stakeholder engagement. The IEHI assessment framework brings together different methods that are currently practiced in EAs, but one of the most significant practical differences is the process of health risk assessment (Figure 5.1).

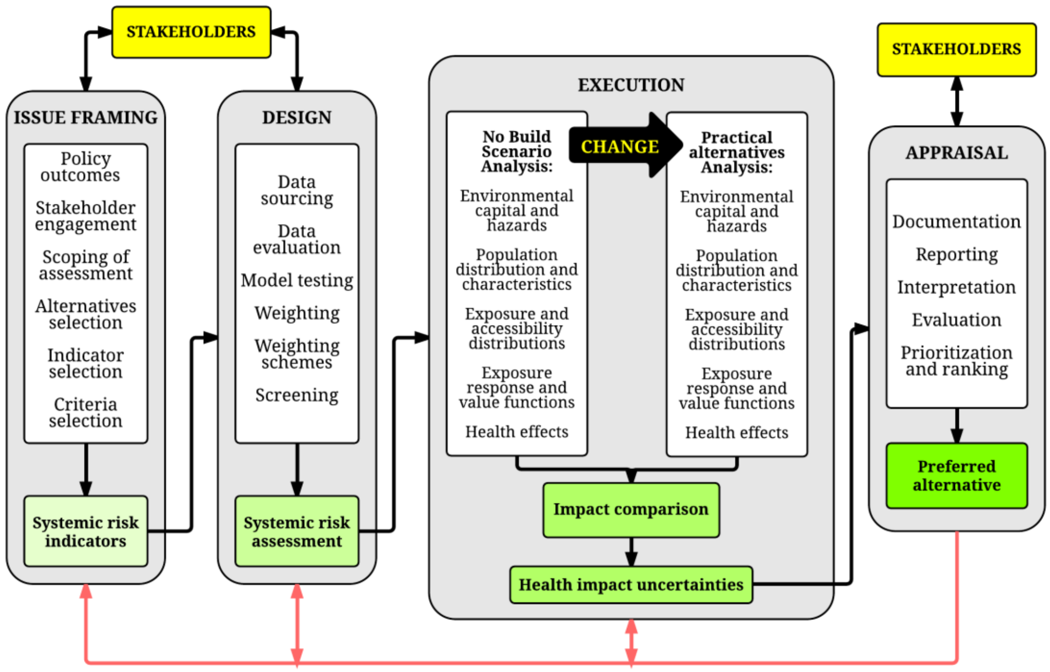

Figure 5.1 - Figure 5.1 - The IDEA procedure framework for integrated environmental health impact assessment (adopted from Briggs, 2008)

Traditional EAs and the most common forms of health impact assessments tend to subscribe to the four-step sequence for risk assessment: hazard identification, dose-response assessment, exposure assessment, and risk characterization. The IEHI assessment process pays much more attention to the pre-assessment stage to identify potential hazards, not just biological health hazards, and relies on stakeholder participation to define the relevant risks, design the appropriate assessment, and ensure that methods to interpret and evaluate risks are properly understood by all stakeholders. Briggs (2008) refers to this as the IDEA process for Issue-framing, Design, Execution and Appraisal (Figure 5.1). The framework proposed by Briggs is the outcome of the European Union projects Health and Environment Integrated Methodology and Toolbox for Scenario Assessment (HEIMTSA:http://www.heimtsa.eu) and Integrated Assessment of Health Risks of Environmental Stressors in Europe (INTARASE: http://www.intarese.org). The following discussion will illustrate the implications and advantages of following this four-stage IDEA procedure in the context of the EA and planning process for the DRIC study in Windsor, Ontario, Canada; first, by providing a brief history and context for the megaproject, and second, by contextualizing different stages of the IDEA process with conflicting perceptions and assessments of health risks in Windsor during the DRIC Study.

5.1.3 *The Windsor-Detroit Gateway: A brief history*

Two primary crossings serve passenger and commercial motor vehicles at the US-Canada border in Windsor and Detroit. The Ambassador Bridge opened for traffic in 1929 and the Detroit-Windsor Tunnel opened the following year. Apart from the addition of a ferry for trucks hauling dangerous goods and the decommissioning of railway ferries, the crossing configuration has remained unchanged since 1930. The Detroit-Windsor Tunnel has only two lanes and joins the downtown areas of the City of Detroit and the City of Windsor. Four lanes and better access to the US and Canadian freeway systems makes the privately owned Ambassador Bridge the busiest border crossing in North America. However, an additional bridge crossing owned by the Canadian government is planned for completion by 2020.

In early 2001, the Canada-US-Ontario-Michigan Border Transportation Partnership adopted a principles document that stated it had formed “to improve the safe and efficient movement of people, goods and services across the U.S./Canadian border at the Detroit and St. Clair Rivers, including improved connections to national, provincial and regional transportation systems, such as I-75 and Highway 401" (Dales, 2011, p. 10). The Partnership consisted of Transport Canada, the US Federal Highway Administration, Ministry of Transportation Ontario and Michigan Department of Transportation. The formalization of the Partnership followed a collaborative traffic survey on origin-destination patterns of cross-border trips in the late 1990s and the early part of 2000, which formed the baseline information for a subsequent Planning Need and Feasibility (P/NF) Study completed between 2002 and 2004 (DRIC Study, 2004a). The P/NF Study identified a long-term strategy for the transportation network in the region, which included major infrastructure projects to address deficiencies at the border crossing. Five alternative crossing corridors for a new access road and border crossing were considered, two of which were the proposed twinning of the Ambassador Bridge span by the Detroit International Bridge Company (DIBC) and the conversion of a rail corridor by the Detroit River Tunnel Partnership (DRTP). The central corridor corresponded roughly to the bridge location proposed by the Mich-Can group, while the south and east corridors were included as opportunities to avoid the city centers of Detroit and Windsor.

The P/NF Study informed the Ontario Ministry of Transportation Terms of Reference (TOR), which were subsequently approved by the Ontario Ministry of Environment in 2004 (DRIC Study, 2004b). An integrated EA process was proposed to meet requirements of environmental study legislation in Canada, U.S., Ontario and Michigan. By November 2005, the DRIC Study team had identified the Central corridor as the "area of continued analysis" based on the generation and assessment of illustrative alternatives (DRIC Study, 2005a). Assessments and impact studies of practical alternatives for an access road and bridge crossing in the area of continued analysis were conducted throughout 2006 and early parts of 2007, and the Technically and Environmentally Preferred Alternative (TEPA) was identified in August 2007. Impact assessments for the TEPA were conducted over the next year, and by yearend of 2008 a draft of the complete EA for The TEPA was available for comments. This included assessments of social impacts, human 'health' risks, air quality, noise and other environmental considerations.

The EA Report was submitted in January 2009, revised by March and approved by the Ontario Minister of Environment in August of 2009. The project required screening by the Canadian Environmental Assessment Agency under the federal Environmental Assessment Act, and received approval in December 2009. The Request For Qualifications to construct the access road closed in late 2009 and in November 2010 the Windsor Essex Mobility Group was awarded the contract to design, build, finance and maintain the Windsor-Essex Parkway. The official start of construction on the Parkway took place in August 2011 and in 2013 the Windsor-Essex Parkway was renamed the Right Honorable Herb Gray Parkway. Legislative, financial and legal issues in the U.S. delayed the forthcoming bridge crossing, although the final legislative hurdle for the DRIC team was a presidential permit signed by President Obama on April 12, 2013. At the time of writing construction of a new bridge has not been initiated, while the Herb Gray Parkway is anticipated for completion by summer 2015.

5.2 Source of uncertainty and tension points in the Detroit River International Crossing Study

Recent research on environmental and health related quality of life (HRQoL) in Windsor suggests that traffic noise and air pollution in the vicinity of the Herb Gray Parkway and

Ambassador Bridge impacts the health and wellbeing of nearby residents (Chapter Three & Four). This is based on high levels of noise annoyance and odour annoyance from cumulative exposures to air pollution and traffic noise negatively impacting functional HRQoL. Annoyance was not considered as a health indicator in the DRIC Study, but ironically the current upgrades to the border infrastructure are likely to have a positive effect on HRQoL through reduced traffic noise in the surrounding communities.

The survey used for Chapters Three and Four also included questions relating to public perceptions of the DRIC study and government stakeholders. The survey revealed that residents in the vicinity of the Herb Gray Parkway (n=264) were strongly in favour of a new border crossing (80.7%) and believed the border was beneficial to the local community (81.4%). However, there was strong discontent with the degree of stakeholder participation in the DRIC Study, as only 36.4 per cent of survey respondents felt that the community had sufficient input to the planning process. Furthermore, 66.3 per cent of respondents did not trust that the federal and provincial governments were providing the necessary information about risks and health impacts of air pollution, and 79.5 per cent strongly believed that border traffic was a strong contributor to air pollution in Windsor. This demonstrates that risk communication and stakeholder engagement strategies for the DRIC Study were poorly planned. However, the DRIC Study itself may have affected wellbeing among community stakeholders (Wakefield & Elliott, 2000). We argue that sources of uncertainty in the DRIC Study discussed below were instrumental to the failed engagement of community stakeholders on environmental health issues, and illustrate how the IDEA procedure of the IEHI assessment can be used to avoid such tension points in future megaprojects.

5.2.1 *Scoping health in the DRIC Study (Issue-framing)*

Arguably, the most crucial stage of any assessment that relies on stakeholder participation concerns what is referred to as issue-framing in the IEHI assessment framework. Issue-framing defines the purpose of the assessment and Briggs (2008) suggests that this requires different stakeholders to work together and create a conceptual model that provides a framework for the assessment. This necessitates a discursive process to design an assessment that can express and accommodate the widely differing languages and realities of diverse stakeholders such as regulators, technical or scientific experts and community representatives. With respect to DRIC, the need for a new crossing was initially framed by a diminishing capacity of the border infrastructure to accommodate increased cross border trade and traffic throughout the nineties and beyond. However, 9/11 changed the discourse from accommodating free trade to include homeland security and the need for redundancy at the border crossing (Sutcliffe, 2011). It also contributed to a new discourse within Windsor that embedded environmental health concerns with border crossing deficiencies.

A report by Gilbertson and Brophy (2001) showed that mortality and morbidity from all causes were higher in Windsor than the rest of Ontario. They also identified anomalously high rates and early onset of diseases that included cancers, immunity disorders, blood disorders, neurological diseases, circulatory and respiratory diseases. The authors suggested that since the rates of premature death and disease were higher than in Hamilton, another industrial city in southern Ontario, high traffic volumes associated with the border crossings and transboundary pollution from Detroit and Michigan were to blame. The frequency of articles in the Windsor Star discussing air pollution in the context of border traffic suggests that it took some time for the local media to pick up this story (Figure 5.2).

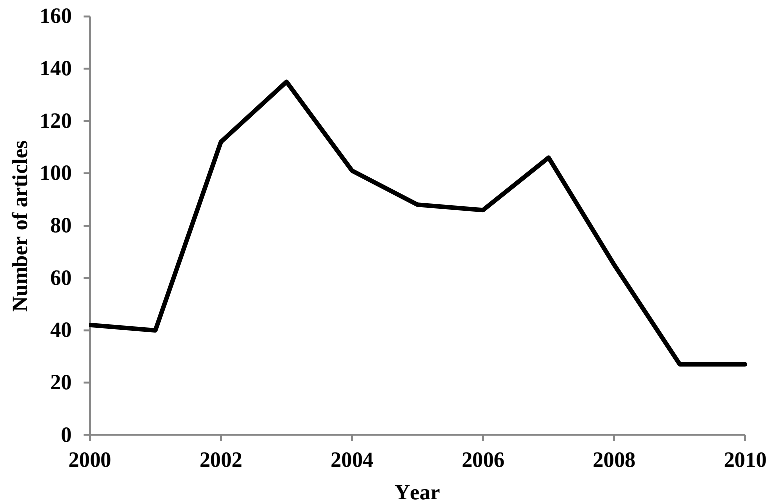

Figure 5.2 - Frequency of articles referring to air quality in the context of border traffic, The Windsor Star (2000-2010)

The number of articles discussing air quality in the context of traffic and the border crossings rose sharply from around 40 at the turn of the millennium to well over a hundred as the Gilbertson and Brophy study became known and as the DRIC Study commenced. These topics were discussed frequently throughout the planning, needs and feasibility study, which was completed in 2004, and the environmental assessment, which was completed in 2008.

