CONSTRUCTING PLACE SPECIFIC MEASURES OF HEALTH AND SOCIO-ECONOMIC INEQUALITY FOR METROPOLITAN VANCOUVER

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Nathaniel Joseph Bell
BA, Michigan State University 2001

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APPROVAL

Name: Nathaniel Joseph Bell

Degree: Master of Arts

Title of Thesis: Constructing Place Specific Measures of Health and Socio-Economic Inequality for Metropolitan Vancouver

Examining Committee:

        Chair: **Dr. Nick Blomley**
Professor, Department of Geography

_____

Dr. Nadine C. Schuurman
Senior Supervisor
Associate Professor, Department of Geography

_____

Dr. Michael V. Hayes
Supervisor
Associate Dean, Faculty of Health Sciences

_____

Dr. Clyde Hertzman
External Examiner
Director of the Human Early Learning Partnership (HELP),
Faculty of Graduate Studies, University of British Columbia

Date Defended/Approved: _October 6, 2006_____

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ABSTRACT

In recent decades researchers have used Census-based socio-economic models to explain why some people are healthier than others. Little attention has been directed to survey-based methods for quantifying socio-economic inequality due to the inherent subjectivity of individual responses in characterizing data. This thesis argues that this very subjectivity allows us to better understand and evaluate social gradients in health status. A survey instrument was developed and distributed to British Columbia's Medical Health Officers (MHOs) as part of a methodology for identifying the socio-economic variables characteristic of local health outcomes specific to urban areas in British Columbia, Canada. A weighted Kappa test statistic and a GIS-based Multicriteria Analysis are used to evaluate the strength of the variables selected by the MHOs. This research demonstrates that place-specific and survey-based methods of constructing deprivation indices are effective strategies for identifying spatial distributions of health and socio-economic outcomes within urban areas in British Columbia.

Keywords: Socio-economic inequality; deprivation index; Multicriteria Analysis; Geographic Information System; Vancouver, British Columbia

Subject Terms: inequality; public health research methodology; geographic information systems; decision making

To my daughter, Charlotte
As one door closes, a new adventure begins.

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CHAPTER 1:
INTRODUCTION

1.1 Introduction

There is a well-known socio-economic gradient in health status. Systematic

differences in socio-economic position routinely provide the strongest explanation for

why some people are healthier than others (Evans, 2002; Hertzman, 1999; Syme, 1996;

Tarlov, 1996). Gradients in socio-economic position stem from variations in income

distributions, educational attainment, occupational class, degrees of social isolation, and

greater functions and norms of society at large (Hayes, 1994; Hertzman, 1999; Marmot,

1986; Townsend, 1987; Townsend, Davidson, & Whitehead, 1986; Townsend,

Phillimore, & Beattie, 1988). Two significant illustrations of the magnitude of this

relationship are R.M. Sapolsky's work on the impact on health in baboons in relation to

the hierarchical orders of their clans (Sapolsky, 1992) and the Whitehall I and II cohort

studies on British Civil Servants (Marmot, Davey Smith, Stansfeld, Patel, North, Head et

al., 1991).

The essence of these and subsequent studies is that health is fundamentally linked

to gradients in social dynamics and living conditions within society. This evidence is

routinely presented using Census-based deprivation indices (Carstairs, 1989; Frohlich &

Mustard, 1996; Jarman, 1983; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000;

Townsend, Phillimore, & Beattie, 1988). These indices are then used elsewhere to draw attention to the inverse relationship between socio-economic position and health at an individual and population scale (Hutchinson, Foy, & Sandhu, 1989; Lorant, Thomas, Deliège, & Tonglet, 2001).

Socio-economic and health inequalities are also geographically differentiated. Research on health and place has consistently demonstrated that living in places with higher relative measures of deprivation has a negative influence on a variety of health outcomes (Kawachi & Berkman, 2003). Townsend's (1988) and Carstairs' (1989) studies on unequal distributions of health amongst the populations in Northern England and Scotland identified that health status was invariably tied to systematic differences in social dynamics and living conditions unique to regions throughout the UK. Subsequent studies conducted by Frohlich (1996) and Pampalon (2000) illustrated the variety of economic and social indicators that beset the health status of Canadians living in Manitoba and Montreal. Geographers have also made significant contributions in population health research. There is an emerging interest in using GIS-based mapping techniques and statistical analysis to highlight the spatial patterning of health inequalities ((Langlois & Kitchen, 2001; Schuurman & Fiedler, forthcoming, 2007).

There is a well-established research methodology for quantifying levels of socio-economic position to contrast against relative health outcomes. However, there is comparably less attention emphasizing the need to construct place-specific measures of socio-economic status. This research builds on deprivation literature and presents a new mixed methods approach for measuring socio-economic inequality in areas within Metropolitan Vancouver. The index is based on primary data obtained from the

provincial Medical Health Officers (MHOs) and secondary data taken from the 2001 Canadian Census. A Geographical Information Systems (GIS), Multicriteria Analysis (MCA) and weighted Kappa test statistic are employed to help quantify and validate the degree to which MHOs agree are the most significant socio-economic variables to understanding relative levels of health status as an aggregate. This research is a new contribution to a socio-economic inequality field that has traditionally relied on either the weighted or un-weighted standardized (z) scores or variations of Principal Component and Factor Analysis to quantify social gradients in health. Furthermore, differentiation of local conditions from generalized measures of socio-economic status (SES) is an opportunity for social epidemiologists and provincial medical health experts to extend their understanding of the effects of place on health.

1.2 Research Problem

The challenges in constructing place-specific measures of deprivation using local knowledge are multifaceted. Standardization of the variables indicative of socio-economic inequality increases semantic interpretation of the conditions that give rise to social gradients in health. It also provides an avenue for health researchers to compare results across scales. The difficulty surrounding standardization is deciding which plausible factors subject one to living a 'deprived' life. There are a number of ways to emphasize socio-economic position relative to health (Evans, 2002). The use of previously constructed measures of deprivation strengthens the validity of the research results. However, this strategy does not let researchers discern which social and economic conditions influence the effect of place on health.

Moreover, the indices are primarily based on robust statistical methods rather than actively pursuing local knowledge from health professionals. This is not to suggest that deprivation indices are created haphazardly, but that a number of variables and techniques have been accepted through rigorously tested scientific approximations. Other than the Jarman UPA8 score (1983) no other widely used deprivation index has been constructed through a survey-based format. The leading argument against the use of surveys to construct deprivation indices is that participant-generated indices generate weighting bias (Carr-Hill & Sheldon, 1991; Davey-Smith, 1991; Talbot, 1991). Survey-based measures have been abandoned in favour of more robust empirical methods based on variations of Principal Component or Factor Analysis. However, research has demonstrated that survey-based strategies of constructing socio-economic models are

valuable tools for contextualizing local demographics (Fiedler, Schuurman, & Hyndman, 2006a, 2006b; Kershaw, Irwin, Trafford, & Hertzman, 2005).

1.3 Research Objectives

This thesis presents a methodology for identifying the socio-economic variables characteristic of local health outcomes specific to urban areas within British Columbia, Canada using MHOs to populate the index. Its objective is to:

1. To formalize a methodology for building a deprivation index using a survey-based method.

2. To outline the construction and validation methodology of amalgamating the MHO responses into a single quantifiable measure of socio-economic position using GIS-based Multicriteria Analysis (MCA).

3. Relate the socio-economic variables selected by the MHOs to data containing self-rated health information for residents living within Metropolitan Vancouver and compare prevalence scores against previously constructed Canadian Census-based deprivation indices.

1.4 Background

Causes for ill health vary widely and can be defined through negative connotation (e.g. chronic disease) or positive nuance (e.g. quality of life). Two often-opposing perspectives are used to explain inequalities in health. One is a medical model, which includes the influence of individual behaviour and access to treatment facilities mentioned earlier. The second is based on a social approach, which emphasizes gradients in health status based on SES. Although the lines between medical and social health models are often ambiguous, both have clearly distinguishable themes that serve as a basis for understanding why certain people are healthier than others. The following section provides a summary of both frameworks.

The medical health model

The best way to explain the medical health model is to outline what it is not. The western medical health model primarily focuses on the examination and treatment of individuals rather than social conditions (Syme, 1996; Townsend, Phillimore, & Beattie, 1988). This type of medical perspective developed largely from Decartes philosophy of science in which the body is viewed – or more specifically diagnosed and treated – using the metaphor of a machine; receiving tune-ups to cure what ails us (Lalonde, 1974; Townsend, Phillimore, & Beattie, 1988). The emphasis is on fixing as opposed to prevention. This may be considered therapeutic, but only first from the point of diagnosis.

The western medical model is successful because it is a symptom based curative system. An individual enters a doctor's office, reports the condition that ails them and the

clinician prescribes the necessary treatment. It relieves society of the burden of educating the public about preventive health strategies. Not only does this place health maintenance on the individual, it abdicates society from playing an active role in addressing health promotion and disease prevention. The benefits of fixing illness as opposed to prevention produces limited results as medical intervention often occurs later in life, usually taking place twenty or thirty years after the start of the pathologic process (Tarlov, 1996).

Universal access to medical health care is also somewhat misleading. If access to medical care erased negative health outcomes then one would expect to see shrinking gradients in health in countries where there is universal health care access. Interestingly, in countries with these benefits lower social status individuals continue to have lower life expectancies than upper class individuals (Evans, 2002). Evan's point is that '…medicine does matter; it is just that social conditions matter more' (Evans, 2002).

The social-economic model

The socio-economic model of population health draws attention to the uneven distribution of a wide number of non-medical determinants. These refer to gradients within society such as average income or educational attainment and slanted distributions within the social environment, such as labour hierarchies. These gradients remain inversely related to health no matter how they are measured (Dunn, 2002). Yet, it is often difficult to provide comprehensive explanations for why some people are healthier than others using a socio-economic model. The strength of its relationship is not consistent across all nations (Evans, 2002). Researchers are also hard-pressed to provide causal

evidence of a social gradient in health status. The underlying social, material, early childhood and physical determinants can be intervening and difficult to measure as stand-alone components (Hayes, 1994).

An extension of this problem is determining how exactly should we measure 'position' in contrast to health. Part of this difficulty rests in deciding on which plausible factors subject one to living a 'deprived' life. Income is frequently cited as the most consistent controlling factor for measuring one's likelihood of obtaining good health (Evans, 2002). There is also an emphasis on what income *does* to decrease the chances of succumbing to increased health risks. This was emphasized by the author's of the *Black Report* (1982) who suggested a 'materialist' explanation for health inequalities, stressing factors relating to the family and work environment, such as labour conditions, household overcrowding, educational attainment or poverty in explaining health inequalities (Black, Townsend, & Davidson, 1982).

The hesitation, especially in the UK, to use income singularly as a causal factor of increased deprivation is two-fold. One is on side of practicality, as questions specific to income are not reported in the UK Census. Instead, proxy measures, such as car ownership or housing tenure, identify the likely level of an individual's wealth relative to the surrounding population (Carstairs, 1989; Townsend, Phillimore, & Beattie, 1988). The other hesitation is that proxy measures of income, if used alone, are unable to account for differences in health outcomes between groups - one of many fundamental findings of the Whitehall I & II studies (Marmot, 1986, 1993; Marmot, Davey Smith, Stansfeld et al., 1991). The point of controversy is that one does not earn their income in a vacuum, but through a relationship with his/her employment conditions, educational

attainment, or housing - factors that are present in varying degree along the social

spectrum arising as a consequence of social structure and organization (Blane, Davey

Smith, & Bartley, 1993). In the UK, the Classification of the Registrar-General's Social

Classes, allows within certain limitations, the ability to measure what a person's

household or educational status is likely to be based on the type of work they do

(Carstairs, 1989; Marmot, Smith, Stansfeld, Patel, North, Head et al., 1991; Townsend,

Davidson, & Whitehead, 1986).

In Canada, measurements of socio-economic deprivation have closely followed

those in the UK, but with some exceptions. This is due to practicality as measures of

social-class are not directly obtainable through the Canadian Census. In substitute,

'class', more commonly referred to as SES, is measured primarily through the

agglomeration of wealth and educational attainment constructs[1]. Townsend's (1987)

definition of deprivation remains influential (Pampalon & Raymond, 2000).

The social-economic model in British Columbia

Early Canadian attempts to move beyond a strictly medical health model can be

traced back to the 1974 publication of the Lalonde Report (1974). The Lalonde Report

took the position that national improvements in health were much more linked to

lifestyles and behaviour than financial investment in health care delivery. The report

primarily emphasized the role of the individual behaviour in influencing health, but was a

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[1] While in and of itself the Census may be seen as a legitimate controlling factor in structuring how 'inequality' can or can not be measured, root causes are generally placed on structural differences between conceptions of 'class', as used in the UK, and 'socio-economic status', as in the US, where the impact of class has largely been ignored (Sagan, 1987).

landmark document for further critical examinations of why some people are healthier than others.

The Epp Report was one of the earliest of many documents in Canadian health care policy to identify the importance that factors such as housing, education, or strengths of our social networks have in influencing the health status of Canadians (Dunn & Hayes, 2000; Epp, 1986; Hayes, 1994; Hertzman, Frank, & Evans, 1994; Ross, Wolfson, & Dunn, 2001). These independent investigations are largely funded by federal research institutions (CIHR, 2004; CPHI, 2002). A significant overarching theme is that many of the factors that influence population health cannot be explained through lifestyle models alone.

At the provincial level, however, the lion's share of advocacy for better health promotion within British Columbia remains primarily invested in remedying problems of capacity by filling in the gaps for health care service and delivery (Seaton, 1991). Of the seven 'key accomplishments' listed in 2004/05 *Annual Service Plan Report* by the provincial Ministry of Health Services two were promotions of individual/lifestyle decisions while the remaining five accomplishments emphasized medical access and immunization programs (Government of British Columbia, 2005). There are, however, many researchers with a keen interest in demonstrating the effect that social gradients have on the health of British Columbian's (Hayes, 1992, 1994; Hertzman, 1999; Hertzman, Frank, & Evans, 1994; Kershaw, Irwin, Trafford et al., 2005) and these investigations are mirrored by wider provincial support. Several of British Columbia's regional health authorities have emphasized the importance of recognizing the non-medical determinants of health specific to individuals and communities within their

jurisdictions (Fraser Health Authority, 2002; Interior Health Authority, 2005; Vancouver Coastal Health Authority, 2005; Vancouver Island Health Authority, 2005). However, British Columbia is still without a proxy measure, such as the ones developed in Townsend (1988) or Frohlich (1996) to evaluate levels of socio-economic inequality and relate them to levels of health status as an aggregate[2].

Measuring socio-economic inequality: Why the Census? Why not?

Deprivation indices primarily rely on aggregate data taken from the National Census as the chief means of measuring socio-economic inequality. Aggregate data is used in absence of individual data to protect anonymity, but also due in part to the 20% sampling frame used to construct the Census questionnaire. The Census is freely available; it covers all political jurisdictions; and includes a number of indirect and direct measures of socio-economic position that are rather straightforward to assemble using a numerator/denominator construction. Socio-economic indicators, such as average income, household demographics, education attainment, mobility, or employment distributions can all be constructed using the Census. When aggregated, they broadly define the population's socio-economic position relative to the surrounding area. Moreover, the Census often becomes a surrogate measure of health and well-being due to the difficulty in accessing robust data on health at a finer spatial scale (Frohlich & Mustard, 1996). However, some caution should be applied when using Census-based

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[2] The P.E.O.P.L.E. project is the closest measure currently available to measure social and environmental variables that influence health outcomes. However, accessing many potential index variables (e.g. crime data, individual health statistics) remains problematic. Additionally, the index is designed to measure the entire Province, whereas British Columbia has distinct demographic and economic profiles in both rural and urban areas.

statistics as it can easily appear as categories such as lone-parent families or household overcrowding are root causes of health inequalities. Not all members of these spatially clustered groups are deprived (Townsend, Davidson, & Whitehead, 1986). Area-based measures are also susceptible to committing the ecological fallacy that all people living in deprived areas are deprived and all people living in privileged districts experience a healthy quality of life (Boyle & Willms, 1999; Reijneveld, Verheij, & de Bakker, 2000).

More robust indicators of SES use small-area statistics (DETR, 2000; NAfW, 2000). These databases are updated more frequently than the UK decennial and Canadian quinquennial Censuses. They are also measured at a finer spatial scale, thus providing researchers with a more representative statistic of the quality. Because vital statistics are published annually in Canada, these datasets can facilitate robust analyses of current living conditions and their relationship with health outcomes. Again, some caution is warranted as private or large-scale surveys are exceedingly difficult to standardize and are likely to be more susceptible to changes over time than nationally standardized Census questionnaires, both of which pose problems for conducting longitudinal studies.

Constructing Census-based indicators of status

Generally, researchers frequently standardize the Census variables indicative of SES to eliminate hidden weights (Martin, Senior, & Williams, 1994). The primary motive for variable standardization is to ensure that the values between two or more variables are comparable, thus eliminating the aggregation of variables stretching from 0 – 5% with those with a range for 25 – 90%, for example. The most preferred method of

standardization has been through the use of a (*z*) transformation (Carstairs, 1989; Jarman, 1983; Townsend, Phillimore, & Beattie, 1988), and to a lesser extent through the use of signed chi-square tests (DETR, 1998). Both methods are accompanied by their caveats, although the signed chi-square test is perhaps the more susceptible to error of the two. (*Z*)-transformations are problematic as there is there is no ceiling for how far the distribution can spread relative to its mean, jeopardizing some of the benefit of standardization. They can also be swayed by the value of the denominator, which becomes problematic when the index is used to compare urban and rural areas. This was the reason for the signed chi-square test as it removes the lack of sensitivity that proportional representations have for size effects (DETR, 1998). However, critics suggest it introduces more problems than it solves (Connolly & Chisholm, 1999; Simpson, 1996).