By early 2003 Windsorites were accustomed to the gloomy characterization of their health and the implications for border improvements, an issue addressed by a Columnist in this way:

> *"The federal and provincial bureaucrats who have the thankless task of persuading Windsor to swallow additional truck routes through the heart of the city confessed this week that they aren't familiar with a landmark study detailing our status as Canada's cancer capital. I wasn't the least bit surprised by the blank looks when I asked these attribution- and camera-shy transportation honchos at an editorial board meeting whether they've read the Michael Gilbertson- James Brophy report which revealed in terrifying detail how Windsorites are dying in droves from environmentally related cancers, including lung, breast and pancreatic tumours. The report, which scared the daylights out of many city residents when it was released last January, confirmed that the price of living in a toxic stew down here in Smogville, the city with the worst air quality in Ontario, is all too often the premature loss of our loved ones to an agonizing disease. But the six members of the committee charged with finding $300 million worth of ways for Windsor to absorb ever-increasing volumes of carcinogen-spewing truck traffic needn't lie awake nights studying the report and fretting over the long-term consequences of their recommendations. None of them lives here."* (Henderson, 2003)

Subsequent health studies in Windsor showed that cardiac and respiratory hospitalizations (1995-2000) were associated with short-term increases in ambient air pollution concentrations (Fung et al., 2005; Luginaah et al., 2005). Luginaah et al. (2006a) found that emergency visits and hospitalizations for respiratory problems increased significantly in the days and months following 9/11, when new security measures resulted in border crossing delays and long lines of traffic in Windsor. More recent research showed that distance to the Ambassador Bridge is a strong predictor of air quality in Windsor; hence border traffic emissions likely constitute a significant proportion of air pollutants in the city's airshed (Luginaah et al., 2006b; Wheeler et al., 2008b).

The City of Windsor made significant efforts to frame the need for a new access road and crossing in terms of environmental health. The City retained the services of a prominent Canadian environmental lawyer and a prestigious engineering firm from New York, and in 2004 presented residents of Windsor with the ‘Schwartz Report,’ which proposed what came to be known as GreenLink Windsor (Schwartz, 2004). The proposal included a fully tunneled access road from Highway 401 and a traffic management center in the same location subsequently chosen by the DRIC team for the Canadian border plaza. The rationale was to reduce health impacts of border traffic on residents in the area, and a 2004 editorial in the Windsor Star captured, perhaps, the motivations behind the Schwartz report: “If the city asks for too little, it will be a strategic blunder from which the city cannot recover.”

The Partnership adamantly maintained throughout the entire duration of the DRIC Study that any potential new infrastructure needed to be assessed because of border transportation deficiencies, not to address health issues from border traffic. This message, however, was challenged in the years following 2001. Another side effect of 9/11 beyond increased congestion in Windsor was significantly reduced border crossing volumes. Other factors exacerbated this, but vehicle crossings at the Windsor-Detroit border dropped from 22 million in 1999 to 15.5 million in 2004 when the EA was initiated. By 2013 crossing volumes were down to 11 million (PBOA, 2014). The P/NF Study and the EA TOR were the outcomes of issue framing for the DRIC Study, and both reports listed increased air pollution among negative effects associated with the border transportation deficiencies. However, improved environmental quality and health were not mentioned as opportunities presented by new border infrastructure. The TOR described the process for generating, assessing and evaluating border crossing and access alternatives as well as the design, and outlined the process for stakeholder participation throughout the study. Interestingly, there was not a single instance of the term ‘health’ in the TOR for the DRIC Study.

5.2.2 *Health indicators in megaproject planning: For whom they may concern? (Design of the assessment)*

In May 2005 the DRIC Study Canadian Project Team (Transport Canada, the Ministry of Transportation Ontario and their consultants) began holding meetings with the public and various stakeholder groups. A total of seven public information open houses and approximately twenty meetings each with the Community Consultation Group (CCG) and Advisory Group were held over the full course of the DRIC Study. Additional workshops and community meetings to gather feedback on the assessment process were held between 2006 and 2008, and two focus groups along with questionnaires and interviews informed the social impact assessment. The Advisory Group was composed of public and private sector representatives, while the CCG was made up of community members (35-50), many of whom represented small interest groups who had committed to meetings beyond the public open houses and workshops, which had attendances in the hundreds. In essence, the DRIC project team provided ample opportunity for public input and feedback on the study, and substantial efforts were put into documenting public commentary. The following statement suggested that this input would be used to design the assessment:

> *"During the integrated environmental study process, MTO will provide the opportunity for interested parties, agencies, stakeholders, etc. to review and provide comments on the factors and criteria used to identify a preferred transportation planning alternative. Comments on the factors and criteria will be incorporated in the identification and assessment of planning alternatives, as appropriate. […] The assessment will be documented* ***clearly*** *and* ***concisely*** *in a format that can be easily understood by all stakeholders"* (DRIC Study, 2004b, p. 26-27, emphasis added)

This implied that a collaborative planning process would be facilitated to give stakeholders the opportunity to design the assessment. However, the DRIC Study team alone determined the assessment process, evaluation factors and criteria, effectively preventing input from community stakeholders on assessing issues that framed their needs for improved infrastructure. For example, the DRIC Study team did not provide any opportunities for residents to incorporate their perceptions of environmental health into the environmental assessment design. The seven evaluation factors were determined jointly by the US and Canadian study teams based on 18 factors previously identified by the Partnership to represent transportation objectives as well as natural, social, cultural, economic and technical considerations (DRIC Study, 2008a). The evaluation factors were used to evaluate different scenarios based on changes in air quality; protecting community/neighbourhood characteristics; maintaining consistency with existing and planned land use; protecting cultural resources; protecting the natural environment; improving regional mobility, and; cost and constructability.

A 'reasoned argument method' and the 'arithmetic method' were included in the TOR and approved by the Ontario Ministry of Environment to assess and evaluate the access road alternatives in the DRIC Study. The Partnership acknowledged that determining the relative importance of different evaluation factors was ultimately a value judgment, and the arithmetic method provided a means to compare and consider the different values of the Study team, public and CCG. However, it was noted that the reasoned argument method was the primary evaluation tool and would be given precedence in case of disagreements between the two methods. The reasoned argument method assessed alternatives based on differences in 'net impacts' derived from congruence with government legislation, policies and guidelines; existing land use and municipal policy; technical considerations; issues and concerns identified in consultations with government agencies, interest groups and the public, and; study team expertise (DRIC Study, 2008a). Needless to say, public input was not important for the reasoned argument method. The following describes how public input on weighting factors were to be considered for the arithmetic method of assessment, 'simply' and 'concisely':

> *"Prior to the evaluation of illustrative alternatives, the Project Team met to establish the Project Team numerical weight (representing level of importance) to assign each of the seven evaluation factors to be used to assess the illustrative alternatives. The Project Team weights will be used in the assessment in establishing decision rules for the reasoned argument evaluation method, as well as developing weighted scores for the arithmetic evaluation method. The members of the public were given an opportunity to provide their view on the importance of evaluation factors, through rating tools distributed at the first Public Information Open Houses**. Forty-five valid rating tools** were received from the public. As well, **15 members** of the Community Consultation Group (CCG) also completed the rating exercise. The Project Team reviewed the results of the public and CCG rating exercise*

> *in developing a set of Project Team weights."* (DRIC Study, 2005b, p. 1, emphasis added)

From 477 attendants at the first round of public information open houses, 45 'valid' rating tools were received. The most pivotal roles of the CCG and the public for the assessment design were then to provide input only on the factor weights that were consequently used to evaluate access road alternatives.

> *"The rating tools received from the public and other stakeholders were arithmetically combined and normalized to percents. It is important to note that the public and CCG weighting scenarios were developed mathematically. The weighting scenarios therefore do not reflect a consensus among study participants; individuals that participated in the rating exercise may hold views that vary significantly from those represented in the weighting scenarios."* (DRIC Study 2008a, p. 40)

In other words, the calculation of rating weights based on public input was simply a reflection of disparate views held by different stakeholders. The value judgment presented as such may be 'democratic,' but it hardly represents an opportunity to gain insight from people most likely to be affected. Opportunities for stakeholder participation were advertised in various local media and the onus was to a certain extent on stakeholders to take advantage of such opportunities. Consequently, lack of engagement could be interpreted as apathy. However, vulnerable groups may be more apathetic because they feel powerless (Day, 2007). The value of an assessment design that does not make considerable efforts to engage such vulnerable groups is highly questionable. Nonetheless, public concerns about environmental health were apparently noted; as the explanation of the arithmetic evaluation method goes on to state that, *"In addition, over 150 comment sheets were received during the first round of consultation. The most frequent comments received included concerns with: Protection of natural features; Reduction of impacts to residential areas; and Air quality/human health. […] The range of views represented in the rating tools and comment sheets received from the first round of consultation provided the Canadian Project Team with an understanding of community values with respect to the relative importance of each environmental feature, which subsequently was considered in the Project Team Weighting."* (DRIC Study 2005a, p. 46)

Following the public's concerns with air quality and human health, the Study team assigned the highest weight to improving regional mobility and the lowest weight to changes in air quality. Figure 5.3 shows the ratings and evaluation weights attributed to different factors by the Study team, public and CCG. Air quality, the closest thing representing 'health,' was rated as 85 and 91 out of 100 and therefore the most important evaluation factors for the public and community stakeholders.

Factor	Project Team		Public		CCG	
	Rating	Weight (%)	Rating	Weight (%)	Rating	Weight (%)
Changes to Air Quality	70	12.39	85	17.31	91	17.30
Protection of Community & Neighbourhood Characteristics	90	15.93	80	15.49	73	13.88
Maintain Consistency with Existing and Planned Land Use	70	12.39	62	12.89	72	13.69
Protection of Cultural Resources	70	12.39	66	13.14	69	13.12
Protection of Natural Environment	90	15.93	78	16.34	90	17.11
Improve Regional Mobility	100	17.70	76	15.28	78	14.83
Minimize Cost	75	13.27	47	9.54	53	10.07
		100		100		100

Figure 5.3 - Factor weighting scores utilized in the Arithmetic Method for assessment of illustrative and practical alternatives in the Detroit River International Crossing Study (DRIC, 2005b)

The DRIC Study team cited public consultations, stakeholder input and consultation with community groups as ‘data sources’ to evaluate community effects of different infrastructure alternatives (DRIC Study 2004c). Specifically, consultations with community groups were cited as one of the measures that would be used to evaluate disruptions to community activities that may affect quality of life, and public consultation was listed as a measure to assess impacts of air quality on human health. Health effects of air pollution and effects of disruptions to the community on quality of life were mutually exclusive, which disassociated air quality and health related quality of life in the assessment. Furthermore, noise was rationalized as a nuisance impact on the community without reference to health, which is consistent with the Ontario and Canada EA Acts, but nonetheless seems to ignore those health effects of noise established by the World Health Organization based on a strong evidence base well before the DRIC Study commenced (Berglund et al., 1999).

Performance measures for the factors were based on the 35 evaluation criteria set out in the TOR and as noted above, traffic noise, but not air pollution was considered as a performance measure for the ability of different access road alternatives to protect community and neighbourhood characteristics (DRIC Study, 2008a). Consequently, community stakeholders were not given the opportunity to assess these as a health effect; to identify or express the strong interaction effect of noise and air pollution on their quality of life (Chapter Three and Four; Klaeboe et al., 2000). The assessment design facilitated a purely toxicological conceptualization of air pollution health effects. The purpose of the design stage in IEHI assessment is to translate a conceptual model that incorporates the issue-framing of all stakeholders into an assessment protocol (Briggs, 2008). Since the DRIC Study team and community stakeholders framed the need for new infrastructure very differently, it is not surprising that the assessment design favoured the Partnership's prioritization of issues.

5.2.3 *Attributing and qualifying health risks (Execution and Appraisal of assessment)*

The execution and appraisal stages of the IEHI assessment correspond to the traditional health impact assessment process, which includes the estimation of health effects and choosing an alternative for which to seek approval. Indicators of health and other impacts are ideally selected collaboratively at the issue-framing stage, but in the DRIC Study air pollution was chosen by the study team to serve as the only indicator of health impacts. The assessment design for the DRIC Study was used to incorporate community input on selecting the Central crossing corridor as the 'area of continued analysis' in 2005 and the Technically and Environmentally Preferred Alternative (TEPA) within the area of continued analysis in 2007. For all intents and purposes, choosing a crossing location, the access road location and its configuration were the most important decisions with respect to impacts on the local community.

Roy Norton, a previous Consul General of Canada based in Detroit, stated during a lecture at Western University in London, Ontario that the DRIC team had to accommodate Michigan's preference for a crossing in the Area of Continued Analysis. This was reflected by the US illustrative alternatives assessment process, which identified two new crossing locations west of the Ambassador Bridge as the top performers. Ross Clarke of the Mich-Can International Bridge Company wrote in Windsor Star guest column "The millions DRIC spent on their study up and down the river brought them right to the place we told the government about in 1991. But it had to be done to fulfill the requirements of the Environmental Assessment Act on both sides of the river."

This suggests that the main goal of the DRIC environmental assessment was to get approval for an access road to the predetermined bridge location in Brighton Beach rather than ensuring that environmental impacts of border traffic were mitigated. In practice, this is the only logical and suitable location for a badly needed new bridge. Very few stakeholders dispute this, except perhaps the owners of the Ambassador Bridge and the Detroit River Tunnel Partnership (DRTP), which proposed converting the current railway tunnel to accommodate truck traffic. The issue of concern is therefore not the outcome of the DRIC Study, but rather the strategy that was chosen to address and delegitimize community health risks of the border traffic.

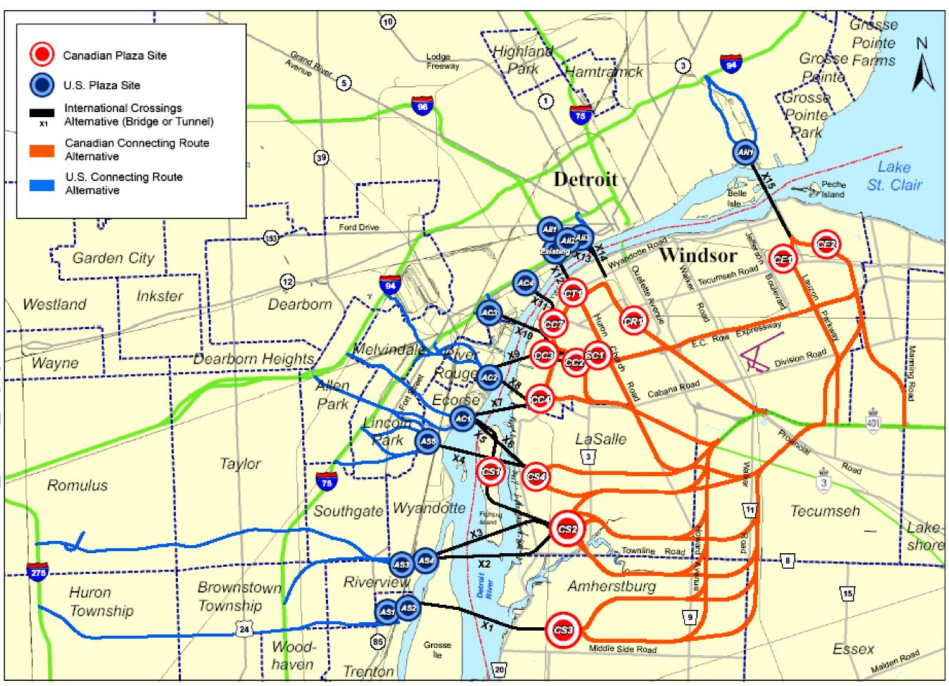

Figure 5.4 - Illustrative crossing and access road alternatives for the Detroit River International Crossing Study (DRIC Study, 2005a)

Community stakeholders were asked to assess 15 crossing locations, 13 Canadian inspection plazas and over 15 route alignments connecting the inspection plazas to Highway 401 (Figure 1; DRIC Study, 2005a). This took place at two public information open houses and seven meetings in total with the CCG and the Advisory Group, which consisted of representatives of First Nations, municipalities, government agencies, crossing operators, the private sector and schools. The CCG and its US counterpart were also treated with a fall boat tour on the Detroit River to view proposed sites for the illustrative crossing alternatives. These alternatives were developed in the P/NF Study, though further refined for the EA in terms of environmental and technical feasibility.

Twinning of the Ambassador Bridge and the DRTP rail corridor were included as illustrative alternatives and effectively eliminated from EA process by the authorities in 2005, although the possibility of connecting a new access road in the Central corridor to the Ambassador Bridge customs plaza in the US was carried forward for assessment as a practical alternative. However, the DIBC and the DRTP continued developing their private proposals as alternatives to the DRIC crossing. In March 2006, while promoting the so-called 'Jobs Tunnel' to the Joint Michigan and Senate Transportation Committees, a DRTP representative argued that the DRIC Study selection process was unfair and based on politics, not technical or environmental factors (DRTP, 2006). The DIBC made similar claims (DRIC Study, 2009a).

The arithmetic method was used to incorporate public input on the evaluation of the illustrative alternatives. The DRIC Study team alone determined and assigned a score from 1 to 7 for each evaluation factor used to assess the illustrative crossing alternatives.

These scores were weighted with the factor weights created by the Study team, CCG and public separately to demonstrate that all three weighting schemes favoured crossing alternative X10, located in Brighton Beach. The DRIC Study team assigned a score of seven for the improvement of regional mobility and a score of four for changes in air quality offered by this crossing alternative, and scores of three or below for all other evaluation factors (DRIC Study, 2005a).

This effectively implied that the Study team, public and CCG all agreed on this crossing alternative, because higher weights assigned to other evaluation factors by the public and CCG were ‘outweighed’ by the high score on regional mobility factor. It also suggested that the Study team were concerned about health because changes in air quality were given the second highest score for the Brighton Beach crossing.

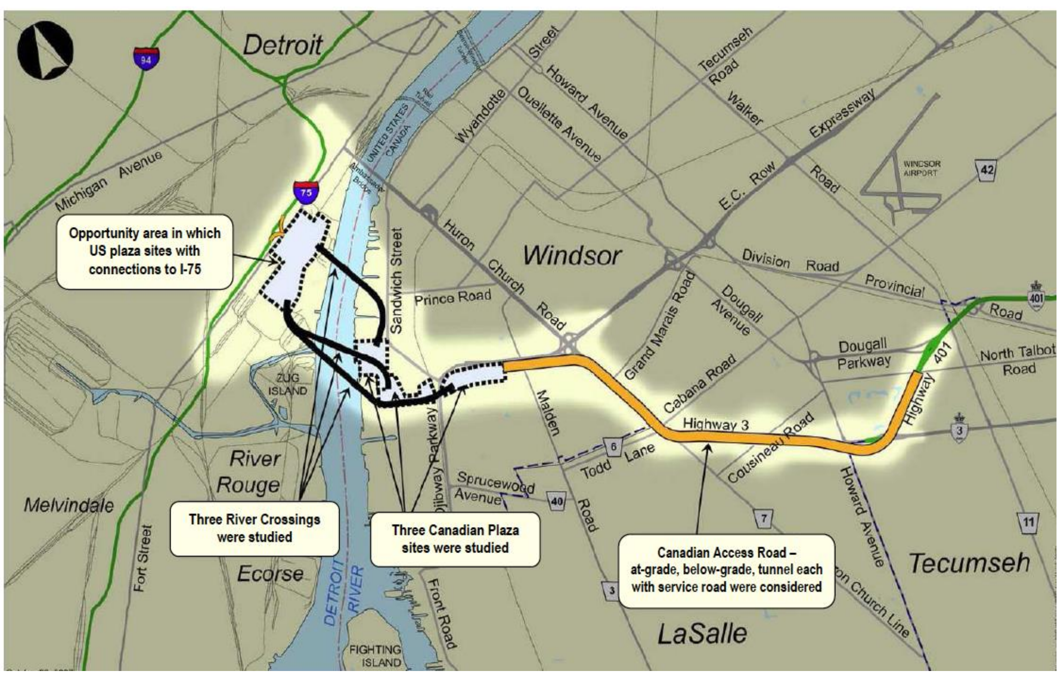

Figure 5.5 - Area of Continued Analysis determined during the evaluation and assessment of illustrative alternatives for the Detroit River International Crossing Study (DRIC Study, 2008a).

The area of continued analysis was defined by the location of this crossing alternative, which only has one feasible access route to Highway 401 along the Ojibway Parkway to E.C. Row Expressway, and Huron Church Road/Highway 3, which provide access to the Ambassador Bridge and were plagued by congestion in the years following 9/11 (Figure 5.5).

Public input on the evaluation of practical alternatives to determine the TEPA was incorporated similarly to the evaluation of illustrative alternatives (DRIC Study, 2008a). The DRIC Study team alone determined factor evaluation scores for the practical alternatives, which again resulted in the same ranking of alternatives by the three factor weighting schemes. Improvements to regional mobility offered by different access road alternatives were given scores of six and the Herb Gray Parkway proposal was scored as seven, and no other evaluation factors received scores above three on the different alternatives. The practical alternatives received the same score on all evaluation factors except mobility and cost/constructability.

The different alternatives considered included a six-lane expressway access roads at-grade, below grade, below grade fully covered corresponding to the $3.6 billion GreenLink Windsor proposal, and the below grade partly covered Herb Gray Parkway. The fully covered tunnel as proposed by GreenLink Windsor was conceived to mitigate vehicle emissions of air pollution and health impacts throughout the corridor. The DRIC Study team argued that this would only serve to displace pollution and not contribute to reducing overall emission levels. The Herb Gray Parkway was consequently appraised for its potential impacts on air quality, noise, society, and health, among other environmental, cultural and economic considerations.

The “No Build” scenario, represented by the signal-controlled access road to the Ambassador Bridge, was used as the reference scenario for impact assessments. A central assumption for the health impact and air quality assessments was that cross-boundary sources were the dominant contributors to air pollution in Windsor (DRIC Study, 2008b/c). The DRIC Study team relied heavily on two publications by the Ontario Ministry of Environment to defend this assumption (DRIC Study, 2009b). One study in 2004 described the results of pollutant monitoring along the Ambassador Bridge access corridor and concluded that contributions of traffic emissions were small because concentrations were similar at distances up to 250m from the road (MOE, 2004). The report states that “transboundary air pollutants from the United States account for up to 50 per cent of smog in Southwestern Ontario. In Windsor, this value may be as high as 90 per cent” (MOE, 2004, p. 3). This was based on a concurrent study on cross-boundary sources of pollution, which concluded, based on comparing emission sources in Ontario to the US, that US emission sources were much more important (MOE, 2005). With reference to fine particulate matter, the report concludes that “In Windsor the picture is similar to ozone: no amount of effort, by those living in the area, will improve air quality in a significant way during smog episodes.” (MOE, 2005, p. 50).

It should be noted that the geographic boundaries used to define ‘Windsor’ were not specified, and the study made no reference to local variations in air quality such as caused by the border traffic. Furthermore, neither of these reports or the DRIC Study actually conducted research on the mixing of air masses across the Detroit River. Recent research on the exchange of air masses between Windsor and Detroit shows that the DRIC Study assumption was false (Miller, Farhana, & Xu, 2010).

The TEPA air quality assessment and health impact assessment found that high concentrations of air pollution in the Central corridor posed a health risk, but these would not be exacerbated by the Herb Gray Parkway. Several peer-reviewed studies on the spatial distribution of air pollution and health in Windsor were published before the TEPA health impact assessment was published in December 2008, however, none of these were cited by the DRIC Study team (Anastassopoulos et al., 2008; Band et al., 2006; Baxter et al., 2008; Fung et al., 2005; Fung et al., 2007; Gilbertson & Brophy, 2001; Gilbertson et al, 2001; Luginaah et al., 2005; Luginaah et al., 2006a; Wheeler et al., 2008a). Remarkably, the DRIC Study team cited a study on hospitalizations from air pollution in Hong Kong and London, England, published in *Environmental Health Perspectives* in 2002, but did not cite a study on increased hospitalizations due to air pollution in Windsor published in the same journal in 2005, or three other publications on the same topic in Windsor published in different journals between 2005 and 2007. More recent studies in Windsor show that there were short-term effects of sulphur dioxide, nitrogen dioxide and carbon monoxide on emergency department visits for asthma in 2002-2009, and that intra-urban variations in air quality in Windsor are related to acute asthma events (Lavigne et al., 2012; Lemke et al., 2013).

The social impact assessment was based on a questionnaire administered to residents displaced or in the vicinity of the Herb Gray Parkway, and comments during meetings, open houses and workshops throughout the DRIC Study, which led to the following conclusion,

> *"Overall the project provides a net benefit to the communities of the City of Windsor, the Town of LaSalle, and the Town of Tecumseh due to improved flow of traffic across the border, separation of local and freeway traffic, the addition of a green space buffer between the freeway and local service roads and adjacent residents, greater connectivity between neighbourhood communities on both sides of the Highway 3/Huron Church Road corridor, opportunities for more than 20 km of recreational trails, and an overall improvement to air quality relative to the future "No- Build" alternative."* (DRIC Study, 2008d, pp. iv)

Although the social impact assessment supposedly considered nuisance and disruptions from noise and air pollution, noise annoyance and odour annoyance were not assessed. And, since the health and social impact assessments were categorically exclusive, there was no opportunity for public stakeholders to express, or the DRIC Study team to assess, interactions between social and environmental determinants of health. The Ontario and Canada environment ministers approved the environmental assessment without requiring any significant modifications to the Parkway. However, the DRIC Study received ample criticism on the impact assessments after the fact.

The internal review by the Ministry of Environment identified numerous problematic issues of the health impact assessment, a significant proportion of which related to standards used to calculate health risks and the definition of 'background' pollution concentrations (DRIC Study, 2009a). Not surprisingly, the lengthiest and most critical external comments were submitted by the DIBC and the City of Windsor. The DIBC argued that the DRIC Study did not follow the TOR in assessing how existing or alternative environments (i.e., twinning the Ambassador Bridge) could meet transportation needs, given the drastic reduction in crossing volumes during the DRIC Study. The City of Windsor submitted 83 pages of comments claiming that the EA process did not meet legal requirements of the Ontario Environmental Assessment Act; that GreenLink was not given due consideration, and; that health and air quality impact assessments were inaccurate. The DRIC Study team rejected the City's claims on the grounds that the DRIC Study facilitated stakeholder participation and therefore incorporated community concerns, and that the project would benefit all residents of Ontario. To this end, they defended that their job on behalf of the Partnership was to improve regional mobility and minimize impacts on quality of life for residents near the Herb Gray Parkway, which was a sentiment reflected through approvals of the environmental assessment by the provincial and federal levels of government.