A third option is to use variations of Principal Component or Factor Analysis to compress the individual socio-economic variables into an underlying dimension (Frohlich & Mustard, 1996; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000). This stems from the complexity of representing any underlying factor (e.g. 'health inequality') that can not be measured directly through the Census. These strategies are statistically robust and reduce bias or subjective weighting of the Census variables. The caveat of this approach is that the extracted components explain a percentage of the variability of the original components. An additional caveat is that the insight of medical health experts is often excluded in the process.

Previous research has demonstrated the added value of survey-based strategies to elicit locally representative information about local health and SES conditions (Dunn, 2002; Dyck, 1992, 1995; Fiedler, Schuurman, & Hyndman, 2006a, 2006b). Constructing

deprivation indices using similar techniques may provide more contextual information about the underlying conditions that influence population health.

Deprivation index construction: a place for GIS-based MCA?

The value of GIS in health research has been in its ability to illuminate the spatial distributions of health outcomes. GIS has utility for visually understanding and contemplating population distributions (Kershaw, Irwin, Trafford et al., 2005). It can also be used as an exploratory analysis framework for location and allocation of health care services (Conner, Kralewski, & Hillson, 1994; Luo & Wang, 2003; Schuurman & Fiedler, 2007; Walsh, Gesler, Page, & Crawford, 1995), environmental hazard and risk-assessments (Kulldorff, 1997; Maantay, 2002), and human and vector born disease ecology (Beck, Rodrigues, Dister, Rodrigues, Rejmankova, & Ulloa A, 1994; Chadee, Williams, & Kitron, 2005; Dragicevic, Schuurman, & Fitzgerald, 2004; Glass, Schwartz, Morgan, Jonson, Noy, & Israel, 1995; Lu, 2004).

Although its utility is well demonstrated, GIS-based MCA is one of the most applied functions of geographical analysis yet to be thoroughly applied in social epidemiology. MCA is a decision-making tool designed to condense decision problems involving multiple criteria into a comparative ranking of the most optimal choice (Chen & Hwang, 1992; Jiang & Eastman, 2000; Malczewski, 1996, 1999; Saaty, 1980). The utility of MCA in the health sciences has been unexplored, though it is introduced by Schuurman (Schuurman, 2004).

MCA is a means of synthesizing the subjective choices of the MHOs into a single, quantifiable model. This is of particular relevance from a Canadian public health policy perspective. Local health conditions are often assessed by provincial MHOs (Foster, Uh, & Collison, 1992). We employ a MCA to re-assess the MHO variable selections using a number of robust weighting strategies. Two MCA-based construction strategies are presented as a means of integrating qualitative and quantitative data. The first is a compensatory weighting strategy using the *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS). Compensatory weighting strategies are ideal in instances with complex interdependencies among the variables, similar in approach to treating SES variables as intervening rather than independent of each other. The variables are aggregated using a (z) score metric, but the final index is based on the degree to which the area scores are separated from all other possible choices rather than the simple aggregation of the individual variables.

The second measure separates the MHO selections into a continuous range of generalized fuzzy aggregation scores using an *Order Weighted Average* (OWA). Methods incorporating fuzzy memberships are a means of addressing uncertainty in the importance of the variables selected by the MHOs (Jiang & Eastman, 2000; Yager, 1988). OWA-based MCA removes some of the inherent uncertainty associated with the MHO weights through a set of *order weights*. Both models are reviewed according to their logical consistency to current area-based measures of socio-economic inequality and the robustness of the weighting logic.

1.5 Thesis Outline

This thesis contains four chapters. Readers should find that the next two chapters within this thesis are designed as stand-alone components designed for individual publication. Chapter one is a concise review of the major theoretical and conceptual frameworks of socio-economic inequalities research, with a brief discussion on how GIS-based MCA fits into this arena. Its purpose is to introduce to the reader ways in which gradients in socio-economic position can be measured before continuing on to the ensuing chapters in this thesis.

Chapter two presents a framework for creating a deprivation index incorporating the knowledge of provincial Medical Health Officers (MHOs). The chapter also outlines a strategy for validating levels of discernment when considering how two or more MHOs judge a particular phenomenon. One of the leading arguments against the use of surveys to construct a deprivation index is the biased weights created in the process of consulting with the key participants (Carr-Hill & Sheldon, 1991; Davey-Smith, 1991; Talbot, 1991). A method of validation is comprised of a weighted Kappa test statistic.

Chapter three outlines a strategy for amalgamating participant responses into a quantifiable measure of socio-economic position using GIS-based measures of Multicriteria Analysis (MCA). Two MCA weighting algorithms are selected to model the socio-economic variables selected by the MHOs. The two methods chosen include a procedure for creating a measure of socio-economic inequality based on a compensatory weighting schema using the *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS) and a second measure that separates the MHO selections into a continuous range of generalized fuzzy aggregation scores using an *Order Weighted*

Average (OWA). Different weighting strategies are used to further explore how varying influences surrounding the weighting of the components conforms to levels of SES within Metropolitan Vancouver.

Chapter four weaves together the methods and research results presented in chapter two and chapter three, reviews key contributions and limitations of the research techniques, and outlines future application of the methodology. A caption of the web survey and questionnaire used to contact the provincial Medical Health Officers is included as an appendix..

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CHAPTER 2:
CONSTRUCTING PLACE-SPECIFIC MEASURES OF DEPRIVATION USING LOCAL KNOWLEDGE: EVALUATING POPULATION HEALTH IN VANCOUVER, BRITISH COLUMBIA[3]

2.1 Abstract

Deprivation indices are frequently used to illustrate a social gradient in health status. When the indices are transported across space and time, their value in describing social inequality can be undermined. An alternative is to develop specific, local deprivation indices based on a combination of primary and secondary data sources. The utility of primary data sources is the underlying understanding that medical health professionals have as to the conditions that influence local health outcomes. We construct a survey-based deprivation index using British Columbia's Medical Health Officers (MHOs). A weighted Kappa test statistic is used as a validation to measure to assess the degree to which participants agree on the socio-economic variables that characterize relative health outcomes. The index, referred to as the *Vancouver Area Neighbourhood Deprivation Index* (VANDIX) is contrasted against two previously constructed deprivation indices using self-rated health data. The variables selected by the MHOs produced consistently wider and more spatially accurate associations between areas of lower socio-economic position and health status in Metropolitan Vancouver.

2.2 Introduction

Research on health and place has consistently demonstrated that health outcomes are invariably tied to geography (Kawachi & Berkman, 2003). Health outcomes follow patterns according to socio-economic distributions (Townsend, Phillimore, & Beattie, 1988), proximity to environmental hazards (Foster, 1994), and access to medical health care (Luo & Wang, 2003). Socio-economic gradients in health are frequently illuminated through deprivation indices, which are constructed using aggregated socio-economic data derived from the Census (Carstairs, 1989; Frohlich & Mustard, 1996; Jarman, 1983; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000; Townsend, Phillimore, & Beattie, 1988). These indices are then used elsewhere to draw attention to the inverse relationship between socio-economic position and health at a variety of spatial scales (Heaney, MacDonald, Everitt, Stevenson, Leonardi, Wilkinson et al., 2002; Martens, Derksen, & Gupta, 2004; Martens, Mayer, & Derksen, 2002; Noble, Wright, Smith, & Dibben, 2006; Odoi, Wray, Emo, Birch, Hutchison, Eyles et al., 2005; Roy, Philip, & Jhavle, 2004). Although treating population health as simply a correlation against socio-economic status (SES) is limiting, broadly speaking, it provides a good indication as to a social gradient in health status (Marmot, 1986; Townsend, Davidson, & Whitehead, 1986).

An appealing benefit of using previously constructed area-based measures of 'position' to illustrate a social gradient in health status is that research results are comparable at a national and international scale. However, this strategy does not let researchers discern how place influences an area's quality of life. While many of these factors are ubiquitous, their level of influence often varies. Constructing place-specific

measures of socio-economic inequality is particularly germane to researchers in the health sector as the inferences of the data translate into policy and are used to pinpoint and administer social and health care expenditures in those locales. Consequently, estimating local socio-economic conditions is a relatively under-explored strategy for quantifying in the social gradient in health status. Yet, in Canada, the importance of creating community-centered social and health care models continues to gain wide support (CIHR, 2004; CPHI, 2002; PHAC, 1999). In BC, parallel promotion strategies are reflected at the health authority (HA) level where several of the HAs have acknowledged the importance of identifying the factors that affect the social and economic environment of the population (Fraser Health Authority, 2002; Interior Health Authority, 2005; Vancouver Coastal Health Authority, 2005; Vancouver Island Health Authority, 2005). Relying on data sources that were constructed elsewhere may mask heterogeneity and fail to elucidate the specific conditions that give rise to socio-economic inequality locally.

This research presents a proof of concept methodology for constructing a place-specific deprivation index for urban areas in British Columbia, Canada. The method uses primary data obtained from provincial Medical Health Officers (MHOs) as well as secondary data taken from the Canadian Census. The index, referred to as the *Vancouver Area Neighbourhood Deprivation Index* (VANDIX), is constructed from data obtained through a web survey. Respondent scores are validated using a weighted Kappa test statistic. Positive health outcomes are contrasted using the VANDIX and two other previously constructed Canadian deprivation indices: the *Socioeconomic Factor Index* (SEFI) (Frohlich & Mustard, 1996) and the *Deprivation Index for Health and Welfare*

Planning in Quebec (DIHWPQ) (Pampalon & Raymond, 2000). Discrepancies between the indices are evaluated using self-reported health data obtained from the Canadian Community Health Survey (CCHS) Cycle 2.1 database. We conclude with a discussion of the benefits of constructing measures of deprivation that are sensitive to local context using local health experts.

2.3   Constructing indicators of socio-economic position

Socio-economic gradients in health status are found in all economically developed and developing countries. Initiatives designed to estimate the effect of social gradients on health status are most frequently constructed using data taken from the Census - a practice dating back to at least early 1970's in the UK (Bartley & Blane, 1994). National Censuses contain a number of direct (e.g. average income) and indirect indicators (e.g. housing tenure as a proxy measure of income) of socio-economic position. Moreover, as Census data are freely available and cover all political jurisdictions, it is a reliable source of data to use for area-based investigations to describe the inverse relationship between socio-economic position and health (Aveyard, Manaseki, & Chambers, 2002; Roos, Magoon, Gupta, Chateau, & Veugelers, 2004; Singh, Paszat, Li, He, Vinden, & Rabeneck, 2004). These data also serve a dual purpose in that they often become a surrogate measure of health and well-being due to the lack of, or difficulty in accessing, robust data on health at a finer spatial unit (Frohlich & Mustard, 1996). Although more robust indicators of socio-economic position use small-area statistics (DETR, 2000; Dunn, 2002; NAfW, 2000), private or large-scale surveys can be exceedingly difficult to standardize and more susceptible to changes over time than nationally standardized Census questionnaires, both of which pose problems for longitudinal studies.

Regardless of the use of Census-based or other small-area socio-economic statistics researchers generally choose to weight and standardize the variables indicative of deprivation. Standardization helps to eliminate hidden weights (Martin, Senior, & Williams, 1994). This also ensures that the values between two or more variables are commensurable. The principal method of standardization for Census variables has been the (z) transformation (Carstairs, 1989; Jarman, 1983; Townsend, Phillimore, & Beattie, 1988). However, (z) scores can be problematic as there is there is no ceiling as to how far the distribution can spread relative to its mean, incidentally removing some of the added benefit of standardization. They are also influenced by the value of the denominator, which is of critical importance if the index is used to compare urban and rural areas simultaneously.

A second option has been to use variations of Principal Component and Factor Analysis to compress the individual socio-economic variables into an underlying dimension. This is the more common strategy used for Canadian indices to operationalize Census variables (Frohlich & Mustard, 1996; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000). The rationale for using PCA/FA stems from the complexity of representing any underlying factor (e.g. 'health inequality') that can not be measured directly through the Census. In comparison to indices based on the aggregation of (z) scores, methods of PCA/FA are more capable of removing multicollinearity from the dataset. However, the extracted 'factors' only explain a percentage of the variability of the original components and so some information loss is generally accepted. An additional caveat of this type of approach is that the index can be constructed without checking to see if the assumptions implicit in that model are valid.

A third and lesser-used option is to use questionnaires or surveys and construct the deprivation index using feedback from health professionals. This was the primary method used by Jarman in constructing the underprivileged area index (UPA8) (Jarman, 1983). Survey-based measures have since been downplayed due to the inherent element of subjectivity in the methodology. Recent survey-based research in other socio-economic investigations, however, has shown that survey-based studies are a valuable technique for uncovering local SES conditions (Fiedler, Schuurman, & Hyndman, 2006a, 2006b; Kershaw, Irwin, Trafford et al., 2005).

2.4   Resuscitating survey-based deprivation indices

The Jarman UPA8 has the distinct disadvantage of being the first widely popularized deprivation index used to draw attention to socio-economic gradients in health status. Although similar in structure to the indices later created in Townsend (1988); Carstairs (1989); and the subsequent Canadian indices, little attention has been given to survey-based deprivation indices since the initial critique of the Jarman UPA8 score.

First introduced in 1983, the Jarman UPA8 served as a workload assessment for British General Practitioners (GP's) to help overcome the problems imbedded in a homogeneous capitation allowance. It was designed as a payment formula for the British NHS to persuade GP's to practice in areas known for having a greater prevalence of individuals receiving deprivation payments and hence, more likely to require greater medical attention of services (Davey-Smith, 1991; Jarman, 1983; Talbot, 1991).

To construct the index Jarman used a 10% sampling frame of British GP's, asking them to comment on the factors that increased their daily stress and workload. The final aggregate index contained eight of the most popular variables selected by the GP's, including: the elderly population living alone, families with children under 5, lone-parents, those in social class V, the unemployed, those with overcrowded living conditions, those with annual mobility, and populations born in the new Commonwealth or Pakistan. All variables were obtained from the UK Census. Weights were assigned to the index variables based on the frequency of GP feedback.

The UPA8 score has since been criticized for its over reliance on Census data; for favouring London over the Northern Regions; for the scale in which it was constructed (UK Census Wards); and its weighting of the survey scores (Carr-Hill & Sheldon, 1991; Davey-Smith, 1991; Talbot, 1991). These critiques are, however, not unique to the Jarman index. When it was integrated into health policy, capitation allowances rose from 45% to 55-60% using the UPA8 as a payment formula. This was followed by additional critique as to the choice of indicators used to determine the capitation allowance (Talbot, 1991).

Despite these shortcomings or criticisms, the Jarman UPA8 score played a valuable role in drawing attention to the underlying conditions that influenced the daily stress and workload of British GP's. It was initially validated against the opinions of local medical committees (Jarman, 1983) and to increase clinician-based screening on all-cause mortality (Charlton & Lakhani, 1985). It continues be used to estimate socio-economic gradients in health status (Kennedy, Iveson, & Hill, 1999; Law & Morris, 1999; Pearson, Taylor, & Masud, 2004).

2.5 The need for local knowledge

No other widely used deprivation index has been constructed through a survey-based format since the UPA8. Although there is still much dispute over how deprivation should be measured (Frohlich, Carriere, Potvin, & Black, 2001), designing methods to better estimate local socio-economic conditions using the underlying knowledge of medical health professionals is a benefit to local health authorities given their underlying understanding of local social and health conditions. British Columbia's MHOs are ideal candidates to comment on socio-economic inequality because their education and professional expertise places them in the unique position to assess conditions that influence health (Foster, Uh, & Collison, 1992). They are responsible for ensuring that communities are well prepared for disease or environmental incidents. They also provide direction and oversight in the community to promote wellness; construct social and health programs; and deliver health care services.

Other Canadian provinces have constructed deprivation indices primarily based on Factor Analysis (Frohlich & Mustard, 1996; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000). These indices have been used to link incidence of low income and readmission of newborns (Martens, Derksen, & Gupta, 2004), identify the conditions that give rise to adolescent reproductive health issues (Martens, Mayer, & Derksen, 2002), conceptualize the spatial dimensions of inequality and the importance of measuring health and well being (Rose & Gilbert, 2005), and structure further health care planning

research (Odoi, Wray, Emo et al., 2005). British Columbia is, however, still without a proxy measure to estimate socio-economic gradients in health status[4].

2.6 Methods

2.6.1 Study area

The VANDIX index is tested against the backdrop of the municipalities within Metropolitan Vancouver. The Vancouver Census Metropolitan Area (CMA), which in the time period leading up to 2001 had a population of just under 2 million people, is divided into 21 municipalities (Figure 2.1). Metropolitan Vancouver is situated in the southwestern corner of British Columbia at the junction between the Fraser River and the Georgia Strait, which empties into the Pacific Ocean on the southern horn of Vancouver Island. It is a relatively 'new city' in comparison to eastern Canadian metropolises of Toronto and Montreal. It was incorporated in 1886 in conjunction with the expanding Canadian Pacific Railway. As a port city, the population is quite diverse with unique demographic compositions and varying socioeconomic needs at the intra-regional level.

There has been a strong interest in exploring the socio-economic and demographic patterns between different neighbourhoods within Vancouver (Bakan, 1978; Burr, Costanzo, Hayes, MacNab, & McKee, 1995; Dunn, 2002; Dunn & Hayes, 2000; Hayes, 1992). For example, Vancouver contains areas with some of the highest and lowest incomes in the country. The Downtown Eastside (DTES) is one of Canada's most deprived areas with an average household income of $20,851, which is less than 30% of

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[4] The P.E.O.P.L.E. project is the closest measure currently available to measure social and environmental variables that influence health outcomes. However, accessing many potential index variables (e.g. crime data, individual health statistics) remains problematic. Additionally, the index is designed to measure the entire Province, whereas British Columbia has distinct demographic and economic profiles in both rural and urban areas.