5.3 Discussion

In essence, tension points between stakeholders on the environmental assessment of the Herb Gray Parkway boiled down to contestable definitions of health and the dubious assessment of border traffic impacts on pollution levels. The issue-framing described above demonstrates that the DRIC Study team followed legislated requirements to ensure that the project did not increase health risks, while community stakeholders viewed the project as an opportunity to mitigate health risks. The DRIC Study team was therefore operating within legal boundaries, although the Terms of Reference were equivocal in describing the role and involvement of community stakeholders. This study also demonstrates that stakeholder input on the assessment of illustrative and practical alternatives was obfuscated. Overall, the DRIC Study illustrates that there are substantial problems with current environmental legislation in Ontario and Canada with respect to the assessment of health impacts.

Although using existing environmental conditions (i.e., the "No Build" scenario) as the reference or baseline condition is a common protocol in environmental impact assessments, there are moral and ethical implications of this in megaprojects such as the DRIC, where the "No Build" scenario is already a significant health risk. Is it fair and responsible for public representatives to spend millions of dollars from public coffers to assess the most expensive road per kilometer in Canadian history ($1.6 billion in total) and only focus on not exacerbating health risks? The DRIC Study team circumvented this ethical impasse by arguing that border traffic was not a significant source of air pollution in Windsor, and that border traffic emissions did not significantly increase background concentrations from cross-boundary sources in the local environment surrounding the access road. In theory, this meant that the existing infrastructure had no negative effects on health. In practice, impact assessments for health estimated how much the different infrastructure alternatives increased health risks from no risk at all. Under these assumptions it was virtually impossible to critique the procedural coherence of the impact assessments, because even a miniscule reduction in receptor exposures to air pollution meant that there were no risks to health from border traffic.

Assessing health risks as determined by chemical hazards alone is insufficient in megaprojects such as DRIC, where scientific methods do not have the capacity to address risk uncertainties. Furthermore, the biomedical model of health is too restrictive for megaproject health impact assessment, which should accommodate the complexity of interactions between multiple exposures and other determinants of health affected by the project (Briggs, 2008). Such interactions can only be observed and assessed by designing the assessment to include local stakeholder issue-framing, and giving community stakeholders a meaningful weight in decision-making. If the DRIC Study had accommodated a systemic health risk assessment, reduced levels of environmental noise and positive social impacts of the Herb Gray Parkway (e.g., added green-space and neighbourhood connectivity) are likely to have positive health effects that could have balanced the uncertainty surrounding air quality and health.

Environmental agencies do not seem to acknowledge that there is an overwhelming evidence base for systemic determinants of health (Marmot, 2005; Marmot et al., 2008; Evans et al., 1994). This absence is pronounced by other agencies such as the Public Health Agency of Canada, for example, which recognizes the social environment and culture along with the physical environment, biology and genetic endowment as key determinants of health. Therefore, environmental legislation, specifically the Ontario and Canadian Environmental Assessment Acts create the knowledge translation gap that led to uncertainty and tensions in the DRIC Study. Health Canada is currently developing guidelines for environmental assessment of noise impacts that include using noise annoyance as a health outcome, which indicates that the Canadian regulatory framework for health impact assessment may facilitate the consideration of more systemic issues in future project planning (Michaud et al., 2008). Although adding noise annoyance as an outcome indicator constitutes a small step in practice, it is a conceptual leap towards institutionalizing sociocultural perspectives on health (Cummins et al., 2007; Krieger, 2001).

Health risk impact assessment has evolved to serve different purposes that range from focusing on stakeholder participation to purely a means of quantification, and the DRIC Study framework clearly prioritized its quantitative utility (Steinemann, 2000). This challenged the consideration of another key determinant of health relating to personal health practices and coping skills, as stakeholder participation constitutes a culturally informed coping mechanism (Renn, 2008). Briggs (2008) argues that developing the assessment with stakeholders engages them in the process of risk governance and promotes cooperation and trust. The survey results in this study showed that residents in the vicinity of the Herb Gray Parkway were highly distrustful towards the government with respect to information on air pollution health risks, even though such information is readily available from multiple government agencies. It is therefore likely that the legitimacy of the government was confounded by health risk communication during the DRIC Study, which was pertinent to the local context.

Elliot et al. (1999a) show that risk communication between experts and community stakeholders is integral to the process of risk governance. Survey respondents in Windsor felt that they were not given the opportunity to participate as stakeholders. There was a strong correlation between distrust and perceived stakeholder opportunities, which supports Briggs' assertion on risk governance. The importance of local context, risk communication and risk governance converge in the systemic risk framework, of which IEHI assessment is a variant. Renn (2008) argues that the categorical gap between expert views on technical risk assessment and public views on the democracy of risk-taking as formulated by Ulrich Beck (1992) in the ‘risk society,’ has been replaced by numerous gaps among experts and publics.

Risk perception depends on place, agency and trust (Bickerstaff, 2004). As exemplified by the DRIC Study, this makes the task of risk managing very difficult because there is currently no legislated procedure to incorporate and balance views on health risks held by different stakeholders, for example those living close versus farther away from the Herb Gray Parkway. Furthermore, challenges exist in making sure different publics are represented because social capital can influence how people act to have their perceptions represented (Wakefield et al., 2001). For these reasons and as is often the case, the legitimacy of public input as justified in risk society was demoted to a procedural requirement in the DRIC Study and institutional or technical expertise provided a safe haven for decision-makers (Renn, 2008).

Previous research shows that strategies for public participation should be sensitive to local context (Abelson et al., 2007). In this regard communication between stakeholders plays an important role in the EA process. Wakefield and Elliott (2003) confirmed that that a local newspaper was an important source of risk information for community stakeholders during the citing assessment of an industrial waste facility, but they also found that risk messages were influenced by journalistic exigencies and furthermore that residents qualified the information based on distrust and personal information networks. This suggests that some of the disparity in issue-framing by the DRIC Study team and the community stakeholders may have been caused by the portrayal of pollution health risks by the Windsor Star and other media in the years following 9/11.

The influence of media on public risk perceptions suggests that it is an important forum for information. Therefore, Flyvbjerg (2012a) argues that researchers need to engage mass-media to facilitate and challenge stakeholder communication during megaprojects. This is a central tenet of phronetic research, which aims to inform public deliberations and practice (Flyvbjerg, 2012b; Schram, 2012). To this end, phronesis calls on scholars to help clarify misunderstandings and contentious environmental health issues in megaproject planning, and Flyvbjerg (2012b) refers to such contentious issues as tension points:

> *"[…] "tension points," similar to Foucault's "virtual fractures" … are lines of fragility in the present … which open up the space of freedom understood as a space of concrete freedom, that is, of possible transformation. This type of power relation is particularly susceptible to problematization and thus to change, because it is fraught with dubious practices, contestable knowledge, and potential conflict. Thus even a small challenge – like problematization by scholars – may tip the scales and trigger change in a tension point."* (p. 171)

This suggests that environmental health theory and practice can play an important role in improving planning practices, decision-making processes, and stakeholder engagement by emphasizing how the social and environmental contexts surrounding megaprojects determine health and inform health risk perceptions during the scoping assessment design of megaprojects in particular, but any project in general. As such, engaging with media to interpret stakeholder communication and risk messages during the planning stages of a project provides an alternative for scholars wishing to promote systemic health risk assessments.

5.4 **Conclusions**

Overall, the DRIC Study represents an impressive exercise as one of the most comprehensive EAs for a transportation project in Canadian history, and was recognized as such with the Environmental Achievement Award from the Transportation Association of Canada. However, as this analysis demonstrates, it left something to be desired in terms of stakeholder participation on the assessment design, which is crucial when planning a project such as the DRIC is closely tied to environmental health and risk perceptions in the local community. This study also demonstrates that incorporating a systemic risk framework may effectively relieve tension points on environmental health issues in megaproject planning. The integrated environmental health impact assessment framework presents an opportunity for this, and most importantly it can facilitate assessment designs that incorporate sociocultural differences in risk perception key determinants of health beyond biological hazards.

The biomedical model of health employed in the DRIC Study is overly simplistic. Governmental health agencies and all major health institutions in the world recognize that the physical environment is only one key determinants of health. Environmental study legislation should be revised accordingly. The DRIC Study team provided opportunities for stakeholder participation, but crucially, residents were not provided any autonomy with respect to defining health and health impacts of environmental quality. Air pollution was only considered a toxicological health risk, and no consideration was given to odour or noise annoyance as health outcomes of exposure and coping. Of course, incorporating a systemic risk framework presents significant challenges as it acknowledges that health is multicausal and probabilistic, thereby discrediting the linear rationality offered by single-agent dose-response models commonly used to quantify health risks (Briggs, 2008). However, emerging research is bringing clarity to the interactions between multiple environmental exposures and their effects on health related quality of life (Chapters Three and Four). Further research will undoubtedly integrate such environmental health models with traditional methods of health risk assessment.

Despite a conflict of interest between the City of Windsor and the DRIC Study team in addressing border deficiencies, the planning process facilitated multilevel governance on each side and across the Detroit River (Nelles & Sutcliffe, 2013; Sutcliffe, 2012). The DRIC Study demonstrates that there is structural capacity for IEHI assessment or systemic health risk assessment in general. Integrating the social and health impact assessments, for example, would have provided a framework for the DRIC Study team and different stakeholders to negotiate divergent conceptualizations of environmental health. Sexton and Linder (2014) argue that risk assessment and sustainability evaluation are complementary methods to understand and organize information about environment-society interactions, and HRQoL is an important indicator of social sustainability. Population growth, urbanization and globalization are contributing to an increasing number of developments on a massive scale that present new challenges to the promotion of environmental health. This study demonstrates that a systemic risk framework can contribute to EAs of megaprojects and consequently promote sustainable development by balancing institutional, social, economic and environmental objectives.

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CHAPTER SIX

6. DISCUSSION

This chapter summarizes the findings of the thesis according to the objectives described in Chapter One. The findings under each objective are discussed in context of underlying theoretical constructs organized by the methodological and conceptual contributions as well as policy implications of the thesis. Finally, the thesis concludes with a commentary on future research needs to address limitations and build on findings from the thesis.

6.1 Outcomes of the research objectives

6.1.1 *Objective 1: Demonstrate the impact of high volume traffic facilities on the noise annoyance dose-response*

This objective addresses uncertainties in the literature regarding environmental factors that influence cumulative exposures of noise and air pollution and consequently health. The research and results that respond to this objective are described Chapter Three. Specifically, the study was designed to demonstrate how the presence of a high volume traffic facility could affect the covariance between assessed levels of traffic noise (DNL) and ambient nitrogen dioxide (NO_2) concentrations in a sample of study participants. This was accomplished by modeling the spatial distribution of noise and NO_2 in two areas of Windsor that differed predominantly by the presence (corridor area) or absence (control area) of a high volume traffic facility hypothesized to affect relative levels of cumulative exposures.

The results indicated that study participants in the corridor area were exposed to significantly higher levels of traffic noise and NO_2, which were attributed to the presence of the border access corridor. Figures 3.4 and 3.5 show the spatial distribution of traffic noise in the two study areas as well as the distribution of NO_2 in Windsor. It can be observed that the high traffic volume border corridor and EC Row Expressway facilities emit significant levels of traffic noise to nearby residential areas. The exposure assessment determined that cumulative exposures corresponded more closely to the road network in the control area, which was reflected by the correlation coefficients between noise and NO_2 for participant residential receptors (Table 3.2).

The correlation between traffic noise and NO_2 was 0.23 in the control area and 0.16 in the corridor area, which confirms that high volume traffic facilities can distort the relationship between noise and air pollution exposure in health studies. Furthermore, the correlation coefficient between exposures for all participants was 0.3, which is comparable to observed correlations in other studies that did not consider intra-urban variations (Allen and Adar, 2011). The results of fitting the noise annoyance data to the effective loudness function as well as an ordinal regression model showed that the noise annoyance dose-response was confounded by the presence of the border access and crossing infrastructure in the corridor area. The scale model tested if there was difference in the variance of residuals (i.e., errors) in the prediction of noise annoyance with NO_2 and traffic noise in the corridor and control areas, and the results showed that the errors were significantly larger (28%) for the corridor sample. This is contributed to the distortion of co-exposure caused by the border traffic corridor. These results satisfy the research objective and make important methodological contributions to research on co-exposure to air pollution and noise, which are discussed in sections below.

6.1.2 *Objective 2: Evaluate the effects of cumulative exposures and odour annoyance on noise annoyance*

This objective addresses the cumulative effects traffic noise and air pollution on subjective responses and makes specific contributions to several aspects of this relationship. To this end, the research builds on Objective One and the identification of the border access corridor as influential on cumulative exposures to noise and air pollution and consequently noise annoyance. Two questions guided the research: (1) Do cumulative effects of noise and air pollution on noise annoyance depend on odour annoyance? (2) Does environmental context influence noise sensitivity and consequently the effect of noise on noise annoyance?

With respect to Question 1, the results under Objective One showed that there was a significant interaction effect of noise and NO_2 on noise annoyance (Table 3.3: Model 2). Further analysis indicated that odour annoyance is an important mediator of this cumulative effect. When the confounding effects of noise sensitivity were controlled in Model 4 the results showed that odour annoyance, which increased with NO_2, had a stronger effect on noise annoyance among residents in the highest noise exposure category. These results demonstrated that there is a cumulative effect of exposure to noise and air pollution on noise annoyance, and that this effect is mediated by odour annoyance.