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the average household income for the rest of Vancouver. Vancouver is also the only municipality within the CMA with a renter to owner proportion of 1:1. Table 2.1 illustrates the varying levels of educational, employment, and demographic distributions at the municipal scale.

Figure 2.1:   Research Study Area
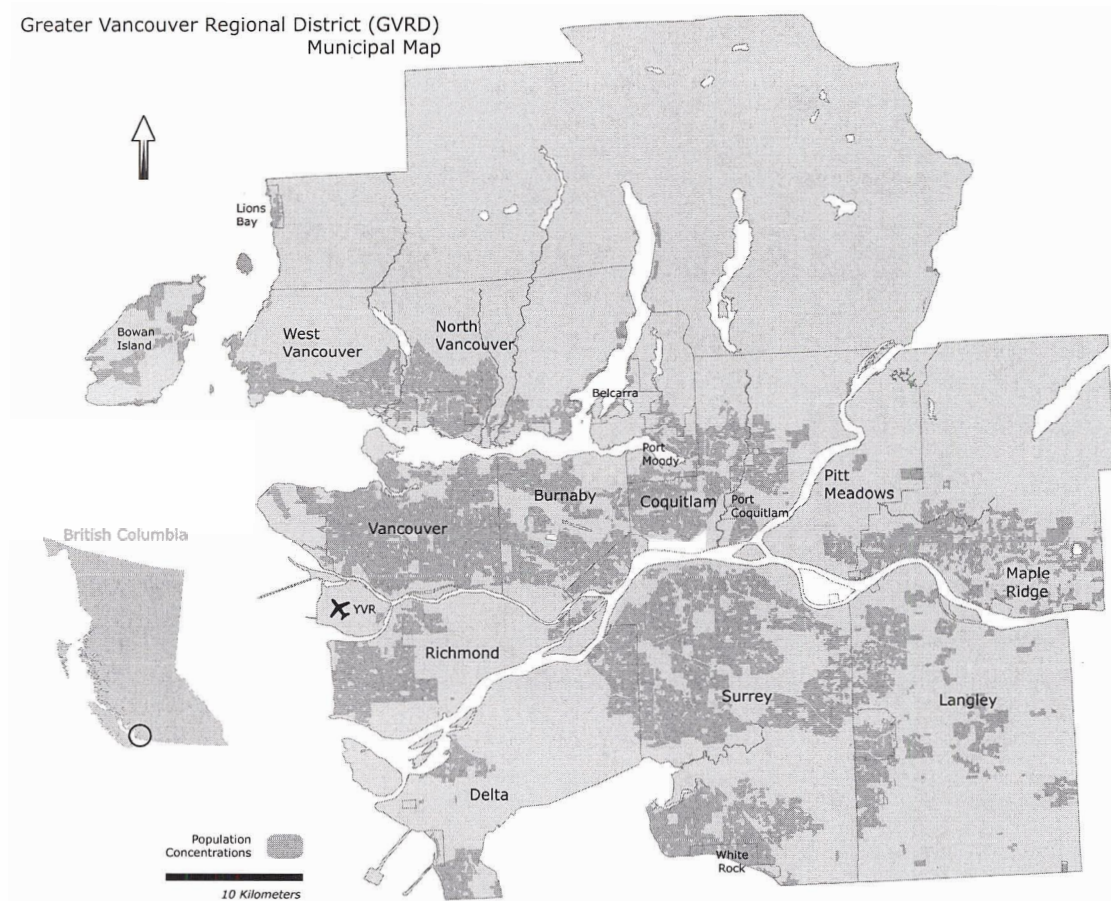
Table 2.1: 2001 Canadian Census population socio-economic characteristics for Metropolitan Vancouver (CMA) and eight of its interior municipalities.

Socio-economic Indicator	Municipality					
	Burnaby	New Westminster	Richmond	Tri-Cities*	Vancouver	CMA†
Material Wealth						
Average Income	27,407	30,038	27,897	31,222	30,683	31,229
Average Dwelling Value	284,070	202,424	279,514	240,444	324,648	288,509
Housing						
Single-detached Housing	45.1%	33.6%	59.8%	58.4%	38.9%	53.2%
Home Ownership	60.1%	51.6%	73.8%	73.8%	50.5%	65.3%
Proportion of Renters	39.9%	48.4%	26.2%	26.3%	49.4%	34.6%
Reside in an Apartment	43.7%	62.5%	22.4%	28.1%	56.0%	37.5%
Demographics						
Elderly 65+ Living Alone	23.5%	35.2%	16.1%	19.7%	29.5%	23.5%
Living Alone	10.6%	19.6%	6.6%	7.3%	16.9%	11.0%
Single Parent Family	15.5%	16.9%	13.9%	15.1%	16.6%	15.2%
Single/Divorced/Widowed	47.6%	54.3%	42.3%	42.4%	55.3%	46.7%
Children Under 5	19.5%	26.4%	17.0%	21.5%	23.1%	21.6%
Family Size Greater than 5 Persons	29.8%	18.1%	37.7%	34.9%	25.7%	31.3%
Mobility						
Moved in the Last 5 Years	45.7%	52.3%	43.1%	44.6%	50.2%	46.2%
Moved in the Last Year	16.8%	19.7%	13.5%	14.0%	19.1%	16.0%
Education						
No High School Completion	21.5%	22.8%	20.2%	18.6%	22.1%	21.4%
with a University Degree	25.5%	20.7%	28.4%	20.9%	33.0%	25.9%
Employment						
Employment Ratio	57.7%	62.0%	59.2%	65.2%	59.3%	61.6%
Unemployment Rate	8.4%	8.2%	7.2%	6.8%	8.6%	7.4%
Proportion of Females in Labour Force	29.5%	32.0%	30.5%	33.1%	31.1%	31.5%
Other						
Non-Canadian Citizen	15.3%	8.9%	14.0%	9.8%	13.5%	11.3%
First Language non Official	5.2%	1.7%	6.5%	2.4%	7.8%	4.5%

* Includes the municipalities of Coquitlam, Port Coquitlam, and Port Moody
†All 21 municipalities within the Vancouver Census Metropolitan Area (CMA)

2.6.2 Health data

Health data is taken from the Canadian Community Health Survey 2.1 (CCHS), a cross-sectional health survey representative of the Canadian population. It is designed to allow for a comparison of health at the sub-provincial Health Region level across Canada. Data for Cycle 2.1 was collected between January and November of 2003. The target population of the CCHS is Canadians over 12 years of age who live in private dwellings. Individual living on Indian Reserves, Crown Lands, institutional residents and full-time members of the armed forces are excluded. Data was collected primarily by telephone using three sampling frames, 48% from an area frame, 50 % from a list frame of telephone numbers and 2% from random digit dialling. In this study we use a sub-set of respondents between 18 and 74 years of age living in the Vancouver CMA (n=6,157).

Self-rated health was assessed from the CCHS question "In general, would you say your health is: Excellent, Very Good, Good, Fair, Poor." While self-assessed health is not a direct measure of health status, research suggests that is a good proxy for health status. It has shown a significant relationship with levels of mortality, morbidity and health care utilization (Kaplan & Camacho, 1983; Miilunpalo, Vuori, Oja, Pasanen, & Urponen, 1997). For analysis purposes, individual responses were dichotomized into a *good health* component comprising responses of 'Excellent, Very Good or Good' and a *poor health* component comprising responses of fair or poor.

Prevalence estimates for the proportion of the population reporting fair or poor self-rated health and confidence intervals of the responses were obtained using 500 bootstrap weights provided by Statistics Canada using SAS software. The bootstrap weights are used to account for the complex design of the CCHS sampling frames. Sample weights were assigned to the self-rated health responses so that results were

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representative of the population living within the Vancouver CMA. The coefficients of variation produced using the bootstrapping weights were used to gauge the quality of estimates between the self-rated health responses and SES quintiles. Estimates less than 16.5% are considered acceptable, estimates between 16.6% and 33.3% are flagged as marginal, estimates greater than 33.3% are flagged, but not released.

2.6.3 Census data

In this study, the spatial unit of analysis were the Census Tracts (CT) administrative boundaries. In the 2001 Census year the Vancouver CMA was comprised of 384 CTs. CTs are small and relatively stable geographic areas with a population of 2,500 to 8,000. The average CT population in the Vancouver CMA is approximately 4000 residents. Health researchers frequently use CT administrative units as they are homogenous and characteristic of urban neighbourhoods (Ross, Tremblay, & Graham, 2004). CTs are only constructed for large urban centers across Canada with an urban core population of at least 50,000 residents.

2.6.4 Survey construction

All 18 of British Columbia's MHOs were invited to participate in the construction of the deprivation index. Respondents were contacted via e-mail and provided with an html link to complete the survey using a secure web server housed within the Faculty of Health Science at Simon Fraser University. The survey was conducted between the months of June and August 2005[5]. The survey generated a return rate of 55% (n = 10)

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[5] The IHRE web-survey can be accessed through the web at: http://www.gis.sfu.ca/survey/survey_intro.html

with an addition one hard decline[6]. The questionnaire was designed using closed-ended questions asking participants to select from the list those socio-economic variables that he or she felt best characterized the relative health conditions in urban areas in British Columbia. Additional space was provided for comments and suggestions. MHOs selected from seven constructs tapping salient measures of socioeconomic deprivation. The variables incorporated into the survey were chosen based on their ability to represent the broad social, cultural, and material components that influence socio-economic inequality. The 21 indicators initially included in the MHO web-survey have been used in other deprivation indices. The idea was to include the variables we thought pertinent to urban areas in BC as well as other variables commonly used to construct deprivation indices elsewhere and let the local experts decide on the ones that were most relevant. The constructs included:

Material Wealth

The *material wealth* construct consisted of two variables: average income and average dwelling value. Average income was selected given its links to a variety of health outcomes and mortality in several Canadian studies (Wilkins R., Houle C., Berthelot J.M., & Ross N.A., 2000). Similarly, dwelling value is an additional measure of material wealth that, like income, is a multidimensional indicator of SES and health (Dunn, 2002).

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[6] We also recorded the number of times a participant elected not participate in the survey by logging their 'decline to participate' selections from the web page.

Housing

The *housing* construct included four variables that indirectly measure socio-economic position (Macintyre, Ellaway, Hiscock, Kearns, Der, & McKay, 2003). They included the % of single-detached housing units, the % of renters and owners, and those residing in an apartment. These variables are important indicators of status and have been known to influence self-rated health within the Vancouver area (Dunn, 2002).

Demographics

Six variables were included in the demographics construct, each of which is linked to long-term health outcomes (Hertzman & Wiens, 1996; Moilanen & Rantakallio, 1988). Variables included the % of elderly 65+ and living alone, the % of the population living alone, the % of single-parent families, the % of the population that are single - divorced - widowed, the % of persons under the age of five, and the % of family sizes greater than 5 persons.

Mobility

Two variables reflecting the proportion of the population that changed residency within the 5 years before the 2001 Census and the percentage having changed residency in the previous year composed the *Mobility* construct. Higher lifetime mobility rates have frequently been shown to be associated with lower SES status and poorer neighbourhood

health outcomes (Ainsworth, 2002; English, Kharrazi, Davies, Scalf, Waller, & Neutra, 2003; Hurley, Reynolds, Goldberg, Hertz, Anton-Culver, Bernstein et al., 2005).

Education

Unlike *Material Wealth, Education* is reflective of social position in that a person can have a low income but still be regarded in higher esteem given their level of education, or title. Education has been included as a measure of socio-economic position in previous socio-economic investigations in British Columbia (Dunn, 2002). The *Education* construct contained two variables: the proportion of the population without a high school education and the proportion of the population with a university degree.

Employment

Employment is a common indicator of deprivation as it reflects the population's ability to find work and is one of the most frequently recurring variables included in deprivation index construction both in Canada and abroad (Carstairs, 1989; Frohlich & Mustard, 1996; Langlois & Kitchen, 2001; Townsend, Phillimore, & Beattie, 1988). Three variables were included in the *Employment* construct, including the employment ratio, the unemployment rate, and the proportion of females in the labour force (which has previously been included as a measure of social exclusion).

Other

The *Other* construct was designed to describe more cultural variables, including: the proportion of non-Canadian citizens and the percentage of the population whose first spoken language was neither English nor French. These variables draw attention to those who are less advantaged given their citizenship, or may be subjected to additional barriers that may inhibit them from obtaining equal employment and status opportunities.

2.6.5 Index construction

Provincial MHO responses from the web survey were tallied using a data matrix. The participants were asked to rank their selections using a Likert scale from strongly agree to strongly disagree. Table 2.3 lists the participant responses to each of the 21 Census variables contained within the original survey. Each of the 21 Census variables were given a value from one through five, with a score of 5 assigned to a strongly agree selection, a 4 to an agree selection, a score of 3 assigned to a neither agree nor disagree selection, 2 to disagree selections, and a 1 to a strongly disagree selection. Only the aggregation of the strongly agree and agree selections were used to determine the overall impact of the indicator variable.

Table 2.2:   MHO selections of the social and economic variables that they felt characterized relative health outcomes within urban areas in British Columbia. SA: Strongly Agree, A: Agree, NAD: Neither Agree or Disagree, D: Disagree, SD: Strongly Disagree

Census Variable	Medical Health Officer									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Material Wealth										
Average Income	A	A	A	SA	SA	A	A	A	NAD	SD
Average Dwelling Value	A	A	D	A	D	D	D	NAD	NAD	D
Housing										
Single-detached Housing	NAD	A	NAD	NAD	D	NAD	D	NAD	NAD	SA
Home Ownership	A	A	A	A	A	A	NAD	NAD	SA	SA
Proportion of Renters	A	A	A	A	A	NAD	A	NAD	SA	SA
Reside in an Apartment	NAD	NAD	D	NAD	D	NAD	D	NAD	NAD	SA
Demographics										
Elderly 65+ Living Alone	A	D	NAD	A	D	SA	NAD	SA	SA	SA
Living Alone	NAD	D	A	A	NAD	A	A	A	A	SA
Single Parent Family	A	SA	A	SA	A	SA	SA	NAD	A	NAD
Separated/ Divorced/ Widowed	A	NAD	NAD	A	D	A	A	NAD	NAD	NAD
Children Under 5	D	NAD	NAD	NAD	D	A	A	NAD	SA	SA
Family Size + 5 Persons	D	NAD	NAD	A	NAD	NAD	NAD	NAD	SA	NAD
Mobility										
Moved in the Last 5 Years	NA	NAD	D	A	NAD	NAD	A	A	NAD	NAD
Moved in the Last Year	NAD	NAD	NAD	A	NAD	A	A	A	A	NAD
Education										
No High school Completion	A	SA	SA	SA	A	A	SA	A	SA	SA
with a University Degree	SA	SA	NAD	SA	A	NAD	SA	A	A	SA
Employment										
Employment Ratio	SA	SA	D	SA	NAD	NAD	A	A	A	SA
Unemployment Rate	SA	SA	A	SA	NAD	SA	SA	A	A	SA
Females in Labour Force	NAD	A	NAD	A	NAD	NAD	A	NAD	A	SA
Other										
Non-Canadian Citizen	D	NAD	NAD	NAD	D	A	A	NAD	A	SA
First Language non Official	D	NAD	NAD	NAD	D	A	A	NAD	NAD	A

Table 2.3: Indicators selected to measure neighbourhood deprivation and the assigned weights. Weights were assigned proportionally according to the number of Strongly Agree and Agree responses. Strongly Agree responses were assigned a value of 5 and Agree responses a value of 4.

Selected Census Indicators	Strongly Agree Responses	Agree Responses	Sum	Rank	Weight (%)
Material Wealth					
Average Income	2	6	34	5.5	0.089
Housing					
Home Ownership	2	6	34	5.5	0.089
Demographics					
Single Parent Family	4	4	36	4	0.143
Education					
No High school Completion	6	4	46	1	0.250
with a University Degree	5	3	37	3	0.179
Employment					
Employment Ratio	4	3	32	7	0.036
Unemployment Rate	6	3	42	2	0.214

We administered a cut-off score to only include aggregate selections that scored greater than or equal to 31, which signified all 10 respondents choosing a non-neutral response greater than 'neither agree or disagree'. Out of the initial 21 variables posted on the web-survey, only eight of them were overwhelmingly agreed upon by the MHOs (with the 8th variable [% of renters] later excluded due to its 1:1 relationship with the % of home owners). Table 2.3 lists the seven variables included in the VANDIX.

The aggregate scores from the variable sub-selections were used to determine the proportional weights of the indicator variables. The selected indicator variables were ordered according to respondent preference using the inverse of the original Likert scale, with the variable that received the highest aggregate sum a ranking = 1, the next most frequently selected variable = 2 and so on. The proportional weights are calculated by

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$$w_i = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

where w_i is the standardized proportional weight for the selected variable, n is the total number of variables in the index, and r_j is the ordinal position of the variable. The eventual weight of the variable is obtained by dividing its ordinal position by the summation of the ranking values $(n - r_j + 1)$.

2.6.6   Response validation

One of the leading arguments against the use of surveys to construct a deprivation index is the biased weights created in the process of consulting with the key participants (Carr-Hill & Sheldon, 1991; Davey-Smith, 1991; Talbot, 1991). Techniques are available to strengthen the validity of the responses from health professionals. To determine the consistency of the MHO responses we incorporated a weighted Kappa statistic to test for the level of expert agreement beyond the level of agreement expected by chance. To help combat the level of subjectivity that more qualitative data sources impart on the model a Kappa statistic can be used to measure the level of agreement beyond the agreement that is expected by chance. Its primary use has been in rating levels of discernment when considering how two or more individuals judge a particular phenomenon (Cohen, 1968). The calculation for k is

$$k_w = \frac{\sum wP_o - wP_e}{1 - wP_e}$$

where $_w p_o$ is the sum of the weighted observed agreement and $_w p_e$ represents the sum of the weighted expected agreement.