Question 2 was answered by estimating community tolerance levels presented in Figure 3.6 and the fitting an ordinal regression model for nose annoyance on the stratified sample (Table 3.4). The estimated community noise tolerance level (CTL) in the control area was 73 dB(A). This CTL is lower than the estimated average CTL of 78 dB(A) based on dose-responses observed in relatively noise environments (Schomer et al., 2012), but further research is needed to examine exactly which aspects of the environmental context may be responsible for reducing community levels of noise tolerance. However, Figure 3.6b shows how the noise annoyance dose-response in the corridor area was confounded, which suggested that there were influences of the environmental context on noise sensitivity. The results of the stratified regression model confirmed this as residents in the corridor who reported being somewhat sensitive to noise were much more likely to be annoyed than highly sensitive respondents. This contradicts findings in the literature as well as the control area, where higher levels of noise sensitivity lead to higher levels of noise annoyance. Given the environmental context in the corridor area, noise sensitivity may then also be a measure of coping ability, which means there are place effects on noise sensitivity. The conceptual and methodological implications of this are discussed below.

6.1.3 *Objective 3: Formulate and test a model for environmental stress effects of multiple exposures on health*

This objective reflects a lack of clarity in the literature concerning health benefits of reducing environmental stress caused by multiple exposures. The results of research for Objective 2 demonstrated the effects of exposure to multiple ambient stressors on a health outcome of psychological stress, namely noise annoyance. Utilizing spatial and survey data, the research to meet Objective 3 consisted of conceptualizing and testing a model for ambient stressor effects on environmental and health related quality of life. An analytical approach that could accommodate hypothesis testing of a causal framework as well as the presence of residual errors in the multiple exposure-response relationship demonstrated for Objectives 1 and 2 was needed. Therefore, structural equation modeling (SEM) was utilized. Since previous research demonstrates that ambient stressors activate a stress response process with coping mechanisms that include cognitive and behavioural adaptations, the research tested the hypothesis that annoyance has mental and physical health dimensions that can be measured by functional health.

The SF-12 measured eight different domains indicative of functional mental and physical health, and comparing the survey results to normative data for the Canadian population demonstrated significantly lower levels of functioning in several domains, most notably mental health, general health and social functioning domains (Figure 4.2). Physical functioning and vitality scores were also significantly lower than the Canadian average. Confirmatory factor analysis (CFA) was utilized to test the presence of latent constructs that represented subjective responses to noise and odours, as well as mental and physical dimensions of functional health. The results suggested that noise annoyance (0-10) is actually a composite measure of disturbances to daily activities caused by noise. The CFA also confirmed the presence of mental and physical constructs of functional health. The SEM model showed that noise responses had a significant and negative impact on both mental and physical constructs of functional health (Figure 4.3). The structural model confirmed that there is a systemic effect of multiple ambient stressors on health related quality of life. These results have policy implications as well as conceptual and methodological contributions discussed below.

6.1.4 *Objective 4: Critically appraise the capacity of environmental assessment frameworks for addressing environmental health in megaproject planning*

This objective applied the systemic risk framework for environmental health and stress in Figure 1.1 and related theories and perspectives that informed research and results for Objectives 1-3 to a megaproject planning process. This was accomplished by designing the quantitative data collection to capture the environmental health context of the Detroit River International Crossing (DRIC) Study, in particular the residential areas affected by the Herb Gray Parkway. Research methods to address Objective 4 included document analysis of environmental assessment reports for the DRIC Study, as well as media analysis of related coverage in the Windsor Star, a local newspaper. The objective was to assess the environmental assessment process for stakeholder participation in scoping environmental health issues and designing the assessment protocol, and contrast the DRIC Study process with an assessment framework designed explicitly to incorporate a systemic health risk perspective.

The results showed that the assessment process, deliberately or not, severely limited public input on decision-making. Rather, the analysis revealed that the assessment process relied on scientific expertise to justify decision-making. However, there were significant and inherent uncertainties in arguments for the Herb Gray Parkway based on scientific evidence on environmental health effects of border traffic in Windsor. These uncertainties validated public health risk perceptions based on evidence from previous health studies in Windsor, which exacerbated the disparity between public and expert perceptions of the issues that framed the need to address border infrastructure deficiencies. Applying the tenets of the integrated environmental health impact assessment framework served to identify specific stages of the DRIC Study process where tension points on environmental health were galvanized, but could have been diffused. Specifically, these stages included issue-framing and scoping health risks of new border infrastructure and furthermore designing the environmental assessment to address such health risk perceptions held by the community.

6.2 Research contributions and implications

6.2.1 *Conceptual and theoretical contributions*

This thesis clarifies annoyance as a health outcome using the psychological and physiological stress perspectives. Within the systemic environmental health and stress framework proposed in this thesis (Figure 6.1), Chapter Four demonstrates that environmental annoyance, conceptualized as a stress response to noise and odour disruptions of intended activities, leads to a reduced health related quality of life. As such, the thesis contributes to research on health effects of combined exposure to noise and air pollution where cardiovascular disease endpoints may be confounded by stress from subjective responses to exposures. Efforts to disentangle stress effects from direct effects of either noise or air pollution (e.g., (Babisch et al., 2013; Clougherty & Kubzansky, 2009) may benefit from applying the proposed environmental health and stress framework to account for functional health effects of psychological stress. The framework can be used to delineate causal pathways from exposure to the stress response and highlight the interaction between physiological and psychological stress responses. For assessing cumulative health effects of exposure, The SF-12 (and SF-36) instrument can be used to compare effects of the psychological stress response (e.g., annoyance) to effects of the physiological stress response (e.g., cardiovascular) on health related quality of life.

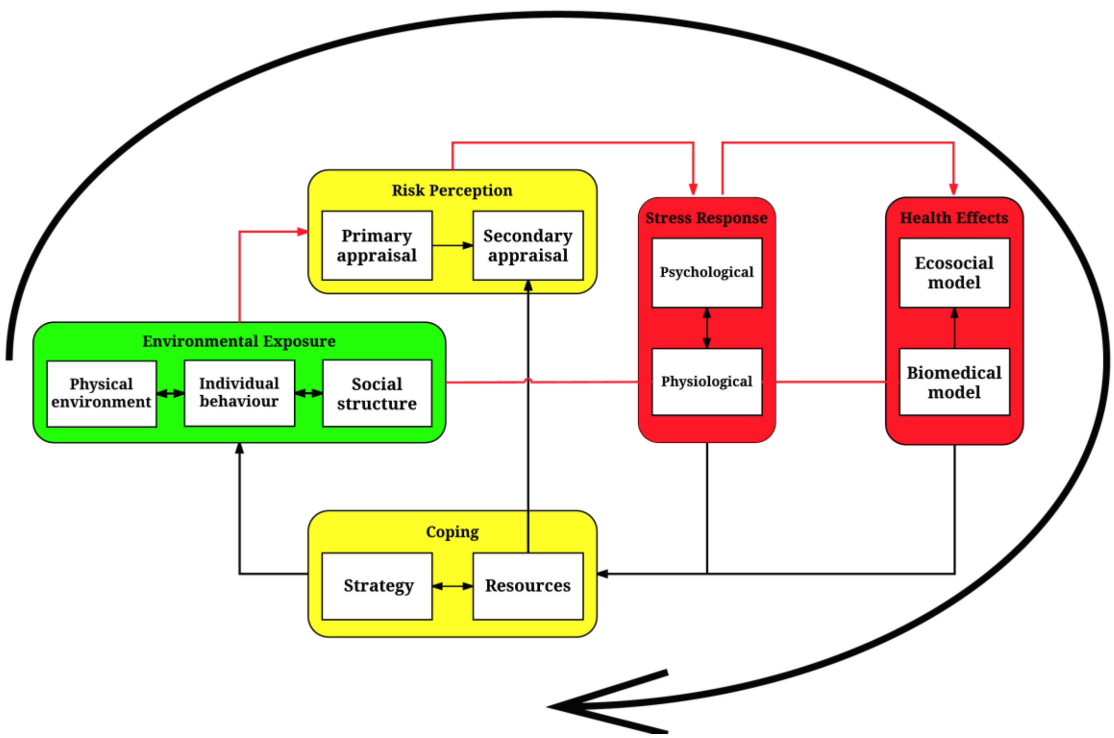

Figure 6.1 - Systemic environmental health and stress framework

However, the most valuable contribution of Chapter Three and Four relate to public health. Chapters Three and Four suggest that controlling exposure to ambient stressors as a public health strategy can have a multiplier effect on reduced stress and consequently improve health related quality of life. Protecting public health by mitigating annoyances and ambient stressors is a good reason to apply the precautionary principle, but the utility of local environmental quality to improve QoL and consequently HRQoL beyond the status quo is also being explored (Tzoulas et al., 2007). Reframing environmental health in this way is an alternative to research traditions that focus on risk reduction as the primary goal, and instead promotes concepts of sustainable development and systems analysis (Alberti et al., 2003). Research on hedonic tone suggests that ambient odours can also be leveraged to promote QoL (Sucker et al., 2008). Sucker et al. (2008) found that hedonic tone, or the (un)pleasantness of odours, has a significant effect on odour annoyance and associated health symptoms. Similarly, Andringa (2013) shows that pleasant environmental sounds can improve health.

The systemic environmental health and stress framework implies that there are several interdependent factors that affect public health in the context of ambient stressors. This is inherent in the soundscape framework, which acknowledges that individuals and communities are interdependent mediators of the relationship between environmental noise and quality of life (Schomer et al., 2013). In Figure 6.1 coping strategies, which can rely on social or individual resources, represents this. Overall, the framework proposes that there is a positive (or negative) feedback loop between coping strategies to reduce (effects of) exposure, risk perceptions, environmental stress and health. The challenge remains, however, in communicating such potential benefits to various stakeholders in environmental management.

6.2.2 *Methodological contributions*

The main methodological contributions of this thesis are (1) to demonstrate the importance of considering high volume traffic corridors and facilities as influential physical features in cumulative exposure assessment for health research, (2) showing that noise sensitivity also relates to environmental context and can therefore be used to assess contextual influences on coping ability, and (3) the development of an environmental health and stress model for assessing the effects of cumulative exposures on health related quality of life.

This thesis demonstrates that subjective responses to noise are influenced by subjective responses to odours, which can seriously confound the relationship between noise and noise annoyance depending on the collinearity of ambient stressors. The results of Chapter Three suggest that the odour response dominates at high levels of air pollution. In general then, the confounding effects of air pollution on the noise annoyance dose-responses increases as the collinearity between noise and malodorous air pollutants decreases. It should be emphasized that there is still an effect of high levels of noise in the presence of malodours, but people may report 'inflated' levels of noise annoyance in the presence of relatively low levels of noise where malodourous pollutants are present. This may contribute to the relatively low levels of explained variance for noise annoyance observed in past research, which is approximately 20 percent on the individual level and approximately 40 percent on the group level (Schomer et al., 2013).

Effects of malodours and low collinearity between noise and odours challenge the methodological rigour of research that questions the role of noise annoyance as a mediator of annoyance effects on cardiovascular disease outcomes (Babisch et al., 2013). Recent studies have investigated the relationship between noise and air pollution and pointed to varying traffic volumes and compositions or meteorology as influential (e.g., Allen et al., 2009; Gan et al., 2012), but very few have conceptualized area influences of the physical environment as influential (Foraster et al., 2011; Tang & Wang, 2007). While traffic characteristics capture the effects of the border corridor to a certain extent, the reduced collinearity between noise and air pollution in this area was in large part due to high convergence of truck and car traffic towards the Ambassador Bridge. Therefore, combined with urban form and other environmental conditions that influence the dispersion of air pollution and traffic noise, this thesis demonstrates the importance of considering potential area effects of high volume traffic facilities for cumulative exposure assessments in future research on noise and air pollution.

The second major methodological contribution of this thesis relates to assessing health impacts of noise and odour annoyances. The prevalence of these annoyances can be estimated with established dose-response relationships for both ambient odour (Sucker et al., 2008; Griffiths, 2014) and noise (Miedema, 2004). With respect to noise, however, there is a lack of consensus on the definition of annoyance, which has complicated the conceptualization of noise as a health outcome. In the broadest sense, all definitions imply that annoyance detracts from a complete state of wellbeing and therefore affects health. Theoretical and empirical research has led to five different definitions of annoyance as emotion; a result of disturbance; as attitude; as knowledge, and as a result of rational decisions (Guski et al., 1999). These multifaceted definitions imply that annoyance can be operationalized as an indication of immediate behavioural effects of noise due to disturbance or interference with intended activities, or annoyance as an evaluative aspect similar to nuisance or unpleasantness (Guski et al., 1999). These two generalized meanings of annoyance have very different implications for health. It is difficult to justify that annoyance as an evaluative aspect is a public health issue.

Conversely, as an indicator of behavioural change in response to a chronic ambient stressor, annoyance becomes a public health concern. This thesis makes a methodological contribution in this regard by assessing effects of such behavioural changes on functional health using the SF-12 health related quality of life instrument. The findings point to the need for policies that can mitigate the effects of ambient stressors on behavioural changes and environmental stress.