An extension of the Kappa test statistic is the weighted Kappa score. We chose to use a weighted Kappa test statistic as it provides a better account for moderate differences between adjacent expert responses (strongly agree and agree) in comparison to more contrasting responses (strongly agree and strongly disagree). Weights were calculated using a quadratic formula

$$w_{ij} = 1 - \frac{(i-j)^2}{(k-1)^2}$$

where w_{ij} is the assigned weight, i and j the difference between the row and category disagreement, and k is the total number categories.

2.6.7 Canadian comparison indices

Two previously constructed Canadian deprivation indices were included to contrast against the VANDIX. Six constructs representing social and material deprivation were used to build the SEFI index (Frohlich & Mustard, 1996) and the DIHWPQ (Pampalon & Raymond, 2000). The SEFI index includes: an age dependency ratio, the % of single parent families, the % of female single parent families, the female labour force participation rate, the unemployment rate, and the % of residences with a minimum of a high school diploma. Factor Analysis was used to compress two measures of unemployment into one factor, which were then aggregated with the other five components. Similarly, the DIHWPQ uses Principal Component Analysis to compress the six indicator variables into their material and social constructs. The index includes three variables reflective of material deprivation: persons with no high school education, the employment ratio, and average income. The social components include the % of

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persons living alone, the % of those who are separated, divorced, or widowed, and the % of single parent families.

2.7 Results

Of the original 6,157 individual self-reported health responses 2237 individual cases were later discarded due either to missing cases, or because they included individuals who were not between 18-74 years of age. 98% of the CTs had at least one resident who completed the survey (n=3920), with an average of 10 residents per Census Tract. Due to the sensitivity of the health data, all individual self-reported health records were aggregated into their corresponding CT and used to represent the prevalence of reporting 'fair or poor health' for the entire Census area. To protect individual confidentiality, the specific CT where the individuals reside is suppressed.

The K_w test for agreement within the MHO respondents was calculated on the original twenty-one variable selections and the seven variables used to construct the VANDIX index. Both K_w tests returned a $k = 0.23$ and $k = 0.22$, respectively, suggesting a fair level of agreement beyond the agreement expected by chance between BC's MHOs and the variables that they felt represented the relationship between socioeconomic inequality and relative health outcomes. Further analysis correlating the similarity of the three indices using a Spearman Rank Coefficient returned a correlation statistic of 0.613 (CI 0.01) between the VANDIX and SEFI index, 0.210 (CI 0.01) between the VANDIX and DIHWPQ index and 0.623 (CI 0.01) between the SEFI and DIHWPQ index.

Figure 2.2: Prevalence scores for reporting fair or poor self rated health by socio-economic quintile ranking. *Quintile 1 (value=5.0%) has a coefficient between 16.6% and 33.3% which is considered marginal according to Statistics Canada data quality guidelines. † Quintile 1 (value=6.2%) has a coefficient between 16.6% and 33.3% which is considered marginal according to Statistics Canada data quality guidelines. ‡ Quintile 1 (value=6.3%) has a coefficient between 16.6% and 33.3% which is considered marginal according to Statistics Canada data quality guidelines.
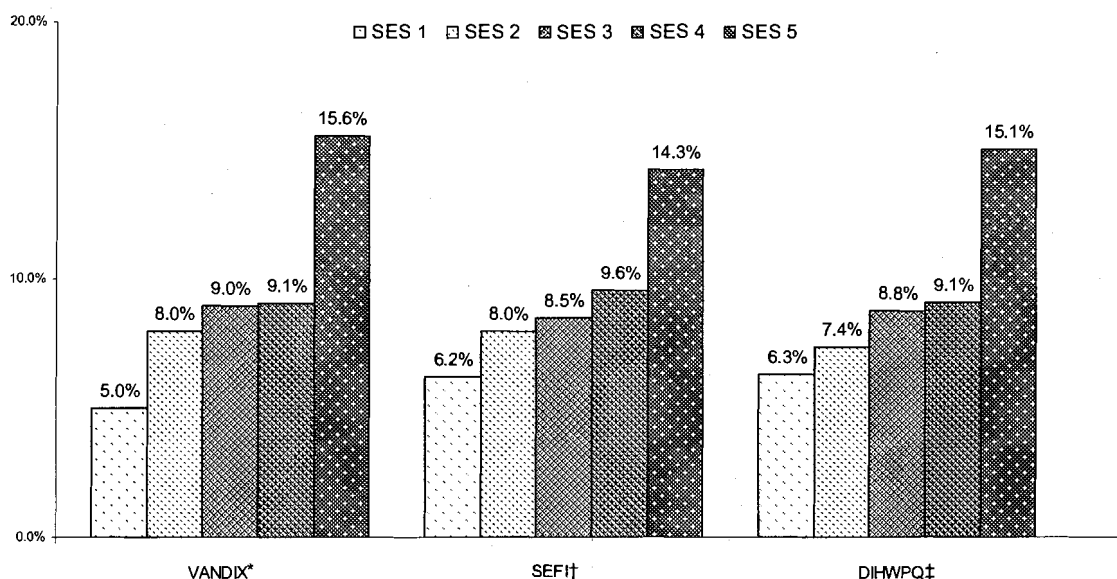
Figure 2.2 illustrates that all indices exhibited a step-wise gradient between

prevalence of reporting fair or poor self-rated health and socio-economic position. A

closer examination of the Census geography revealed a number of similarities and

variations between the three deprivation indices. Areas within the DTES, which include

the resident neighbourhoods of Strathcona, Chinatown, Oppenheimer Park, and the

Hastings Corridor, ranked high in nearly every single socio-economic attribute and were

likewise identified as some of the most disadvantaged neighbourhoods using all three

indices. Only the VANDIX index extended a similar ranking into the

Grandview/Woodlands, Hastings/Sunrise, and Kensington neighbourhoods - areas that

have historically shown a strong association between socio-economic characteristics and

incidence of mortality (Burr, Costanzo, Hayes et al., 1995). Interestingly, the SEFI and

DIHWPQ extended higher quintile rankings into the Kitsilano neighbourhood, which has

historically lower instances of most conditions relating to socio-economic inequality.

The VANDIX score placed the Renfrew/Collingwood neighbourhood, which has

historically had similarly higher instances of socio-economic inequality, into the most

deprived socio-economic quintile. In contrast, the DIHWPQ produced an inverse SES

ranking for the Renfrew/Collingwood neighbourhood. Interestingly, areas within the

Point Grey and Yale Town districts were all equally classified as experiencing greater

deprivation using the DIHWPQ and SEFI indices. Both are neighbourhoods with

historically lower instances of poorer SES and comparably more privileged than other

areas within Greater Vancouver.

Figures 2.3 – 2.5 display mapped variations in SES quintiles between all three

deprivation indices at the Census Tract geography. The Whalley, Bridgeview and

surrounding urban core neighbourhoods in Surrey were identified as amongst the more

deprived neighbourhoods of the Metropolitan area using all three indices, but with

comparably higher proportions of CTs in the highest quintile using the VANDIX. These

neighbourhoods have previously been identified as having lower SES and more

vulnerable to harmful effects on early childhood development (Kershaw, Irwin, Trafford

et al., 2005). In Burnaby, the VANDIX score produced similar quintile classifications

that are consistent with other studies (Kershaw, Irwin, Trafford et al., 2005). Areas within

the Edmonds and Sperling/Westridge neighbourhoods were identified as experiencing

lower SES using the SEFI and DIHWPQ indices, which is not consistent with current

studies (Fiedler 2006a; Fiedler 2006b).

Dissimilar socio-economic position classifications where the VANDIX index reported a 'least deprived' socio-economic score in comparison to a 'most deprived' quintile score reported by the SEFI and DIHWPQ indices were found in select areas within districts in Kitsilano, Westend, and North Vancouver. Dissimilar area classifications in which the SEFI and DIHWPQ reported a 'least deprived' quintile ranking in comparison to a 'most deprived' quintile ranking using the VANDIX index were found in the Strawberry Hill, Green Timbers, and Johnson Heights neighbourhoods in Surrey. All three neighbourhoods are areas known to have a higher prevalence of socio-economic inequality (Kershaw, Irwin, Trafford et al., 2005). No instances were recorded where areas identified as the most deprived using the SEFI and DIHWPQ indices were simultaneously classified as the least deprived using the VANDIX index. Figure 2.2 illustrates that all three indices demonstrate a clear social gradient in health status, but that this relationship is wider using the VANDIX score. The 10.7% gradient between the least and most deprived socio-economic area and self-reported health using the VANDIX was significantly larger than the gradients of 8.1% and 8.8% produced using SEFI and DIHWPQ indices.

A greater proportion of residents reporting fair or poor self-rated health and living within the *least* deprived quintile were recorded using the SEFI and DIHWPQ indices than when using the VANDIX index. Values ranged from 6.2% to 6.3% using the SEFI and DIHWPQ indices. The prevalence rate was reduced to 4.9% when using the VANDIX index. Similar trends were exhibited within the most deprived SES quintiles. The VANDIX corresponded with 15.6% of the individuals living within the most deprived quintile and rating their health as either fair or poor. In contrast, these values

were significantly lower using the corresponding SEFI and DIHWPQ indices, with values ranging from 14.3% to 15.1%.

2.8 Discussion

Our first goal was to create a deprivation index based on primary knowledge of MHOs combined with secondary data taken from the Census. Comparison of the VANDIX index results with two other well known Canadian indices suggest that the indicator variables selected by the MHOs provided greater separation between areas of lower and higher socioeconomic inequality and the prevalence of reporting 'fair or poor self-rated health' at the Census Tract (CT) geography. Moreover, the VANDIX was more reliable in predicting both deprived and privileged areas.

Our second goal was to create a framework for constructing deprivation indices using a survey-based formula. Although the VANDIX index is more subjective than methods of Principal Component or Factor Analysis it produced more accurate representations of neighbourhoods in the Vancouver CMA known to be more socio-economically vulnerable. Significantly fewer populations living in the least deprived quintiles reported fair or poor self-rated health when neighbourhoods were classified using the socio-economic variables selected by the provincial MHOs in comparison to two previously constructed deprivation indices. Likewise, significantly greater populations living in the most deprived quintiles reported fair or poor self-rated health when neighbourhoods were classified using the socio-economic variables selected by the provincial MHOs in contrast to the two previously constructed Canadian indices.

Figure 2.3 – Greater Vancouver Census Tract (CT) SES quintile rankings – VANDIX Index

SES Quintiles

- Census Tracts (CT)
- Non-Residential Parcels

- Quintile 1 (least deprived)
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada. 2001 Census Tract (CT) Census data

49
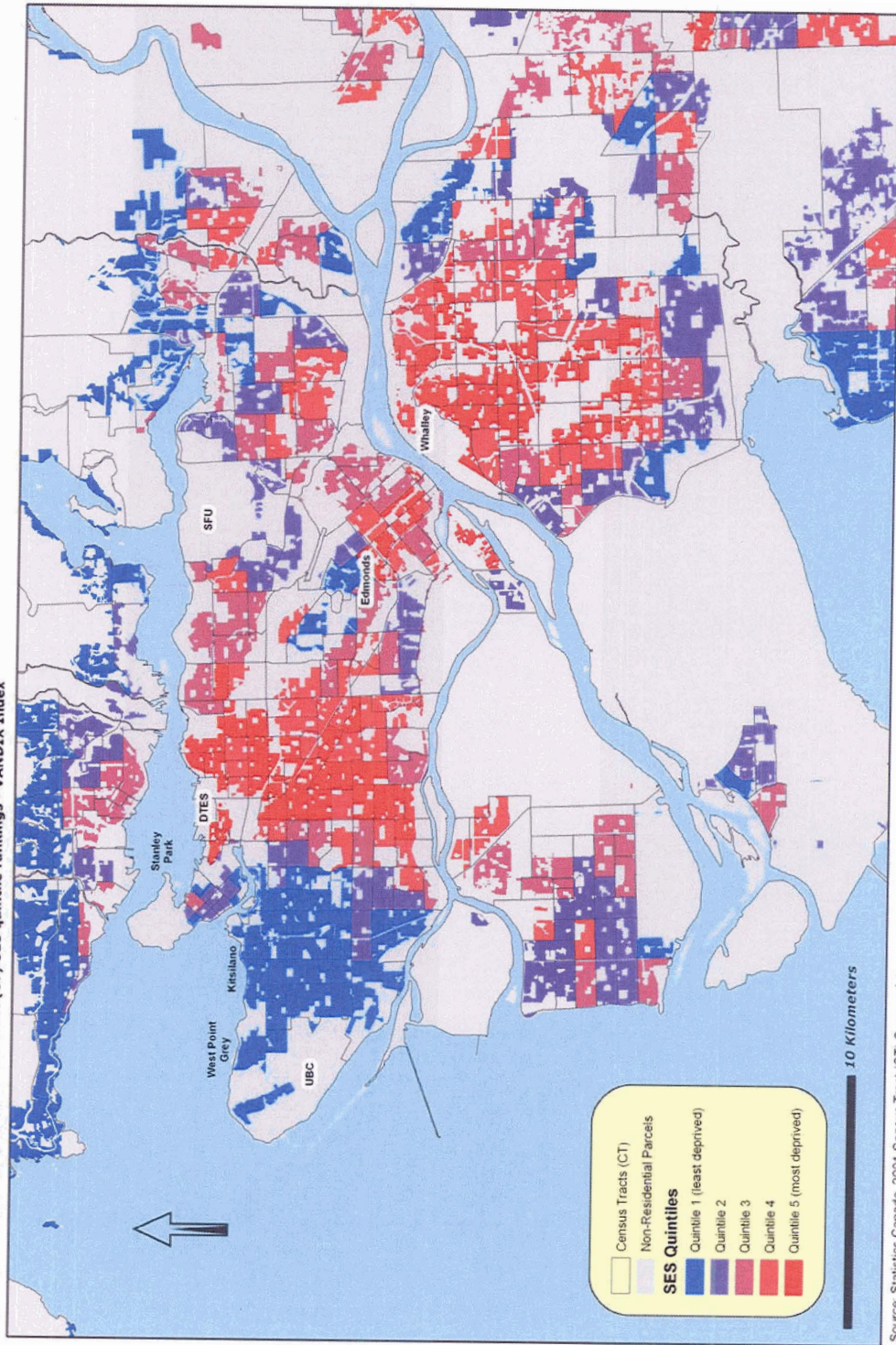
Figure 2.4 - Greater Vancouver Census Tract (CT) SES quintile rankings - SEFI Index

Census Tracts (CT)
Non-Residential Parcels

SES Quintiles
Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada, 2001 Census Tract (CT) Census data

50
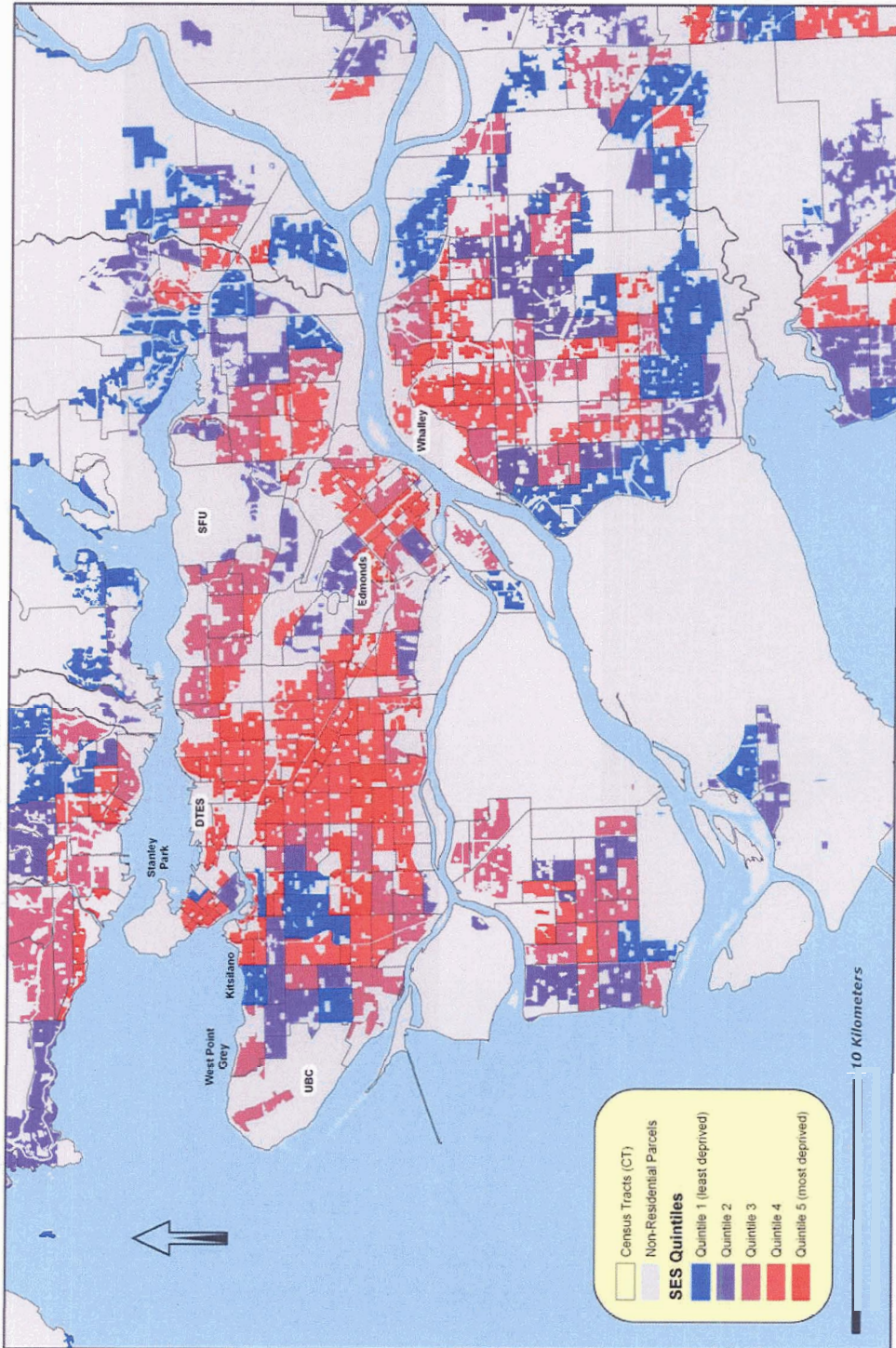
Figure 2.5 - Greater Vancouver Census Tract (CT) SES quintile rankings – DIHWPQ Index

SES Quantiles
- Quintile 1 (least deprived)
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 (most deprived)

Census Tracts (CT)
Non-Residential Parcels

10 Kilometers

Source: Statistics Canada, 2001 Census Tract (CT) Census data

51
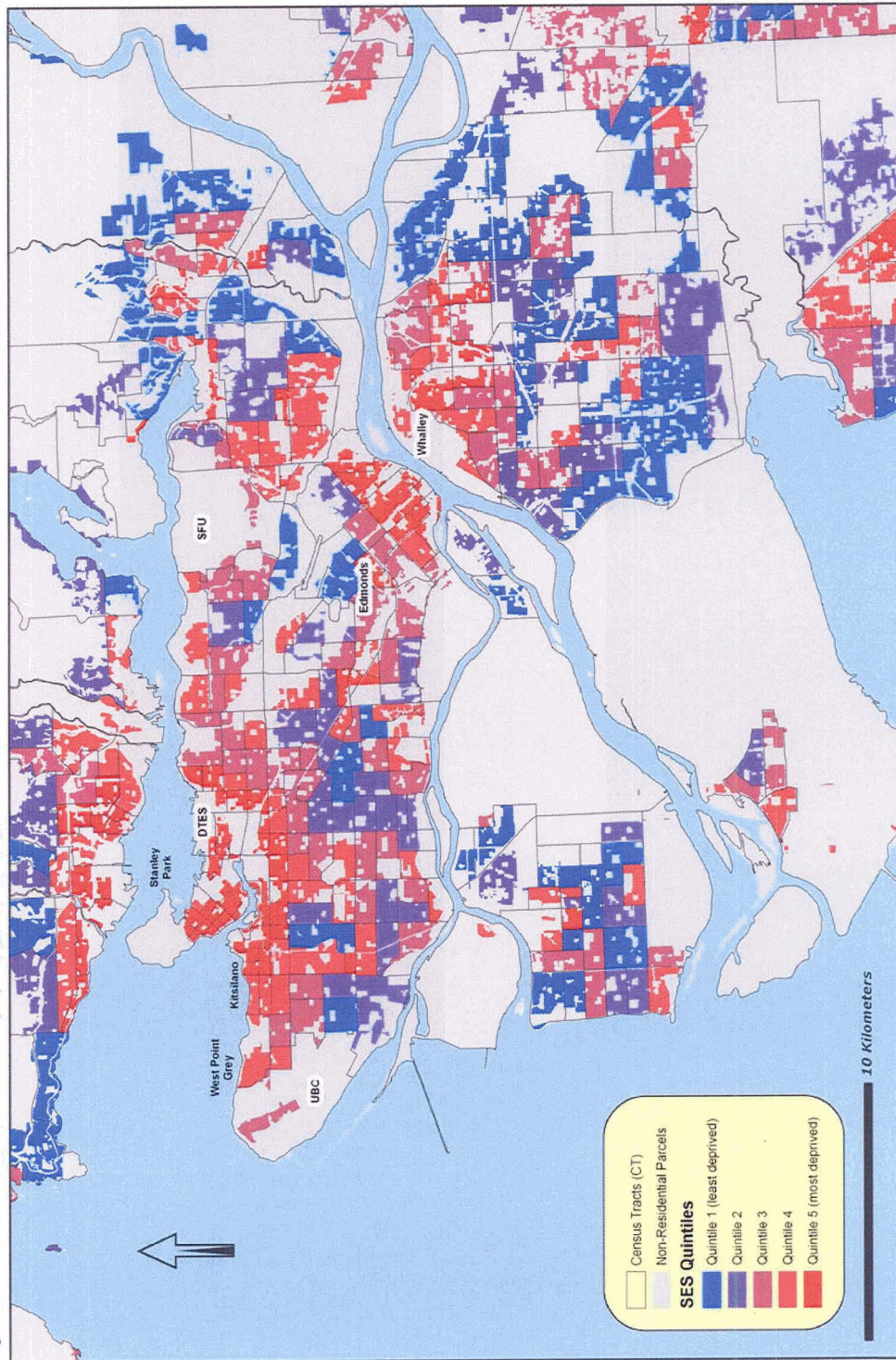
There are a number of limitations of the VANDIX socio-economic index. The outcome measures in this study were based on aggregate data, which does not allow us to adjust for the potentially confounding effect of age. Uneven age distributions can be controlled using standardized percentages or *standard mortality ratios* (SMR). The SMR is the ratio of observed deaths within each age group to the number that would be expected if each age block had the same rates as the standard population. Standardized percentages using Census data can only be calculated using contingency tables, more frequently referred to as cross tabulations.

Spurious correlations resulting from age are especially problematic with educational values as the importance of higher education is largely a phenomenon of post World War II economies. Hence, those areas classified as more deprived due to lower university education scores may simply be representative of populations with greater proportions of seniors. Figure 2.6 is a randomized sample of 30 Census areas from the least and most deprived SES quintiles. Although there is a slightly higher percentage of seniors in the most deprived quintiles, at the aggregate, SES quintile scores are unlikely due to a disproportion of residents with higher education.

Figure 2.6: **Plausible spurious relationship between age and education breakdowns in the most and least deprived quintiles.**

Quintile 1 (N=15)

Quintile 5 (N=15)

0.5

0.4

0.3

0.2

0.1

0.0

% Seniors   % with University
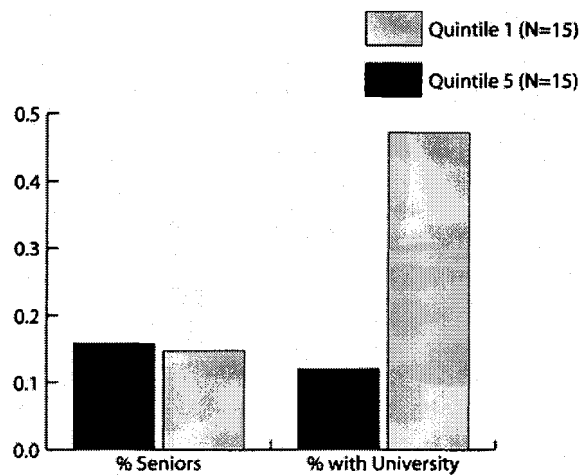
The second limitation is that the low *n* derived by provincial MHO responses to the web survey may produce skewed results. Although there were relatively few MHOs at the time the web survey was administered (n = 18), administering a web-survey to a wider and perhaps more political audience may potentially change the strength of the index. The index is also susceptible to bias. Other medical health experts responding to different or the same survey questionnaire may produce different levels of consistency in their responses. The use of hypothetical and leading questions was avoided as much as possible by structuring a closed-ended survey questionnaire. The weighted Kappa test statistic produced only a 'fair' level of agreement beyond the level of agreement that we would expect by chance that provincial MHOs will routinely select similar socio-economic indicators when provided with a set of constructs. Additionally, MHOs oversee a substantially larger political area than national Census Tract boundaries. Further studies could be conducted as to how medical health professionals spatially conceptualize communities and if Census Tract geographies are an adequate geography in which to ask

health professionals to comment on the socio-economic conditions that influence social gradients in health status.

2.9 Conclusion

Patterning of SES carries with it information about the determinants of health. These distributions are difficult to measure when importing previously constructed deprivation indices. Socio-economic measures should be developed specific to the area in which they are intended to be used. This is a benefit for policy intervention, such as community based planning or resource distribution, that are conducted at the local level. British Columbia's MHOs have a strong understanding of the factors that influence quality of life within urban areas of the province. Constructing deprivation indices using survey-based methods is a novel approach for creating relative measures of socio-economic position. Importing previously constructed deprivation indices leads us further away from a universal indicator of social position, but is necessary in order to unmask the specific conditions that characterize local socio-economic inequality.

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CHAPTER 3:
USING GIS-BASED METHODS OF MULTICRITERIA ANALYSIS (MCA) TO EVALUATE EXPERT GROUP WEIGHTED DEPRIVATION INDICES[7]

3.1 Abstract

Survey-based deprivation indices are frequently overlooked due to the inherent subjectivity of characterizing data using expert knowledge. Data weighting schematics using GIS-based methods of Multicriteria Analysis (MCA) can be used to help validate survey-based deprivation indices as they allow a combination of qualitative and quantitative health data. Using Metropolitan Vancouver, British Columbia as a study area, eight MCA weighting scenarios are placed on the *Vancouver Area Neighbourhood Deprivation Index* (VANDIX), which was originally constructed by provincial Medical Health Officers (MHOs) using a web survey. The indices are tested against two additional Canadian deprivation indices using self-rated health data obtained from the Canadian Community Health Survey (CCHS) Cycle 2.1 database. The MCA models confirm the strength of the VANDIX and suggest that this very subjectivity allows us to better understand and evaluate social gradients in health status then by importing previously constructed measures. Although all weighting schemes are susceptible to a common dilemma (different weights yield different results), developing comprehensive strategies for incorporating local knowledge into deprivation index construction is an effective strategy for identifying spatial distributions of health and socio-economic inequalities.

3.2 Introduction

Like most developed and developing countries, health in Canada is inversely

related to socio-economic position (Martens, Derksen, & Gupta, 2004; Martens, Mayer,

& Derksen, 2002; Odoi, Wray, Emo et al., 2005; Ross, Tremblay, & Graham, 2004;

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[7] The following chapter has been submitted to *Health and Place* with the co-authorship of Dr. Nadine Schuurman and Dr. Michael Hayes.

Ross, Wolfson, & Dunn, 2001). Aggregated social, cultural, or economic data taken from the Census are frequently used to illustrate social gradients in health and longevity amongst the population (Carstairs, 1989; Frohlich & Mustard, 1996; Jarman, 1983; Langlois & Kitchen, 2001; Pampalon & Raymond, 2000; Townsend, Phillimore, & Beattie, 1988). Referred to in the literature as deprivation indices, the indicators are a mechanism for public health policy-makers to assess some of the principal conditions that give rise to inequalities in health (CPHI, 2002; Epp, 1986; Romanow, 2002).

A principal theme in socio-economic research has been to use previously constructed deprivation indices across spaces to help strengthen research results at a national and international scale. This also increases semantic interpretations of the conditions that give rise to social gradients in health as one of the caveats of social models of population health is in deciding on which plausible factors subject one to living a 'deprived' life (Evans, 2002). However, other socio-economic research has shown that developing place-specific socio-economic status (SES) models are more objective in revealing the spatial distribution of local conditions (Fiedler, Schuurman, & Hyndman, 2006a, 2006b). Examining how place-specific and imported deprivation indices characterize urban areas emphasizes the spatial relationship between SES and levels of population health.

A point of significance in contrasting multiple deprivation indices is the weighting strategy used to characterize the spatial unit. We present a Geographical Information Systems (GIS)-based Multicriteria Analysis (MCA) approach testing the robustness of place-specific measures of SES. The MCA variable weighting scenarios are tailored onto the variables used to construct the *Vancouver Area Neighbourhood*

Deprivation Index (VANDIX). The VANDIX was originally constructed using feedback

from British Columbia's Medical Health Officers (MHOs) through a web-survey. Using

urban areas within Metropolitan Vancouver, British Columbia as a study area, we build

several scenarios using MCA that indicate possible locations of urban populations at-risk

for poorer health outcomes. Both MCA environments are tested against the original

VANDIX score in addition to the *Socio-economic Factor Index* (SEFI) and the

Deprivation Index for Health and Welfare Planning in Quebec (DIHWPQ)[8]. Indices are

contrasted against self-rated health data obtained from the Canadian Community Health

Survey (CCHS) Cycle 2.1 database. The weighting strategies proposed in this research

explore the balance between the indicator and its weight in summarizing variations in

health between populations in different social positions.

3.3 GIS-based MCA

In the health sciences, Geographical Information Systems (GIS) have utility for

visually understanding and contemplating population socio-economic distributions

(Kershaw, Irwin, Trafford et al., 2005). They are also frequently used as an exploratory

analysis framework for location and allocation of health care services (Conner,

Kralewski, & Hillson, 1994; Luo & Wang, 2003; Walsh, Gesler, Page et al., 1995),

environmental hazard and risk-assessments (Kulldorff, 1997; Maantay, 2002), and

exploring human and vector born disease ecology (Beck, Rodrigues, Dister et al., 1994;

Chadee, Williams, & Kitron, 2005; Dragicevic, Schuurman, & Fitzgerald, 2004; Glass,

Schwartz, Morgan et al., 1995; Lu, 2004). Although its utility has been demonstrated,

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[8] The SEFI and DIHWPQ were created to measure the socio-economic conditions that characterize population health for populations within the provinces of Manitoba and Quebec (Frohlich 1996; Pampalon 2000).

GIS-based methods of Multicriteria Analysis (MCA) have yet to be thoroughly tested by population health researchers (Schuurman, 2004).

MCA is a decision-making tool designed to condense complex problems involving multiple criteria into a comparative ranking of the most optimal choice (Chen & Hwang, 1992; Jiang & Eastman, 2000; Malczewski, 1996, 1999; Saaty, 1980). MCA decisions are made from the product of multiple inputs and each one may have a more or less favourable influence on the final decision than another. This is primarily a quantitative approach to problem solving. The technique has gained considerable popularity in Geography, but originally stems from the decision-analysis paradigm in which researchers were searching for a means to predict an outcome when the outcome action is either unknown or uncertain (Keeney & Raiffa, 1976). It remains particularly useful in the event that the degree of suitability of the criteria selected by the experts is complex and overwhelming for manual calculation (Carver, 1991).

At its most fundamental level, the MCA environment breaks down complex real-life problems into a number of descriptive chunks (e.g. attributes) that decision makers then re-build to assess a strategy for the most preferred alternatives or choices (Saaty, 1980, 1990). In a GIS environment, MCA strategies have utility in location analyses tied to the resolution of site suitability conflicts (Eastman, Jin, Kyem, & Toledano, 1995; Jiang & Eastman, 2000; Joerin, Theriault, & Musy, 2001) and balancing the tradeoffs and risks associated with various expert opinions engaged in public policy implementation (Bell, Hobbs, Elliot, Ellis, & Robinson, 2001; Hokkanen & Salminen, 1997; Janssen, 2001). In many instances, these are overlapping and even conflicting environments (Chung & Poon, 1996; Landis, 1994). This type of structural framework adds additional

value to complex decision making as it provides a mechanisms for the decision maker to reflect upon the complexity of the problem itself and the value of the conflicting opinions that they must consider (Myšiak, 2006).

In a typical MCA environment, the decision maker oversees the opinions of a number of participants. The participants select a number of criteria that they feel best satisfies the particular goal at hand or the best strategy in which to make a decision. Participants assign weights to the criteria in order to separate one selection from the next. Figure 3.1 illustrates three conventional weighting strategies used to transform qualitative information into quantifiable data, ranging from logical Boolean algebraic *intersection* ($\cap$) and *union* ($\cup$) operators to simple additive weighting techniques. In both strategies, the preferred choice either maximizes or minimizes the criteria with respect to the attributes and its weights.

The utility of MCA in the health sciences is in synthesizing the subjective choices of MHOs into a single, quantifiable model. We present two MCA-based construction strategies as a means of integrating qualitative and quantitative data. The first is a compensatory weighting strategy using the *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS). Compensatory weighting strategies are ideal in instances with complex interdependencies among the variables (Chen & Hwang, 1992; Malczewski, 1999). The approach is similar to the (z) score method using in Townsend (1988) and Carstairs (1989), but the final index is based on the degree to which area score is separated from all other possible choices (Malczewski, 1999). Interdependency is frequently associated with quantifying socio-economic inequality. Many of the

underlying social, material, environment, and early childhood determinants are difficult

to measure as stand-alone components (Hayes, 1994).

Figure 3.1: **Five sample Dissemination Areas (DA) and three MCA weighting techniques. In the Boolean *intersection* model, the lowest of the three area scores (unemployment rate, female lone parents, average income) is used as the proxy measure if SES. In the Boolean *union* model, the proxy measure of area SES is created from the highest area score. In the additive model, the proxy score is constructed from the summation of each of the SES scores.**

Three aggregation strategies for combining multiple criteria
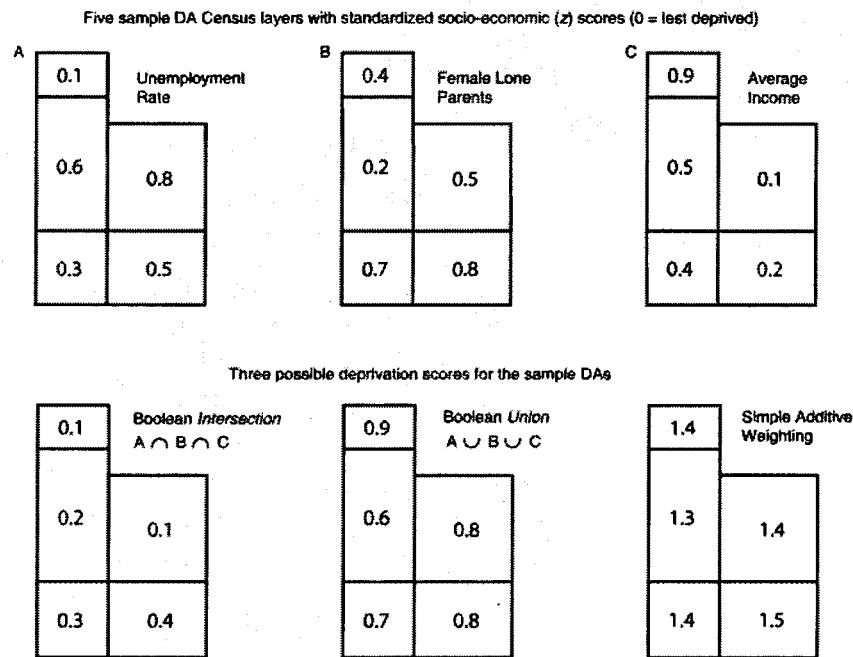
Five sample DA Census layers with standardized socio-economic (z) scores (0 = lest deprived)

Three possible deprivation scores for the sample DAs

The second measure separates the MHO selections into a continuous range of

generalized fuzzy aggregation scores using an *Order Weighted Average* (OWA).