6.2.3 *Policy implications*

Using a soundscape framework to compare legislative approaches to environmental noise in New Zealand and Australia, Thorne and Shepard (2013) argue that quietness rather than maximum sound levels should be valued, because quiet is a midpoint, not an endpoint along the psychoacoustic continuum from tranquil to intrusive. The authors suggest that legislative guidance based on wellbeing and quality of life is more amenable to the soundscape framework, hence a systemic view of environmental health. It is therefore important to conduct research on environmental Qol and HRQoL that provides policy makers with clear evidence to support legislation on environment and health.

In 2006, Health Canada published a review in support of using the percent highly annoyed (%HA) as a health outcome in projects requiring a health impact assessment for noise under the Canadian Environmental Assessment Act (Michaud et al., 2008). This was preempted with large national surveys on noise annoyance discussed in Chapter Three, and Health Canada currently recognizes noise-induced hearing loss, sleep disturbance, interference with speech communication, complaints and change in %HA as endpoints for noise-induced health effects (Health Canada, 2011). However, there are still no federal noise annoyance guidelines, enforceable thresholds or standards. Likewise, there are no guidelines or standards for odour assessment or health impacts at the federal or provincial levels in Canada. Nonetheless, this thesis shows that subjective responses to both odours and noise are indicators of functional health effects, which offers a new way to conceptualize health risks for development of policy in the future.

Miedema (2007) argues that there is ample evidence to develop and support policies for noise annoyance mitigation. The argument for mitigating annoyance is especially salient considering increased population densities and pressures on residential development that bring people closer to industrial land uses and large infrastructure. The results of critically analyzing the DRIC Study in Chapter Five present further evidence in support of developing policies to address environmental health. As new infrastructure (mega)projects restricted by residential development take place, it will be important to recognize that environmental risk perceptions and ambient stressors responses will continue to cause tension between public stakeholders and developers and will frequently require policy intervention.

Furthermore, by revealing the limitations of the current environmental assessment process, this thesis contributes to the rapidly advancing field of cumulative risk assessment (Sexton, 2012), which is broadly described as either concerned with effects of multiple chemical hazards, or a mixture of stressor-based and chemical hazards. Cumulative risk assessment is essentially what takes place during the execution stage of the IDEA process for systemic health risk assessment (Briggs, 2008). Most regulatory jurisdictions are processing or have already legislated some form of cumulative risk assessment. In fact, the Canadian Environmental Assessment Agency offers a "Cumulative Effects Assessment Practitioner's Guide" (Hegman, et al. (1999). However, Duinker and Greig (2006) argue that this has been a failed project for several reasons including a predominant focus on project approval, separation of cumulative effects from project-specific impacts, and a weak knowledge base on the evaluation of cumulative effects.

6.3 Future research needs

Research in environmental health geography needs to continue advancing to grow the knowledge base on cumulative exposures. Borrowing from critical and humanistic perspectives in health geography and quantitative advances in medical geography, past research certainly provided support for the ecosocial, or socio-ecological health model of ambient stressors as an alternative to the reductionist biomedical model of health. However, the increasing recognition of systemic health risks in multiple dimensions of everyday lives (e.g., social, cultural and environmental), and the consequent relevance of cumulative exposures means that much of the environmental health research to date is reductionist by rarely addressing more than one type of environmental hazard. Focusing only on cumulative exposures divorced from their social and environmental context is likewise a reductionist approach. A significant limitation in exposure assessment is the reliance on 'static' estimates (e.g., residential) that do not take into account time-space activities, which was the case for this study. However, recent developments in GIS that facilitate the assessment of individual exposures temporally and spatially, combined with a systemic environmental health and stress perspective that considers cumulative exposures, holds great promise for a future environmental health research that is interdisciplinary and policy relevant.

Even so, Foraster (2013) argues that varying methods of modeling and estimating exposures for noise and air pollution cause the inconsistent findings in the literature. Given resource restrictions and a diversity of local conditions, it is not likely that methods for exposure assessment will be standardized. However, exposure assessment for noise currently shows higher congruence than assessment for air pollution. While land use regression has become, perhaps, the dominant form, recent research questions the reliability of health effects estimated with land use regression models (Basagana et al., 2013). As in this thesis, such challenges are compounded by lacking information on the daily activities in time and space for study participants. Therefore, significant amounts of work remain to characterize the individual and community level variables that affect multiple exposures. One example of work needed to build on the current thesis is to compare communities in different context with similar levels of noise exposure to see if community tolerance levels are determined by cultural or built environment characteristics, or both. To this end, future research will also have to use qualitative methods to get a more nuanced understanding of the relative effects of the physical environment and built form versus sociocultural context on ambient stressor health outcomes.

Mixed methods will continue to be a requirement in future research to get a clearer picture on how people define, and therefore respond to survey questions on environmental annoyances. This thesis showed that noise annoyance was a composite measure of disturbances to intended activities, but more research is needed to understand annoyance as an evaluation. Schomer et al. (2013) points to negative scales used to measure noise (and odour) annoyances as an impediment to research in this field, and suggest that survey items should also include a positive scale component. That is, respondents should be given the opportunity to rate ambient exposures on scales that range from highly unpleasant or annoying to highly pleasant. This will facilitate a better understanding of how quantitative measures of exposure reflect qualitative responses to exposure.

Developing and practicing more effective ways of communication between researchers, public stakeholders and institutional actors is arguably the most crucial task for future work on the environmental health effects of cumulative exposure. Environmental health and the Detroit River International Crossing Study in Windsor, Ontario teaches us that the task of weighting the costs versus benefits of technology -- environmental hazards versus economic growth -- is an incredibly difficult task that challenges democracy and science at once, and the very foundations of modernity that continue to drive human progress through technology. We may never discover the exact formula for calculating the cumulative human health risks of multiple environmental exposures, but an informed and ongoing discussion facilitated by research on the costs and benefits of technology will go a long way to ensure science and democracy serve their intended purpose.

6.4 References

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Appendices

APPENDIX A: LETTER OF ETHICS APPROVAL

Western Research

Research Ethics

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Isaac Luginaah
File Number:103300
Review Level: Full Board
Approved Local Adult Participants: 0
Approved Local Minor Participants: 0
Protocol Title: Community Health and Tranpsortation Infrastructure Development: A Case Study in Windsor, Ontario
Department & Institution: Social Science\Geography,Western University
Sponsor:
Ethics Approval Date: February 22, 2013 **Expiry Date:** December 31, 2013

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Protocol		2012/12/02
Western University Protocol		2012/12/02
Other	Responses to REB Suggested Revisions	2013/02/15
Other	Query on Third Party Confidentiality Issues	2013/02/15
Other	Canadian Viewpoint Corporate Policy	2013/02/15
Other	Canadian Viewpoint Nondisclosure Agreement	2013/02/15
Letter of Information	Letter of information	2013/02/15
Recruitment Items	Postcard to potential participants	2013/02/15
Instruments	Survey questionnaire	2013/02/15

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above named research study on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Ethics Officer to Contact for Further Information

✓ Grace Kelly (grace.kelly@uwo.ca)	___ Janice Sutherland (jsutherl@uwo.ca)

This is an official document. Please retain the original in your files.

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6A 3K7 t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/services/ethics

APPENDIX B: LETTER OF INFORMATION AND ONLINE SURVEY INVITATION

Your household has been selected to participate in a study on community health and transportation being conducted by researchers at Western University and the University of Windsor!

By completing the survey before [closing date], you will be entered into a draw for a chance to win 1 of 10 $100 Gift Certificates to Devonshire Mall.

This letter serves as an invitation to complete the online survey, and to provide you with information regarding the purpose and confidentiality of the study. If you do not complete the online survey, we may contact you by phone within a few weeks of the closing date above.

How to participate?

Go to www. .com where you will be asked to enter the 5-digit PIN that is printed directly above your mailing address at the top of this page. Once you have entered the online survey you will be provided detailed directions on completing the online survey.

If you *prefer* to conduct the survey by telephone, please call .

You must be 18 years of age or older to participate and preferably the household member whose birthday is next.

Questions about completing the online survey can be directed to .com

University of Windsor thinking forward

Western

LETTER OF INFORMATION

<u>Project Title</u>:
Community health and transportation infrastructure development: A case study in Windsor, Ontario

<u>Principal Investigator</u>:
Dr. Isaac Luginaah, PhD, Department of Geography, Western University, London, Ontario

I am an Associate Professor and Canada Research Chair in Health Geography in the Department of Geography at Western University. I am part of a team of researchers from Western and the University of Windsor who are conducting a study of the community health impacts of border traffic and the effects of the current infrastructure development on quality of life in Windsor. You or someone in your household are invited to participate in this study because your home is located within our specific areas of interest. These areas include neighbourhoods along the corridor leading to the Ambassador Bridge from Highway 401 as well as neighbourhoods east and northeast in Windsor for comparison. The purpose of the Letter of Information is to inform you about the study and to provide you with the information required to make a decision on participating.

The purpose of the survey is to gather information about residents' general health, perceptions of pollution and transportation infrastructure development, and opinion on a range of issues related to the construction of the Windsor Essex Parkway and forthcoming border crossing. Combined with environmental data on traffic noise and air pollution, the survey responses will allow us to investigate associations between environment and health. Additionally, we are interested in how perceptions and opinions of environmental health can influence wellbeing and quality of life. Understanding these issues will be of value to future development in Windsor and Canada at large, as well as policy-making in air quality and transportation management along with health care in highly trafficked areas.

We ask that the household member over the age of 18 whose birthday is next complete a phone survey. If this person cannot complete the survey anyone over the age of 18 is eligible. If a member of your household agrees to participate in the study, they will be asked to select answers to questions posed by the interviewer. A representative from the professional survey agency Canadian Viewpoint Incorporated will conduct the interview, which will take approximately 20-30 minutes to complete. <u>Completion of the survey is indication of your consent to participate</u>. The survey will be introduced in English, but a French-speaking interviewer is available upon request. No personal information will recorded within the survey and no personal identification will be used in any report or publications. If you want to enter into the draw for one of ten $100 gift certificates to Devonshire Mall upon completion of the survey, we will ask for your preferred method of contact, but this information will kept separately from your survey responses and destroyed after the gift certificates are drawn.

Risks and discomforts to you if you participate in this study:

- There are no known risks to your participation in this study. You can refuse to answer any question(s) during the survey that may discomfort you.

The benefits to you if you take part in this study:

- While there is no immediate personal benefit from participating in this study, your participation will help local planners and policy makers determine the overall extent and impact of the environmental and other changes taking place in Windsor as a result of the construction of the new parkway and border crossing. Additionally, your participation will help advance our understanding of traffic effects on health and wellbeing, which is needed to effectively manage health in Windsor and elsewhere.

Participation and Withdrawal:

- Participation in this study is voluntary.
- You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on you.
- If you are already participating in another study at this time, please inform the interviewer right away to determine if it is appropriate for you to participate in this study.

Specific things you should know about confidentiality:

- All the information obtained from people participating in the study will be strictly confidential. Your research records will be stored in the following manner: All survey responses will be encrypted on a secure data base by Canadian Viewpoint Inc. until the survey is completed. At this time <u>all data</u> will be securely transferred to our research team, who will store the encrypted data within a secure database at Western University. The data will be destroyed after 5 years. Note that information collected separately by Canadian Viewpoint Inc. for the purpose of gift certificate draws will also be encrypted and stored on a secure database, but only until draws have been completed, at which time the information will be destroyed. Our research team will not have access to this information, and it will not be possible to link this information to the survey responses.

- Your name will not be used and no information that discloses your identity will be released or published without your specific consent to the disclosure. Your confidentiality will be respected. The results of the study will be published in academic journals and a summary report will be made available to stakeholders and participants upon request.

- The Research Ethics Board at The University of Western Ontario may contact you directly to ask about your participation in the study. If we find information we are required by law to disclose, we cannot guarantee confidentiality. We will strive to ensure the confidentiality of your research-related records. Absolute confidentiality cannot be guaranteed as we may have to disclose certain information under certain laws.

Contact persons:

If you have any questions about this study please contact Dr. Isaac Luginaah at or Tor H. Oiamo

- If you have questions about the conduct of this study or your rights as a research subject you may contact:

Office of Research Ethics
Western University

Research Ethics Board
University of Windsor

Other pertinent information:

- You will not be compensated for your participation in this study.
- You do not waive any legal rights by signing the consent form.
- If the results of the study are published, your name will not be used.
- If you would like to receive a copy of the overall results of this study please put your name and address on a blank piece of paper and give it to the interviewer.

Thank you in advance for your participation in this important study.

Sincerely,

Isaac Luginaah (Principal Investigator)
Associate Professor of Geography

This letter is yours to keep for future reference.

APPENDIX C: SURVEY INTRUMENT FOR WINDSOR STUDY OF HEALTH AND TRANSPORTATION

Sections:

a. **Attitudes towards community**
b. **Environmental exposure and perceptions**
    a. **Time/activity pattern**
    b. **Exposure to Airborne Irritants**
    c. **Exposure to Noise**
    d. **Traffic noise annoyance**
    e. **Odour Annoyance**
    f. **beliefs about pollution sources and effects**
c. **Transportation Framework**
    a. **Stakeholder perceptions**
    b. **Travel behaviour**
d. **Health Status**
e. **Socio-Demographic Questions**

The following text will be used to introduce the phone interviews:

Hello, my name is [ ] from Canadian Viewpoint and I am conducting a survey for researchers at Western University in London, Ontario, and the University of Windsor. May I speak to the person 18 years or older, whose birthday is next?