Methods incorporating fuzzy memberships are a means of addressing uncertainty in the

importance of the variables selected by the MHOs (Jiang & Eastman, 2000; Yager,

1988). OWA-based MCA removes some of the inherent uncertainty associated with the

MHO weights through a set of *order weights*. The order weights are not associated with

the weighting coefficients supplied by the MHOs, but through the ordered position of the criterion value in the dataset (Jiang & Eastman, 2000; Malczewski, 1999). Both TOPSIS and OWA methods are reviewed according to their logical consistency to current area-based measures of socio-economic inequality and the robustness of the weighting logic.

3.4 Methods

3.4.1 Study Area

This research focuses on Census population areas within the 21 municipalities of Greater Vancouver. Regions within Metropolitan Vancouver were chosen for this analysis as they encompass a wide collection of highly deprived and highly privileged areas. As a result, Vancouver is a strong candidate for accurate geographic information as to the spatial distributions of socio-economic and health distributions. Part of the reason for the wide array of Census demographics is that Greater Vancouver exhibits one of the widest income gaps in the country. For example, the West Point Grey, Shaughnessy, and Kitsilano neighbourhoods, which are some of the wealthiest neighbourhoods in the country, closely border the Downtown Eastside, Oppenheimer, and Chinatown districts, widely considered as some of the poorest neighbourhoods in Canada. Over the past two decades a considerable number of investigations have shown an inverse association between SES and health outcomes within a number of neighbourhoods within the region (Burr, Costanzo, Hayes et al., 1995, Dunn 2000; Dunn 2002). There is also a growing interest in identifying the spatial distributions of health outcomes within the suburban regions of the Fraser Valley (Kershaw 2005).

3.4.2 Participants

The MCA-based deprivation indices were constructed using the original variables selected to create the *Vancouver Area Neighbourhood Deprivation Index* (VANDIX). Briefly, the VANDIX index was constructed using feedback from the Provincial Medical Health Officers (MHOs). MHOs were contacted via e-mail. Their e-mail listings were obtained through the Chief Provincial Medical Health Officer of British Columbia. Participants were provided with an overview of the research objective and asked to comment on the specific Census variables that they most strongly felt influenced socio-economic inequality and relative health outcomes within urban areas of the province. The questions were closed ended. Responses were tallied using a Likert scale (strongly agree – strongly disagree).

Table 3.1   VANDIX weights are proportional to the number of responses by the MHOs. Strongly Agree responses were assigned a value of 5 and Agree responses a value of 4.

Socio-economic Constructs	Strongly Agree Responses	Agree Responses	Sum	Rank	Weight (%)
Material Wealth					
Average Income	2	6	34	5.5	0.089
Housing					
Home Ownership	2	6	34	5.5	0.089
Demographics					
Single Parent Family	4	4	36	4	0.143
Education					
No High school Completion	6	4	46	1	0.250
with a University Degree	5	3	37	3	0.179
Employment					
Employment Ratio	4	3	32	7	0.036
Unemployment Rate	6	3	42	2	0.214

The survey was organized into seven sections containing a total of 21 variables

taken from the Census. Each section provided the MHOs with a number of socio-

economic indicators that can be broadly classified as representing one of the many social,

cultural, or material constructs indicative of deprivation. Table 3.1 lists the constructs and

MHO selected variables used to create the VANDIX.

3.4.3 SEFI and DIHWPQ comparison indices

Both the Socioeconomic Factor Index (SEFI) developed in Frohlich (1996) and

the Deprivation Index for Health and Welfare Planning for Quebec (DIHWPQ)

developed in Pampalon (2000) compress the individual socio-economic variables into an

underlying dimension using variations of Principal Component Analysis. Six constructs

representing social and material deprivation were used to build the SEFI and DIHWPQ

indices. The SEFI index includes: an age dependency ratio, the percent of single parent

families, the percent of female single parent families, the female labour force

participation rate, the unemployment rate, and the percent of residents with a minimum of

a high school diploma. The DIHWPQ uses Principal Component Analysis and log

reductions to compress the six indicator variables into their material and social

constructs. The index includes three variables reflective of material deprivation: persons

with no high school education, the employment ratio, and average income. The social

components include the percent of persons living alone, the percent of those who are

separated, divorced, or widowed, and the percent of single parent families.

3.4.4   Geographic scale

Summary socio-economic statistics were assessed using Census Tracts (CTs) and Dissemination Area (DA) administrative boundaries. CTs are only created for urban areas with a core population of over 50,000 people. They represent small and relatively stable geographic boundaries with a single CT usually ranging from 2,500 to 8,000 in population, with an average population of 4,000. In the 2001 Canadian Census, the DA boundaries replaced the Enumeration Area (EA) as the basic unit of geographic dissemination. DA boundaries are similar in scope to a single or multiple neighbourhood blocks. Typically, they contain a target population ranging from 400 to 700 persons. Both the CT and DA/EA Census geographies have been previously been used to assess the socio-economic conditions for areas in Manitoba and Montreal although CT boundaries are frequently the more popular unit of choice as they are homogenous and characteristic of urban neighbourhoods (Ross, Tremblay, & Graham, 2004). In the 2001 reporting Census year the Vancouver CMA was comprised of 384 CTs and 3269 DAs.

3.4.5   Health outcome data

Self-reported health data were obtained from a subset of the Canadian Community Health Survey (CCHS) Cycle 2.1 database from the question "In general, would you say your health is: Excellent, Very Good, Good, Fair, Poor." The CCHS is a cross-sectional population health survey primarily focusing on working-age individuals living in private households across Canada. 98% of the CCHS sampling frame is obtained from regional and telephone sampling frames and with 2% from random digit dialling. Self-rated health data was collected between the months of January and November 2003.

3.5 Statistical Analysis

3.5.1 Self-rated health data

Data were taken from a sub-set of respondents between 18 and 74 years of age living in the Vancouver CMA (n=6,157). Individual responses were dichotomized into two constructs: *good health*, which was comprised of 'Excellent,' 'Very Good', and 'Good' responses and *poor health*, which was comprised of 'Fair' and 'Poor' responses. Dummy variables were constructed from the dichotomized health responses and compared against quintile rankings of the socio-economic area scores. Prevalence of reporting fair or poor self-rated health was the control variable and contrasted against each socio-economic quintile ranking. Prevalence estimates were obtained using 500 bootstrap weights provided by Statistics Canada using SAS software. Bootstrapping weights are introduced into the data to account for the complex design of the CCHS sampling frames. Sample weights were assigned to the self-rated health responses so that results were representative of the population living within Metropolitan Vancouver. The bootstrap coefficients gauged the quality of estimates between the self-rated health responses and SES quintiles. Estimates less than 16.5% are considered acceptable, estimates between 16.6% and 33.3% are flagged as marginal, estimates greater than 33.3% are flagged, but not released.

3.5.2 MCA analysis using TOPSIS

The TOPSOS deprivation index is constructed based on compensatory weighting of the variables. The most deprived area score is simultaneously the area with least distance from the most deprived score and the greatest distance from the least deprived score. The separation measure is determined using a distance metric, which is adjusted

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depending on the level of concern for separating the minimum and maximum distance from the ideal (Chen & Hwang, 1992). The distance metric uses a monotonically increasing value, which is similar to the studies conducted in Townsend (1988), Carstairs (1989), and Jarman (1983) where deprivation scores are designed to maximize the level of inequality within the study area.

Census variables (v_{ij}) were assigned their original proportional significance as provided by the original VANDIX weights (w_i) listed in Table 3.1. The first measure of separation was calculated by subtracting the weighted variables by their reciprocal maximum and minimum values. For all v_{ij} the maximum value was 1 and the minimum value for all v_{ij} was assigned a value of 0, symbolizing both extremes of socio-economic inequity and prosperity. The second separation measure calculated the distance from the minimum and maximum ideal using a Euclidean distance metric:

$$s_{i+} = \left[\sum_i (v_{ij} - v_{+j})^2 \right]^{0.5}$$

$$s_{i-} = \left[\sum_i (v_{ij} - v_{-j})^2 \right]^{0.5}$$

where s_{i+} is the separation of the ith socio-economic variable from the maximum level of socio-economic inequality, s_{i-} is the separation of the ith socio-economic variable from the lowest level of socio-economic inequality, v_{+j} is the highest level of socio-economic inequality (most deprived), v_{-j} is the lowest level of socio-economic inequality (least deprived), and p is the Euclidean distance metric. The separation of each area score relative to the surrounding area was determined by

$$c_{i+} = \frac{S_{i-}}{S_{i+} + S_{i-}}$$

where the most deprived area scores were assigned based on c_{i+} values that approached 1

(Chen & Hwang, 1992; Malczewski, 1999). Area scores were reclassified into quintiles,

with the least deprived socio-economic areas assigned a value of 1 and the most deprived

socio-economic areas assigned a value of 5.

3.5.3 MCA analysis using OWA

The strength of association between socio-economic variables can also be seen as

inherently fuzzy due to the complex interdependency between the indicators. Concepts

such as age comparisons (this person is much *younger* than him) or health comparisons

(this area is *substantially* healthier than that area) can be compared through fuzzy value

approximations. Unlike classical set theory (Boolean *Intersection* [∩] and *Union* [∪]),

fuzzy set theory is intended to help identify the membership of a given object, *x* to a

given crisp set, *U*. The utility of this approach in deprivation index construction is

measuring the strength of the indicator relationships selected by the MHOs.

The membership rules of fuzzy logic are derived from research conducted by

Lofti Zadeh in the 1960's and numerous others. Methods for ranking fuzzy sets in an

MCA environment are quite diverse (Banai, 1983; Chen & Klein, 1997; Deng, 1999; Raj

& Kumar, 1998; Yeh & Deng, 2004). Seldom are situations so homogenous that a single

method of ranking fuzzy sets can be used and no one set that can be used to model all

circumstances. We chose the *Order Weighted Average* (OWA) because its continuous

scaling framework between crisp Boolean *Union* and *Intersection* sets provides a

platform to address relationship uncertainty amongst the weighted data.

The OWA method is appealing because it tests the inherent subjectivity and bias in the indicator weights selected by the MHOs. This is done by assigning a set of *order weights* to the variables selected by the panel. The order weights are not assigned to the survey variables based on the MHO weights. They are assigned to the Census variables based on the value of each variable within the Census area. This allows the deprivation index to reflect the variables selected by the MHOs and the inherent value of the SES variable in the dataset. For example, consider an urban area evaluated in terms of its level of socio-economic inequality using four variables: level of education, average income, unemployment rate, and percent of residents living alone. The standardized area scores for each variable are (x_i = 0.4, 0.2, 0.5, 0.7), bound by the Boolean *AND* (*intersection*, 0, $\cap$) and *OR* (*union*, 1, $\cup$). The rank order of variable importance is the unemployment rate, level of education, average income, followed by the percentage of residents living alone (w_{ij} = 0.4, 0.3, 0.2, 0.1). The area's socio-economic score as determined by the rank weights would be = (0.4 x 0.3, 0.2 x 0.2, 0.5 x 0.4, 0.7 x 0.1) = 0.43. Assigning order weights to the original variables results in (0.7 x 0.4, 0.5 x 0.3, 0.4 x 0.2, 0.2 x 0.1) = 0.53.

Table 3.2   Order weights assigned to the seven VANDIX socio-economic variables using the rank order selected by the provincial MHOs. The Boolean *union* is the inverse of the Boolean *intersection.* As the number of criteria within both sets approach the averaging operator the closer the trade-off amongst the variables is equal to one.

Operator	Order Weights	ANDness	Orness	Trade-Off
MIN (a) (AND)	1, 0, 0, 0, 0, 0, 0	1	0	0
MIN (b)	0.7, 0.15, 0.1, 0.05, 0, 0, 0	0.92	0.08	0.35
MIN (c)	0.4, 0.25, 0.15, 0.1, 0.05, 0.025, 0.025	0.78	0.22	0.63
TRADE-OFF (Ave)	0.142, 0.142, 0.142, 0.142, 0.142, 0.142, 0.142	0.5	0.5	0.93
MAX (c)	0.025, 0.025, 0.05, 0.1, 0.15, 0.25, 0.4	0.22	0.78	0.63
MAX (b)	0, 0, 0, 0.05, 0.1, 0.15, 0.7	0.08	0.92	0.35
Max (a) (OR)	0, 0, 0, 0, 0, 0, 1	0	1	0

Using OWA, the seven variables from the VANDIX are weighted from the Boolean risk-adverse AND ($\cap$) and the risk-seeking OR ($\cup$) sets, resulting in a continuous range of area scores from the MHO responses. Table 3.2 illustrates this effect. A risk-adverse, or *AND* ($\cap$), model assigns an order weight of 1 to the MHO selected variable that produces the lowest area score of the seven factors and a 0 to all subsequent variables. This method is the inverse of current deprivation indices. It essentially minimizes the level of socio-economic inequality in the study area. It is synonymous to the metaphor 'a chain is only as strong as its weakest link' (Chen & Hwang, 1992). The inverse of the *AND* ($\cap$) model is a risk-seeking OR ($\cup$) operator. This model assigns an order weight of 1 to the MHO variable that produces the highest area score of the seven factors and a 0 to all subsequent variables. It is based on the principle that an athlete is selected based on her best attribute (Chen & Hwang, 1992). This is similar in scope to the UK indices where scores were assigned to Census wards to maximize the level of deprivation within each area. There is some alteration as the full OR ($\cup$) model is

represented by a single socio-economic variable, which implies *single* versus *multiple* deprivations. Gradients between the logical AND ($\cap$) and OR ($\cup$) are scaled between both extremes. These combinations use two through six of the indicators selected by the MHOs. A full trade-off (Averaging) of the order weights is obtained when all seven indicators are used. The OWA order weights are calculated by

$$ANDness(w) = \frac{1}{n-1}\sum_r (n-r)w_r$$

$$ORness = 1 - ANDness$$

$$TradeOff(w) = 1 - \left[\frac{n\sum_r (w_r - 1/n)^2}{n-1}\right]^{0.5}$$

where n is the number of criteria in the MCE, r is the position of each criterion, and w_r is the weight of the particular criterion, r (Jiang & Eastman, 2000; Malczewski, 1999).

The order weights assigned to the MHO factor scores resulted in the generation of seven deprivation indices based on the original rank order of the variables originally selected for the VANDIX. Each index was reclassified into quintiles. The least deprived socio-economic areas were assigned a value of 1 and the most deprived socio-economic areas assigned a value of 5.

3.6 Results

98% of the CTs had at least one resident who completed the survey (n=3920[9]), with an average of 10 residents per Census Tract. The number was slightly less for the DAs (n=3879), with 53% of the DAs having at least one resident who completed the

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[9] 2,237 of the original 6,157 responses were discarded due either to missing cases, or because they included individuals who were not between 18-74 years of age.

survey and an average of 2 residents per DA. Due to the sensitivity of the health data, all individual self-reported health records were aggregated into their corresponding Census administrative boundaries and used as a marker representing instances of reporting 'fair or poor health' self-rated health for the individual CT or DA unit. To protect individual confidentiality, the specific DA and CT boundaries where the individuals reside are suppressed.

Figures 3.2 - 3.12 list socio-economic quintile rankings for Dissemination Area geographies within greater Vancouver using the original VANDIX, SEFI, DIHWPQ indices in addition to the eight MCA-weighted VANDIX scores. Visual analysis of the geographies shows clear variations in neighbourhood SES quintile ranking across the indices, with the greatest dissimilarities between the DIHWPQ and the more risk-adverse (MIN a, b) MCA variations. At the DA spatial extent, each index illustrates that most areas of west Vancouver are at the opposite end of the socio-economic spectrum compared to neighbourhoods in Vancouver, although the VANDIX indices are more demonstrable of this effect.

Figure 3.2 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - VANDIX Index

Legend:

Census Tracts (CT)
Non-Residential Parcels

SES Quintiles

Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada 2001 Dissemination Area Census data

Map labels: Stanley Park, West Point Grey, Kitsilano, UBC, DTES, SFU, Edmonds, Whalley
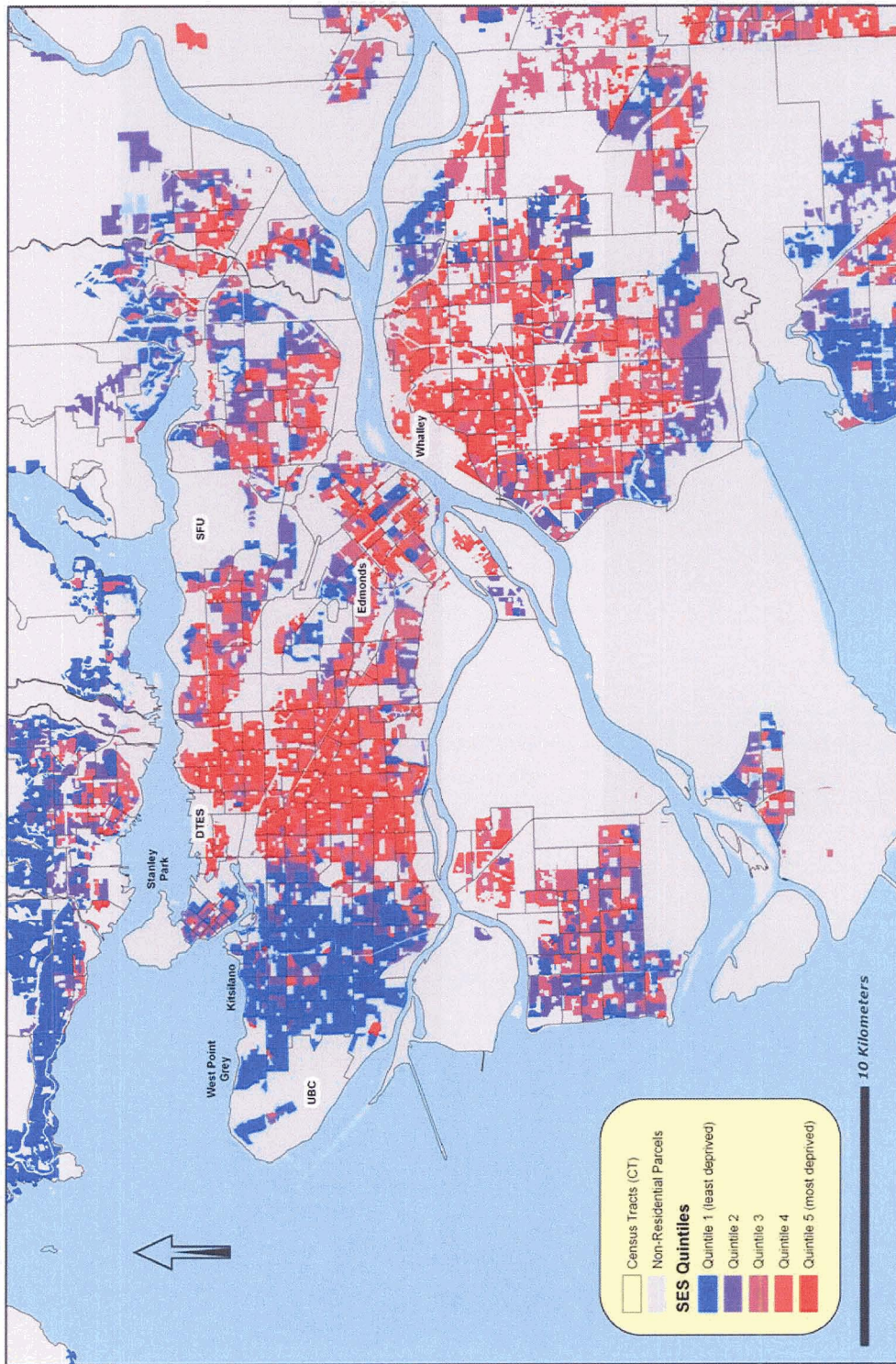
Figure 3.3 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - SEFI Index

Census Tracts (CT)
Non-Residential Parcels
SES Quintiles
Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada, 2001 Dissemination Area Census data

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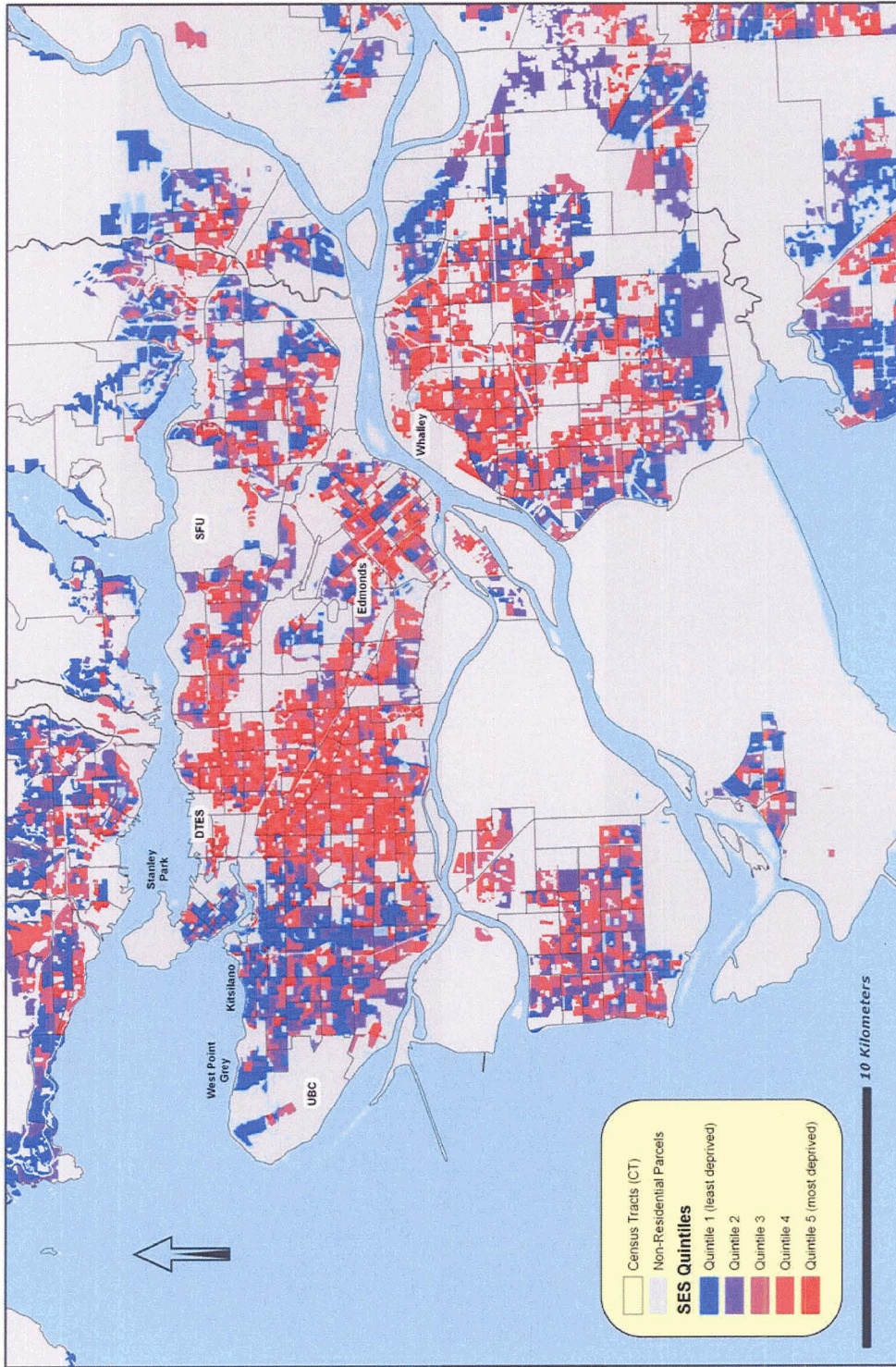
Figure 3.4 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - DIHWPQ Index

10 Kilometers

SES Quintiles
☐ Census Tracts (CT)
☐ Non-Residential Parcels
■ Quintile 1 (least deprived)
■ Quintile 2
■ Quintile 3
■ Quintile 4
■ Quintile 5 (most deprived)
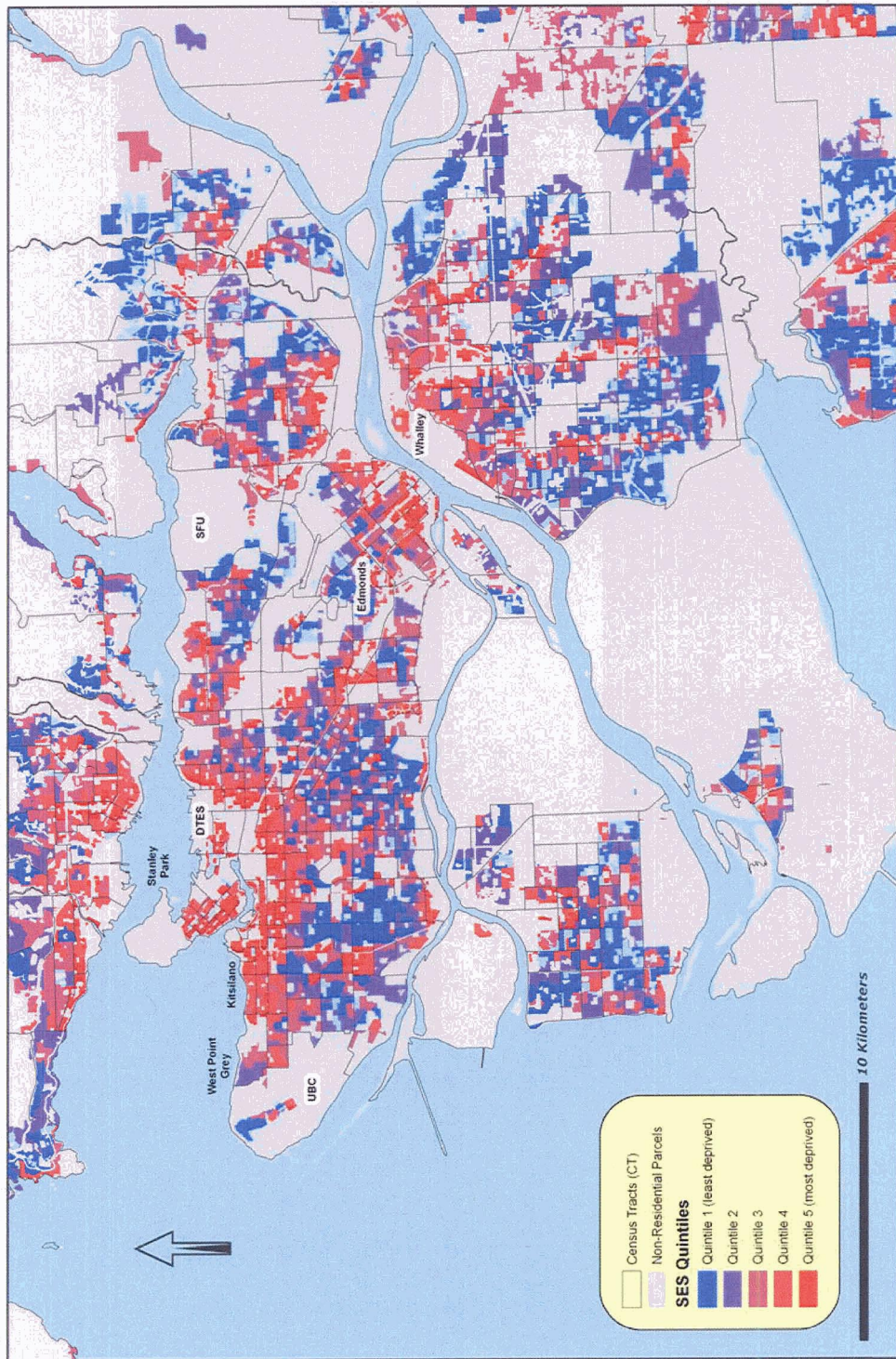
Source: Statistics Canada, 2001 Dissemination Area Census data

Figure 3.5 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - TOPSIS Index

Census Tracts (CT)
Non-Residential Parcels

SES Quintiles
Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada, 2001 Dissemination Area Census data

Figure 3.6 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Min (a) Index

SES Quintiles

- Census Tracts (CT)
- Non-Residential Parcels

Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada, 2001 Dissemination Area Census data

Figure 3.7 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Min (b) Index

SES Quintiles

- Census Tracts (CT)
- Non-Residential Parcels

Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

West Point Grey
UBC
Kitsilano
Stanley Park
DTES
SFU
Edmonds
Whalley

Figure 3.8 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Min (c) Index

Census Tracts (CT)
Non-Residential Parcels

SES Quintiles
Quintile 1 (least deprived)
Quintile 2
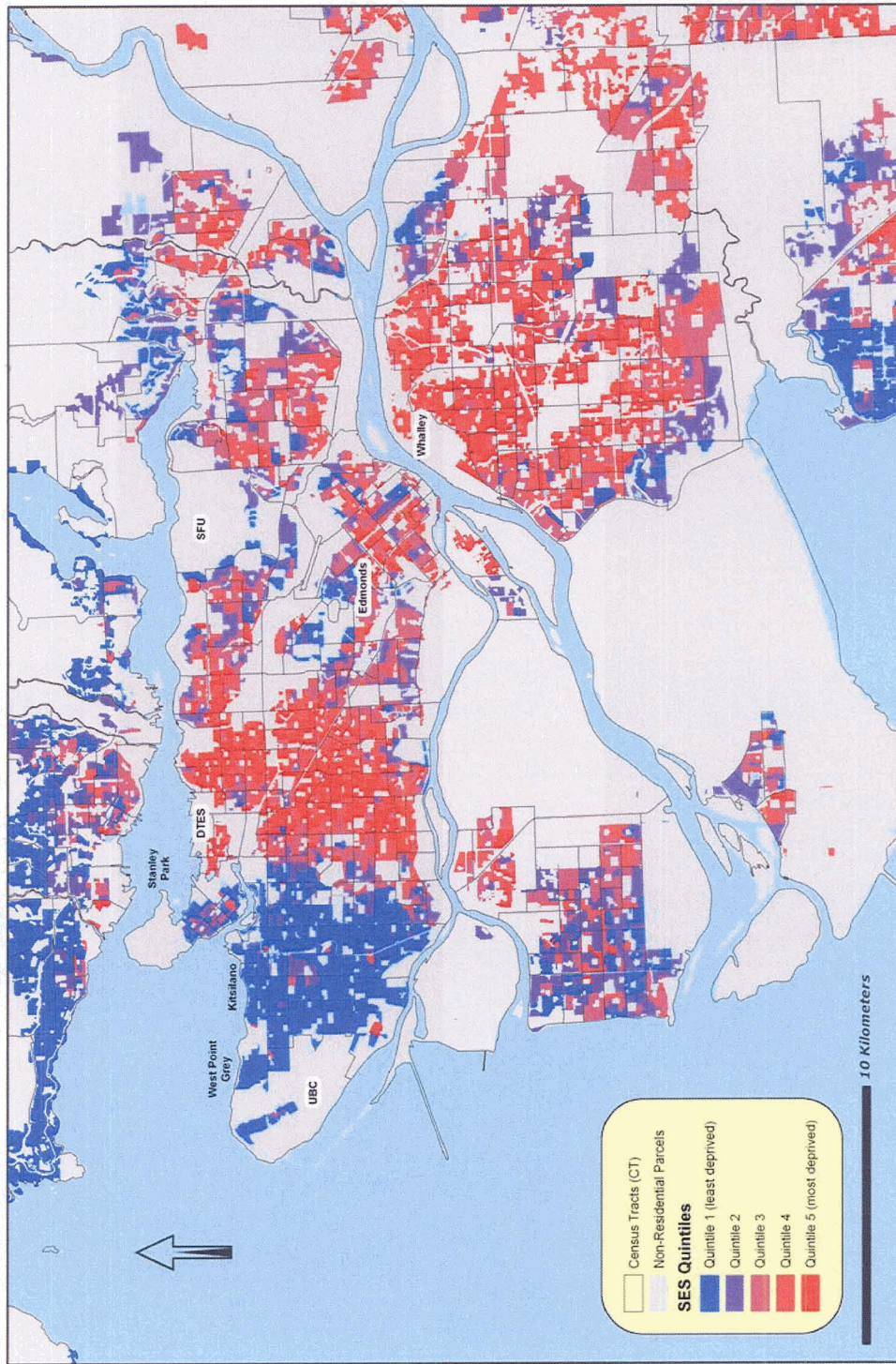Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers
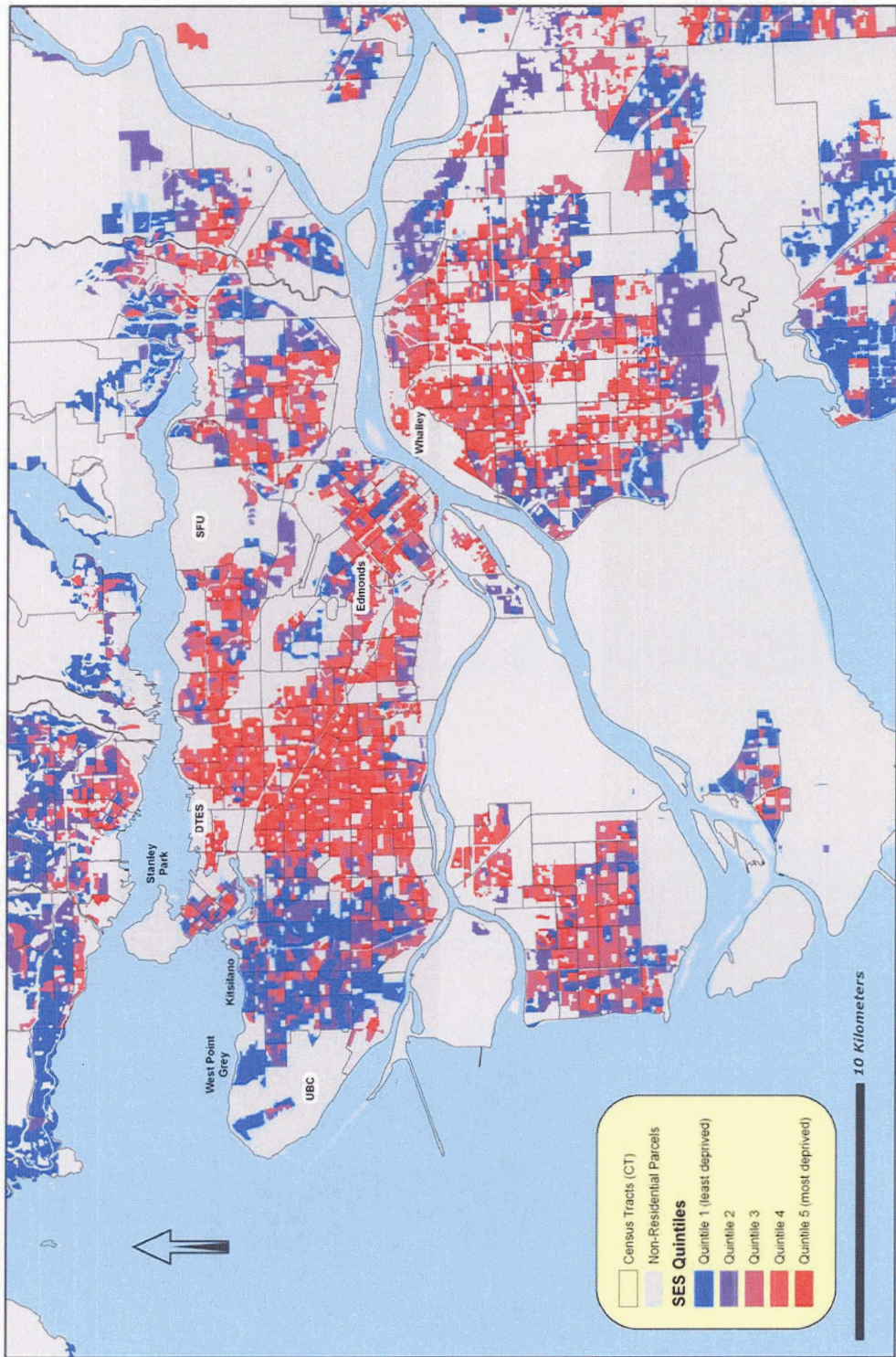
Source: Statistics Canada, 2001 Dissemination Area Census data