The study is concerned with how transportation affects community health and how transportation planning and development can be used as a tool to improve community health. You have been selected as a participant because of where you live and your input is very important to us. Please be aware that by completing the survey you have consented to take part in the study. You have the right to refuse to participate, and you also have the right to refuse to answer any questions at any time during the interview. If the results of the study are published, no information that discloses your identity will be released or published without your specific consent to the disclosure. The results of this study will have important implications for future urban development in Windsor and Canada at large. Therefore, upon completion of the survey you will be automatically entered into draws for ten $100 gift certificates at Devonshire Mall.

Some of the questions are of a personal nature and some ask about mental and physical health. However, your responses will be reported in such a way that your anonymity will be protected. All the information obtained from people participating in the study will be strictly confidential. This is not a test and there are no correct or wrong answers. Choose the response that best represents the way you feel. The interview will take approximately 20 minutes.

The following text will be used to introduce the online survey:

Hello, thank you for your decision to participate in this survey!

Canadian Viewpoint is conducting this survey for researchers at Western University in London, Ontario, and the University of Windsor. The study is concerned with how transportation affects community health and how transportation planning and development can be used as a tool to improve community health. You have been selected as a participant because of where you live and your input is very important to us. Please be aware that by completing the survey you have consented to take part in the study. You have the right to refuse to participate, and you also have the right to refuse to answer any questions. All the information obtained from people participating in the study will be strictly confidential. If the results of the study are published, no information that discloses your identity will be released or published without your specific consent to the disclosure. The results of this study will have important implications for future urban development in Windsor and Canada at large. Therefore, upon completion of the survey you will be automatically entered into draws for ten $100 gift certificates at Devonshire Mall.

If you would prefer to complete the survey by phone, please call x-xxx-xxx-xxxx and provide a good time for us call you.

You will only have one opportunity to complete the survey, but if you cannot finish the entire survey in one sitting, you can resume this study by clicking the original link. Our system saves your previous answers and will allow you to resume where you left off so long as the study remains open. You can refuse to answer any question by selecting the SKIP button.

Some of the questions are of a personal nature and some ask about mental and physical health. However, your responses will be reported in such a way that your anonymity will be protected. This is not a test and there are no right or wrong answers. Choose the response that best represents the way you feel. Please take time to read and answer each question carefully, and click the circle that best represents your answer.

Before you start, are you 18 years or older and the household member whose birthday is next? If yes, please continue.

INTERVIEWER:

Are you 18 years of age or older?

Are you Male or Female?

SECTION A: ATTITUDES TOWARD THE LOCAL AREA WHERE YOU LIVE

First, I'd like to ask you a few questions about your local community.

A1 How many years have you lived in Windsor?
- Less than 1 year
- Enter number of years
- Don't Know
- Not applicable/refused

A2 How many years have you lived in this neighbouthood?
- Less than 1 year
- Enter number of years
- Don't Know
- Not applicable/refused

A3 How long have you lived at your current address?
- Less than 1 year
- Enter number of years
- Don't Know
- Not applicable/refused

A4 In general, are you satisfied or dissatisfied with your community as a place to live?
- Very dissatisfied
- Somewhat dissatisfied
- Neither satisfied or dissatisfied
- Somewhat satisfied
- Very satisfied
- Don't Know
- Not applicable/refused

SECTION B: Environmental exposure and perceptions

a. Time/activity pattern

We would like to ask a few questions about your **typical daily activity pattern over 24 hours** (excluding days off or holidays if you work or go to school full time)

B1 Approximately how many hours per day do you spend away from home, for example at work or other location of regular activity?

- Enter number
- Don't know
- Not applicable/refused

B2 What is the approximate location of where you spend most of your time away from home, at work or during other regular activity? Please provide at least one of the following:

- Street address
- Postal code
- Nearest intersection
- Don't know
- Not applicable/refused

b. Exposure to Airborne Irritants

We would now like to ask you some questions about possible exposures to airborne irritants and environmental noise at your home and workplace.

B3 Are you currently or have you ever been exposed to gases, fumes or chemicals at work?

- yes
- no
- don't know
- Not applicable/refused

B4 Are you currently or have you ever been exposed to dust at work, for example from sanding, sweeping, or vacuuming?

- yes
- no
- don't know
- Not applicable/refused

B5 In the past twelve months have you used a fireplace in your home?

- yes
- no

- don’t know
- Not applicable/refused

B6 In the past twelve months have cats, dogs or birds been kept as pets in your home?

- yes
- no
- don’t know
- Not applicable/refused

B7 What types of flooring does your house have? Does it have: (READ LIST; select all that apply)

- Wall-to-wall carpets
- Ceramic tiles
- Wooden floor
- Vinyl, linoleum or cork flooring
- One or more big heavy rugs
- Other (specify)
- Not applicable/refused

B8 In the past twelve months has an air conditioner been used in your home?

- yes
- no
- don’t know
- Not applicable/refused

B9 In the past twelve months have you used an air humidifier in your home?

- yes
- no
- don’t know
- Not applicable/refused

B10 In the past twelve months have you used an air filter excluding the filter on your AC or furnace) in your home?

- yes
- no
- don’t know
- Not applicable/refused

c. Exposure to Noise

B11a Are you currently or have you ever been exposed to loud noise at work?

- Yes
- No

- Don’t know
- Not applicable/refused

B11b If yes, how many hours per week are you exposed to that noise?

- Enter number
- Don’t know
- Not applicable/refused

B12 Do you currently use hearing protection at work or during other regular activities?

- yes

- no
- don’t know
- Not applicable/refused

B13 Do noise levels at work or during other regular activity prevent conversation with co-workers in a normal voice?

- yes

- no
- don’t know
- Not applicable/refused

B14 Do you regularly engage in noisy hobbies such as use of motorcycles, power tools, firearms, or listen to loud music?

- yes

- no
- don’t know
- Not applicable/refused

d. Traffic Noise Annoyance

B15 Thinking about the last 12 months or so, what number from 0 (no disturbance) to 10 (intolerable disturbance) best shows how much you are bothered, disturbed or annoyed by road traffic noise?

- Enter number
- Don’t know
- Not applicable/refused

B16 Thinking about the last 12 months or so, when you are **in your neighbourhood**, is traffic noise highly, somewhat, or not annoying?

- Not annoying
- Somewhat annoying
- Highly annoying
- Don’t know
- Not applicable/refused

B17 Thinking about the last 12 months or so, when you are **inside your dwelling**, is traffic noise highly, somewhat, or not annoying?

- Not annoying
- Somewhat annoying
- Highly annoying
- Don’t know
- Not applicable/refused

B18 Thinking about the last 12 months or so, when you are **outside your dwelling**, is traffic noise highly, somewhat, or not annoying?

- Not annoying
- Somewhat annoying
- Highly annoying
- Don’t know
- Not applicable/refused

B19 Would you say you are highly, somewhat, or not sensitive to noise?

- Not sensitive
- Somewhat sensitive
- Highly Sensitive
- Don’t know
- Not applicable/refused

B20a Over the past 12 months or so, while you were at home, did road traffic noise never, seldom, sometimes, often or always interfere with your ability to… sleep?

- never
- seldom
- sometimes
- often
- always
- don’t know
- Not applicable/refused

B20b …hear other people or the TV and radio inside your home?
- never
- seldom
- sometimes
- often
- always
- don't know
- Not applicable/refused

B20c …concentrate on tasks such as reading and writing?
- never
- seldom
- sometimes
- often
- always
- don't know
- Not applicable/refused

B20d …feel relaxed and peaceful at home?
- never
- seldom
- sometimes
- often
- always
- don't know
- Not applicable/refused

f. Odour Annoyance

B21 During this past 12 months, how often, if ever, did you notice odours that you think were from industry or traffic when you were at home or in your yard?
- never
- seldom
- sometimes
- often
- always
- don't know
- Not applicable/refused

B22 On a scale of 0-10 (no disturbance at all) to 10 (intolerable disturbance), how much are you annoyed by odours from traffic and industry at your actual home, if you keep the windows open?

- Enter number
- Don't Know
- Not applicable/refused

B23 How often did you have to keep the windows closed because of odours in the past 12 months?
- Often
- Occasionally
- Seldom
- Don't Know
- Not applicable/refused

g. Beliefs about pollution sources and effects

Now we would like to ask you a few questions about your opinion on environmental quality in Windsor and the new border crossing.

B24 Relative to other areas in Windsor, do you think the level of air pollution in your neighbourhood is low, the same, or high?
- Low
- The same
- High
- Don't Know
- Not applicable/refused

B25 Relative to other cities in southwestern Ontario, do you think the level of air pollution in Windsor is low, the same, or high?
- Low
- The same
- High
- Don't Know
- Not applicable/refused

Please indicate how much you believe the following sources contribute to air pollution at your home on a scale from 6 being a lot to 1 being not much:

B26 Trans-boundary pollution from the US
- Enter number
- Don't Know
- Not applicable/refused

B27 Industry in Windsor
- Enter number
- Don't Know

- Not applicable/refused

B28 Border traffic
- Enter number
- Don't Know
- Not applicable/refused

B29 Local traffic
- Enter number
- Don't Know
- Not applicable/refused

B30 Do you believe that pollution from traffic is causing health problems in your community?
- Yes
- No
- Don’t know
- Not applicable/refused

B31 Would you say you Strongly Believe, Believe, are Neutral, Disbelieve or Strongly Disbelieve that pollution is a health risk to people who live in Windsor?
- Strongly Believe
- Believe
- Neutral
- Disbelieve
- Strongly disbelieve
- Don't Know
- Not applicable/refused

B32 Do you trust that federal and provincial ministries are providing the necessary information about risks and health impacts of air pollution?
- Yes
- No
- Don’t know
- Not applicable/refused

B33 Do you trust that the City of Windsor is providing the necessary information about risks and health impacts of air pollution?
- Yes
- No
- Don’t know
- Not applicable/refused

SECTION C: Transportation Framework

a. Stakeholder perceptions

Now we would like to ask you a few questions about transportation planning and development in Windsor.

C1 Do you think a new border crossing is necessary?
- Yes
- No
- Don't know
- Not applicable/refused

C2 Have you relocated because of the Windsor-Essex Parkway or Detroit River International Crossing project?
- yes
- no
- don't know
- Not applicable/refused

C2b If yes, were you expropriated?
- yes
- no
- don't know
- Not applicable/refused

C3 Do you know someone who is presently affected by the construction of the Windsor Essex Parkway?
- yes
- no
- don't know
- Not applicable/refused

C4 Do you know someone who has relocated because of the Parkway or DRIC?
- yes
- no
- don't know
- Not applicable/refused

C4b If yes, were they expropriated?
- yes
- no
- don't know

- Not applicable/refused

C5 Are you presently affected by the construction of the Windsor-Essex Parkway?
- yes
- no
- don’t know

- Not applicable/refused

C6 Do you think Windsor residents had sufficient input to the planning process of the Windsor-Essex Parkway?
- yes
- no
- don’t know

- Not applicable/refused

Please indicate on a scale from 6 to 1 how much you agree or disagree with the following statements:

C7 The growing usage of energy for road transportation is concerning
AGREE 6 5 4 3 2 1 DISAGREE
- don’t know

- Not applicable/refused

C8 Too much land in Windsor is dedicated to transportation uses
AGREE 6 5 4 3 2 1 DISAGREE
- don’t know

- Not applicable/refused

C9 The border crossings are beneficial to the local economy
AGREE 6 5 4 3 2 1 DISAGREE
- don’t know

- Not applicable/refused

C10 Transportation planning in Windsor should prioritize **commercial and industrial activities**
AGREE 6 5 4 3 2 1 DISAGREE
- don’t know

- Not applicable/refused

C11 Transportation planning in Windsor should prioritize **active modes of transport (walking and bicycling)**
AGREE 6 5 4 3 2 1 DISAGREE
- don't know

- Not applicable/refused

C12 Transportation planning in Windsor should prioritize **public transit**
AGREE 6 5 4 3 2 1 DISAGREE
- don't know

- Not applicable/refused

C13 Transportation planning in Windsor should prioritize **automobiles**
AGREE 6 5 4 3 2 1 DISAGREE
- don't know

- Not applicable/refused

a. Travel behavior

Now we would like to ask some questions about your personal transportation use.

C14 Do you own a motor vehicle?
- Yes
- No
- Don't know
- Not applicable/refused

C15 How often do you utilize public transit for daily commuting to work or regular activity, domestic chores, leisure or recreation?
- never
- seldom
- sometimes
- often
- always
- don't know
- Not applicable/refused

C16 How often do you utilize active transportation such as walking or bicycling for daily commuting to work or regular activity, domestic chores, leisure or recreation?

- never
- seldom
- sometimes
- often
- always
- don’t know
- Not applicable/refused

C17 What is the typical one-way travel time (in minutes) required for work or other regular daily activity
- Record number
- Don’t know
- Not applicable/refused

SECTION D: HEALTH STATUS SF12v2

We would like to better understand how well you are able to do your usual activities and how you rate your own health. To help us better understand these things about you, please complete the following questions about your general health.

D1 In general, would you say your health is:
- Excellent
- Very good
- Good
- Fair
- Poor

D2 The following questions are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a) **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf			
b) Climbing **several** flights of stairs			

D3 During the **past 4 weeks**, how much of the time have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a) **Accomplished less** than you would like					
b) Were limited in the **kind** of work or other activities					

D4 During the **past 4 weeks**, how much of the time have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a) **Accomplished less** than you would like					
b) Did work or other activities **less carefully than usual?**					

D5 During the **past 4 weeks**, how much did pain interfere with your normal work (including both work outside the home and housework)?

- Not at all
- Slightly
- Moderately
- Quite a bit
- Extremely

D6 These questions are about how you feel and how things have been with your **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the **past 4 weeks**…

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a) Have you felt calm and peaceful?					
b) Did you have a lot of energy?					
c) Have you felt downhearted and depressed?					

D7 During the **past 4 weeks**, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

- All of the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

D8 Have you ever stopped working at a job or changed your job because of reasons related to your health?

- yes
- no
- don’t know
- Not applicable/refused

D9 Are you sensitive to airborne environmental allergens?

- Not at all
- Slightly
- Moderately
- Quite a bit
- Extremely
- Not applicable/refused

D10 Do you have hay fever or allergic rhinitis?

- Yes
- No
- Don’t know/never been told
- Not applicable/refused

D11 Do you have any skin conditions such as eczema or atopic dermititis?

- Yes
- No
- Don’t know/never been told
- Not applicable/refused

D12 Are you currently taking any medication for allergies, including antihistamines, decongestants, or corticosteroids?

- Yes
- No
- Don't Know
- Not applicable/refused

D13 Do you have allergic asthma?
- Yes
- No
- Don’t know
- Not applicable/refused

D14 Have you been woken by an attack of shortness of breath at any time in the last 12 months?
- Yes
- No
- Don't Know
- Not applicable/refused

D15 Have you had an asthmatic attack in the last 12 months?
- Yes
- No
- Never been told
- Not applicable/refused

D16 Are you currently taking any medication for asthma, including inhalers, aerosols or tablets?
- Yes
- No
- Don't Know
- Not applicable/refused

D17 Have you been hospitalized or visited a doctor for acute respiratory problems during the past 12 months?
- Yes
- No
- Don’t know
- Not applicable/refused

D18 Do you have Chronic Obstructive Pulmonary Disease (COPD)?
- Yes
- No
- Don’t know
- Not applicable/Refused

D19 Do you have any other respiratory problems?
- Yes
- No
- Don't Know
- Not applicable/refused

D20 Do you have a cardiovascular disease?
- Yes
- No
- Don’t know
- Not applicable/refused

D21 Have you been diagnosed with high blood pressure?
- Yes
- No
- Don’t know
- Not applicable/refused

D22 Do you have any other chronic diseases?
- Yes
- No
- Don’t know
- Not applicable/refused

D22b If yes, please specify ______________

D23 Do you have noise-induced hearing loss?
- Yes
- No
- Don’t know
- Not applicable/refused

D24 Do you have any other hearing problems, including but not limited to tinnitus (ear ringing) or otosclerosis?
- Yes
- No
- Don’t know
- Not applicable/refused

D25 Do you have a regular family medical doctor or health care provider?
- Yes
- No
- Don’t know
- Not applicable/refused

D26 In the past four weeks, how many times have you seen or talked on the telephone with your family doctor or health care provider about your physical, emotional or mental health?
- Enter number

- Don’t know
- Not applicable/refused

D27 How long does it take you to get to your doctor or health care provider?
- Less than 20 minutes
- 20-40 minutes
- More than 40 minutes
- Don’t know
- Not applicable/refused

D28 In the past 12 months, about how many hours a week did you spend exercising?
- Enter number
- Don’t know
- Not applicable/refused

D29 At the present time how often do you smoke cigarettes, cigars or other smokables? Would you say daily, occasionally, or not at all?
- Daily
- Occasionally
- No
- don't know
- Not applicable/refused

D28 Did you ever smoke? Would you say daily, occasionally, or not at all?
- Daily
- Occasionally
- No
- don't know
- Not applicable/refused

D29 Does anyone else in your household smoke inside your home?
- Yes
- No
- Don’t know
- Not applicable/refused

D30 During the past 12 months, how often did you drink alcoholic beverages?
- Less than once a month
- Once a month
- 2-3 times a month
- Once a week
- 2-3 times a week
- 4-6 times a week

- Every day
- Don’t know
- Not applicable/refused

SECTION E: Socio-demographic

You are almost done the survey; we just have a few more questions about demographic and socioeconomic status. We want to remind you that your responses are recorded anonymously so that you will not be identifiable by any information you provide in this survey

E1 In what year were you born?
- Enter year of birth
- Don't Know
- Not applicable/refused

E2 At present are you married, living with a partner, widowed, divorced, separated, or have you never been married?
- Married or living with a partner
- Widowed
- Divorced
- Separated
- Never Married
- Don't know
- Not applicable/refused

E3 Including yourself, how many people live in your household?
- enter number
- don’t know
- Not applicable/refused

E4 How many of the children in your household are 5 years old or younger?
- Number
- Don’t know
- Not applicable/refused

E5 How many of the children in your household are 18 years old or younger?
- Number
- Don’t know
- Not applicable/refused

E6 How tall are you? (m/cm or ft/ in)
- enter weight in kg or lb
- don't know
- Not applicable/refused

E7 How much do you weigh? (kg or lb)
- enter weight in kg or lb
- don't know
- Not applicable/refused

E8 What is the highest level of education you have completed?
- Less than high school
- Completed high school (NS+PQ = 11, Ont. = 13, other =12)
- Some post-secondary school
- Completed post-secondary
- Don't know
- Not applicable/refused

E9 Are you presently working for pay in a full-time or in a part-time job, are you unemployed, retired, a homemaker, a student or something else?
- Full-time job, including during vacations from work
- Part-time job
- Sick leave, maternity leave, strike, etc.
- Unemployed
- Retired
- Homemaker
- Student (includes students working part-time)
- Other (specify)
- Don't know
- Not applicable/refused

E10 Are you presently or have you in the past worked in the auto sector (including parts production, assembly, sales, or administration)?
- Currently
- Previously
- No
- Don't know
- Refused
- Not applicable/refused

E11 Could you please tell us how much **total** income you and other members of your household received in 2011? We don't need the exact amount; could you tell us which of these broad categories it falls into?

- ...less than $10,000
- ...between $10,000 and $20,000 ($19,999.99)
- ...between $20,000 and $30,000 ($29,999.99)
- ...between $30,000 and $40,000
- ...between $40,000 and $50,000
- ...between $50,000 and $60,000
- ...between $60,000 and $70,000
- ...between $70,000+
- ...Don't know
- ...Not applicable/refused

E12 Is this dwelling in which you live owned by you, a member of this household, or it is rented?

- you
- a member of this household (even if it is still being paid for)?
- rented (even if no cash rent is paid)?
- don’t know
- Not applicable/refused

E13 Does the building need major repairs?

- yes
- no
- don’t know
- Not applicable/refused

Thank you for your participation in this study. If you will like to be entered into the gift certificate draws, please provide us with your preferred method of contact. If you do not provide a method of contact we cannot enter you into a prize draw.”

Enter participant’s preferred method of contact: Address, or Email or Telephone Number.

CURRICULUM VITAE

EDUCATION

PhD in Geography (Environment & Sustainability) (December 2014 ECD). Western University, London, Ontario, Canada.

Bachelor of Arts, Honors Specialization in Geography (2009). Western University, London, Ontario, Canada.

Bachelor of Science, Honors Specialization in Comparative Physiology (2008). Western University, London, Ontario, Canada.

AWARDS & SCHOLARSHIPS

- Postdoctoral Fellowship, Social Sciences and Humanities Research Council (2014; $81 000)
- Environment & Sustainability Merit Award, Collaborative Graduate Program, Centre for Environment and Sustainability, Western University (2013; $1000)
- Graduate Travel Award, Collaborative Program, Centre for Environment and Sustainability, Western University (2013; $750)
- Doctoral Fellowship, Social Sciences and Humanities Research Council (2012-2014; $40 000)
- Doctoral Scholarship, Ontario Ministry of Training, Colleges and Universities (2012; $15 000, declined)
- Graduate Travel Award, Collaborative Program, Centre for Environment and Sustainability, Western University (2012; $500)
- Western Graduate Research Scholarship, School of Graduate and Postdoctoral Studies, Western University (2009-2013; $6 600 per annum)
- Vanier Canada Graduate Scholarship nomination, Social Sciences and Humanities Research Council (2011)
- Doctoral Scholarship, Ontario Ministry of Training, Colleges and Universities (2011; $15 000)
- Joseph-Armand Bombardier CGS Master's Scholarship, Social Science and Humanities Research Council of Canada (2010; $17 500)
- Master’s Scholarship, Ontario Ministry of Training, Colleges and Universities (2010; $15 000, declined)
- Lead Graduate Internship, Department of Geography, Western University (2009: $ 5000, declined)
- The Canadian Association of Geographers Undergraduate Award (2009)
- Department of Geography Undergraduate Thesis Award, Western University (2009)
- Dean’s Honour List, Western University (2006-2009)

EMPLOYMENT HISTORY

Work Experience

Research Associate (October 2014 - current)

Transportation and urban sustainability; cross-border initiatives on clinical research and medical technology development. Project collaborators: Dr. William Anderson and Dr. Hanna Maoh, Cross Border Institute, University of Windsor

Clinical Research Assistant (Summer 2013)

"Outdoor Physical Activity and Health Study." Assisted study participants with providing respiratory and cardiovascular measurements for research on physical activity in Kincardine, ON, Canada. Health Canada and Western University

Research Associate (2010-2014)

"Air Pollution Exposure, Health Effects and Environmental Inequity: Land Use Regression Analysis and Air Pollution Sampling in Ottawa and London Ontario, 2010-2011." Project Principal Investigators: Dr. Michael Buzzelli and Dr. Isaac Luginaah. Health Canada and Western University

Project Coordinator (Summer 2010

Health Canada Air Quality Monitoring Campaign, London, Ontario. Project Principal Investigators: Dr. Michael Buzzelli and Dr. Isaac Luginaah. Health Canada and Western University

Ecologist Planning Assistant (2009)

Assisted the City of London Ecologist Planner on matters relating to conservation, monitoring and planning for natural areas within London. Parks Planning and Development, Department of Planning and Development, The Corporation of the City of London, ON, Canada

Research Assistant (2006-2008)

Involved in all aspects of research in a cardiovascular neurophysiology laboratory. Duties included running in vivo experiments, immunohistochemistry, bioassays, and data analysis. Principal Investigator: Dr. John Ciriello, Department of Physiology and Pharmacology, Western University

Teaching Experience

Lecturer, Department of Geography, Western University

Geography 2430 – Public Health and Environment (2014)

Geography 2153 – Environment, Economy and Society (2012, 2013, 2014)

Teaching Assistant, Department of Geography, Western University

3432: Environmental Hazards and Human Health (2014)

2010: Geography of Canada (2013)

2450: Intro to resource and environmental management (2012)

2430: Health Geography (2011)

2210: Introduction to Spatial Analysis (2011)

3210: Quantitative Analysis in Geography (2010)

2050: Western Europe (2010)

1500: Society and Nature (2009)

RESEARCH CONTRIBUTIONS

Refereed Publications

Oiamo, T.H., Johnson, M., Tang, K., Luginaah, I.N. Land use regression modeling of NO_2 and volatile organic compounds in Ottawa, Ontario, Canada (under review by Health Canada)

Oiamo, T.H., Lafreniere, D. and Parr, J. (forthcoming). The making of a key North American environment of mobility: the Windsor-Detroit borderland. In: Coates, C., Young, J., and Bradley, B. (Ed.). *Moving Natures: Environment and Mobility in Canadian History*. Calgary: University of Calgary Press and NiCHE series: Energy, Ecology, and the Environment.

Luginaah, I.L., Oiamo, T.H., Armah, F.A. (2014). Environmental Health Geography. In: Cockerham, W.C., Dingwall, R. and Quah, S.R. (Ed.). *The Wiley-Blackwell Encyclopedia of Health, Illness, Behavior, and Society.* Wiley-Blackwell.

Oiamo, T.H. (2014) Ozone. In: Michalos, A.C. (Ed.). *Encyclopedia of Quality of Life and Well-Being Research*. Springer, Dordrecht, Netherlands. Springer, pp. 4559-4561.

Oiamo, T.H., Luginaah, I.N. 2013. Extricating sex and gender in air pollution research: a community based study on cardinal symptoms of exposure. *International Journal of Environmental Research and Public Health*, 10: 3801-3817.

Oiamo, T.H., Luginaah, I.N., Buzzelli, M., Tang, K., Johnson, M., Brook, J.R., Xu, X., and Wheeler, A.J. 2012. Assessing the spatial distribution of nitrogen dioxide in London, Ontario. *Journal of the Air and Waste Management Association,* 62: 1335-45.

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