Figure 3.9 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Ave (trade-off) Index

Source: Statistics Canada. 2001 Dissemination Area Census data

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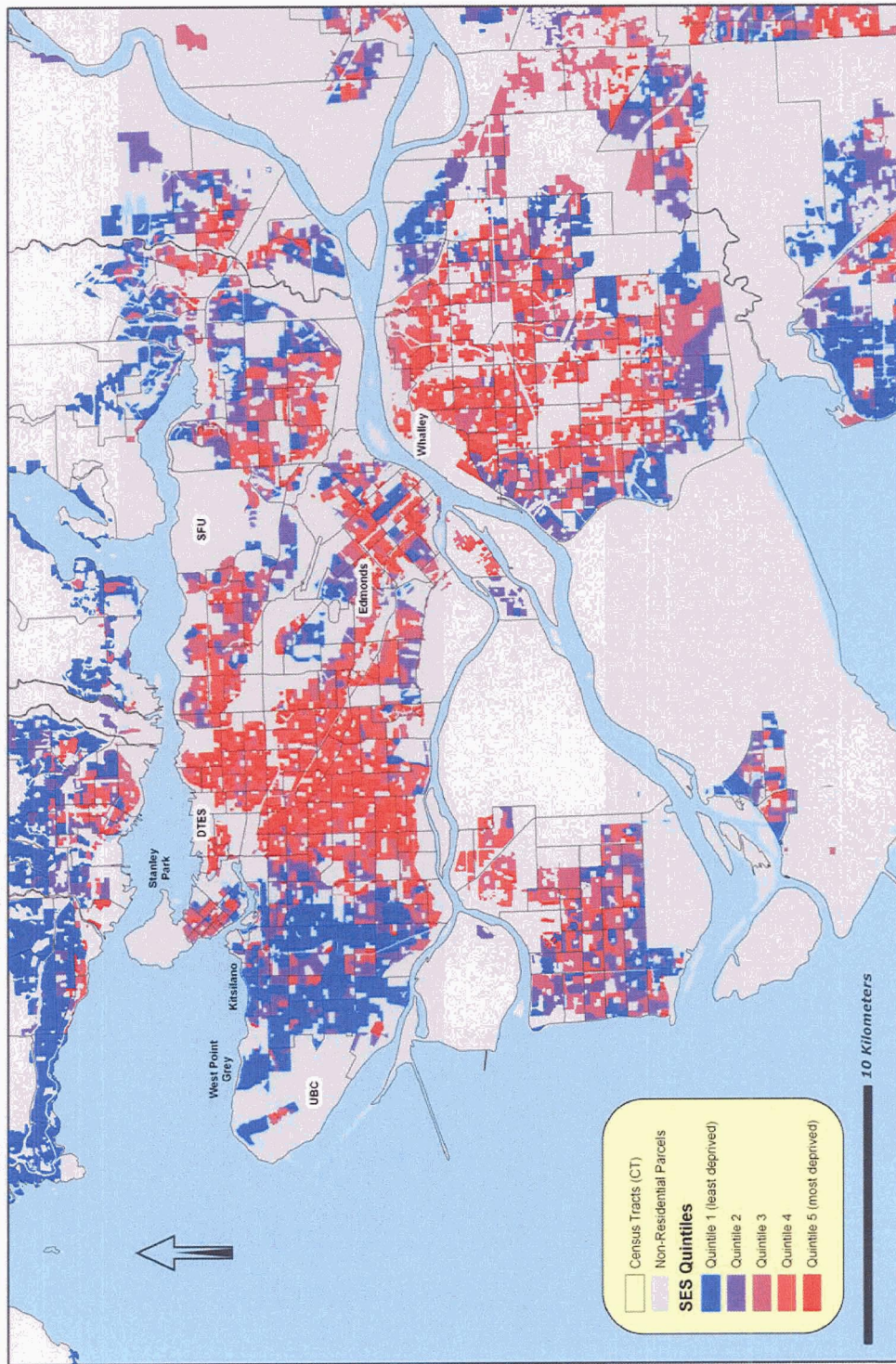
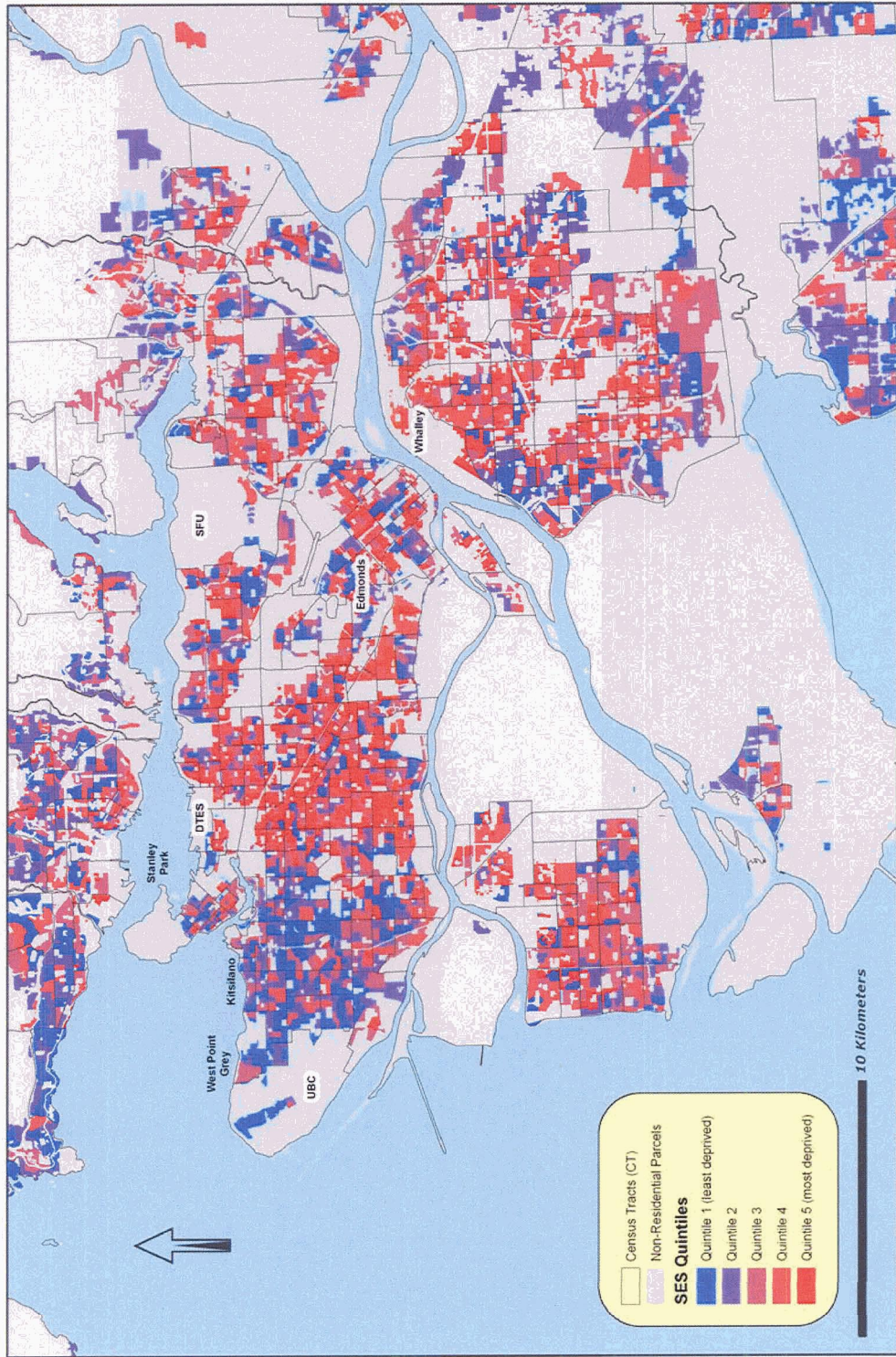Figure 3.10 – Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Max (c) Index

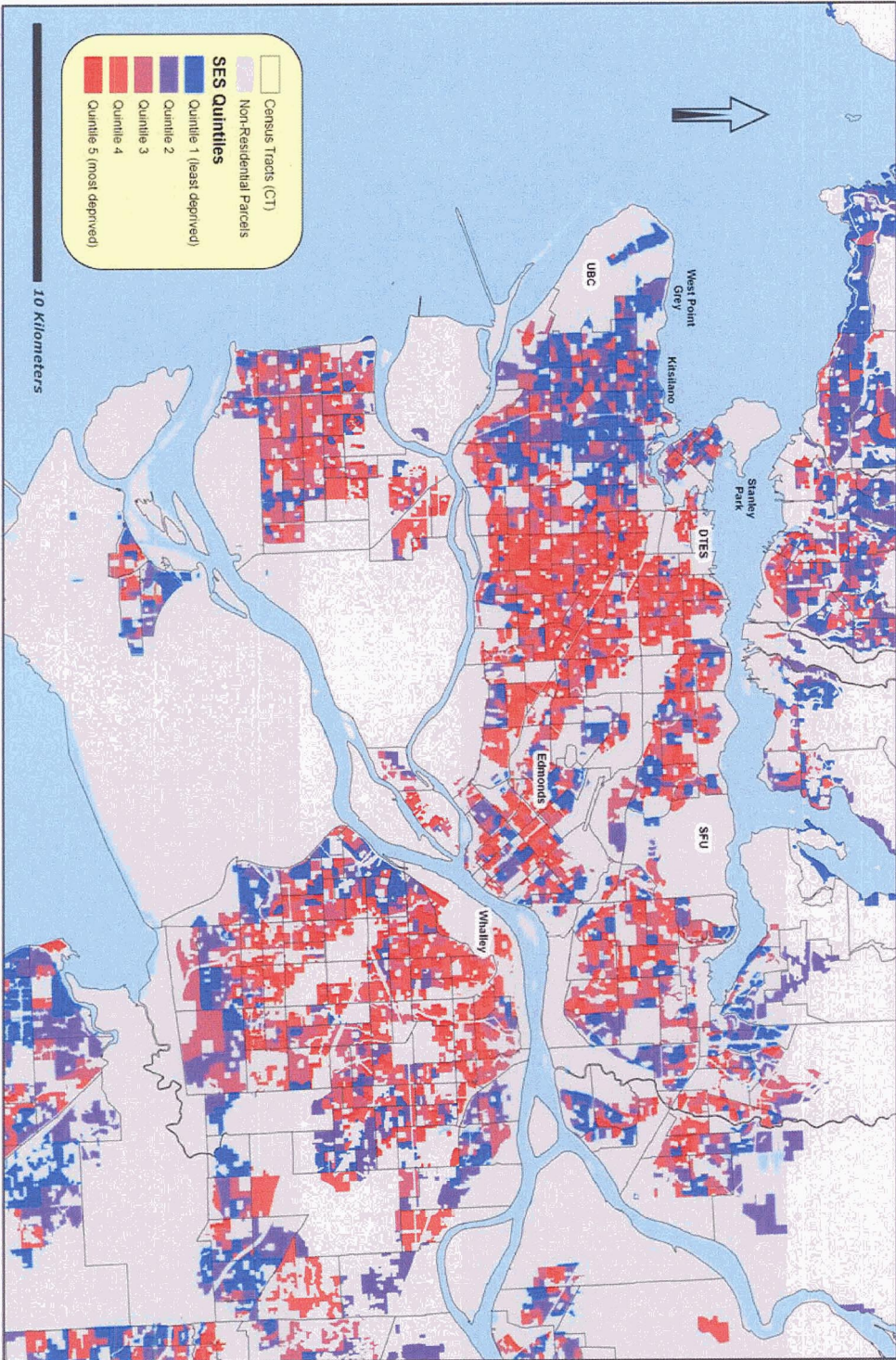Source: Statistics Canada. 2001 Dissemination Area Census data

Figure 3.11 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Max (b) Index

Census Tracts (CT)
Non-Residential Parcels
SES Quintiles
Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)
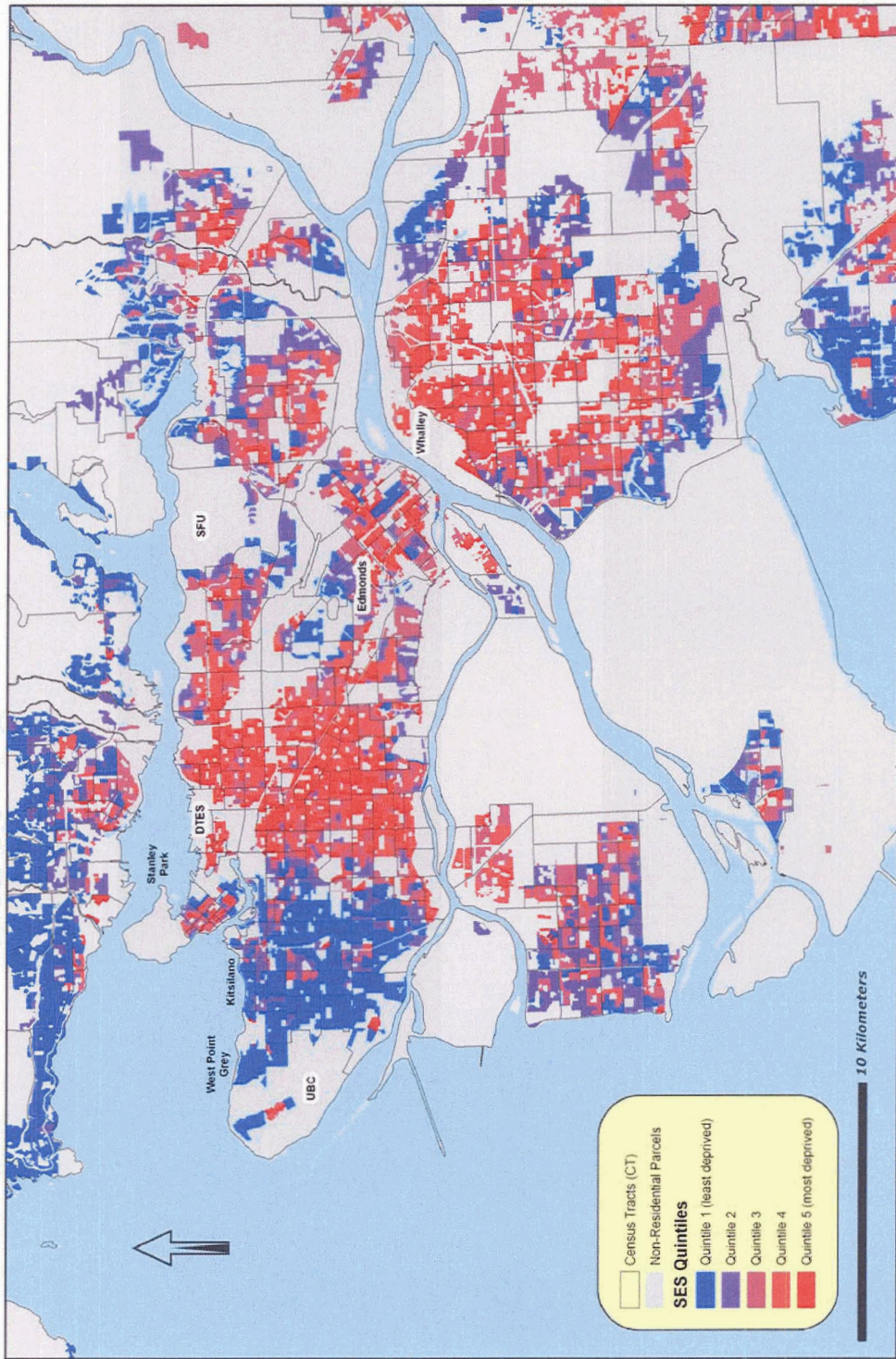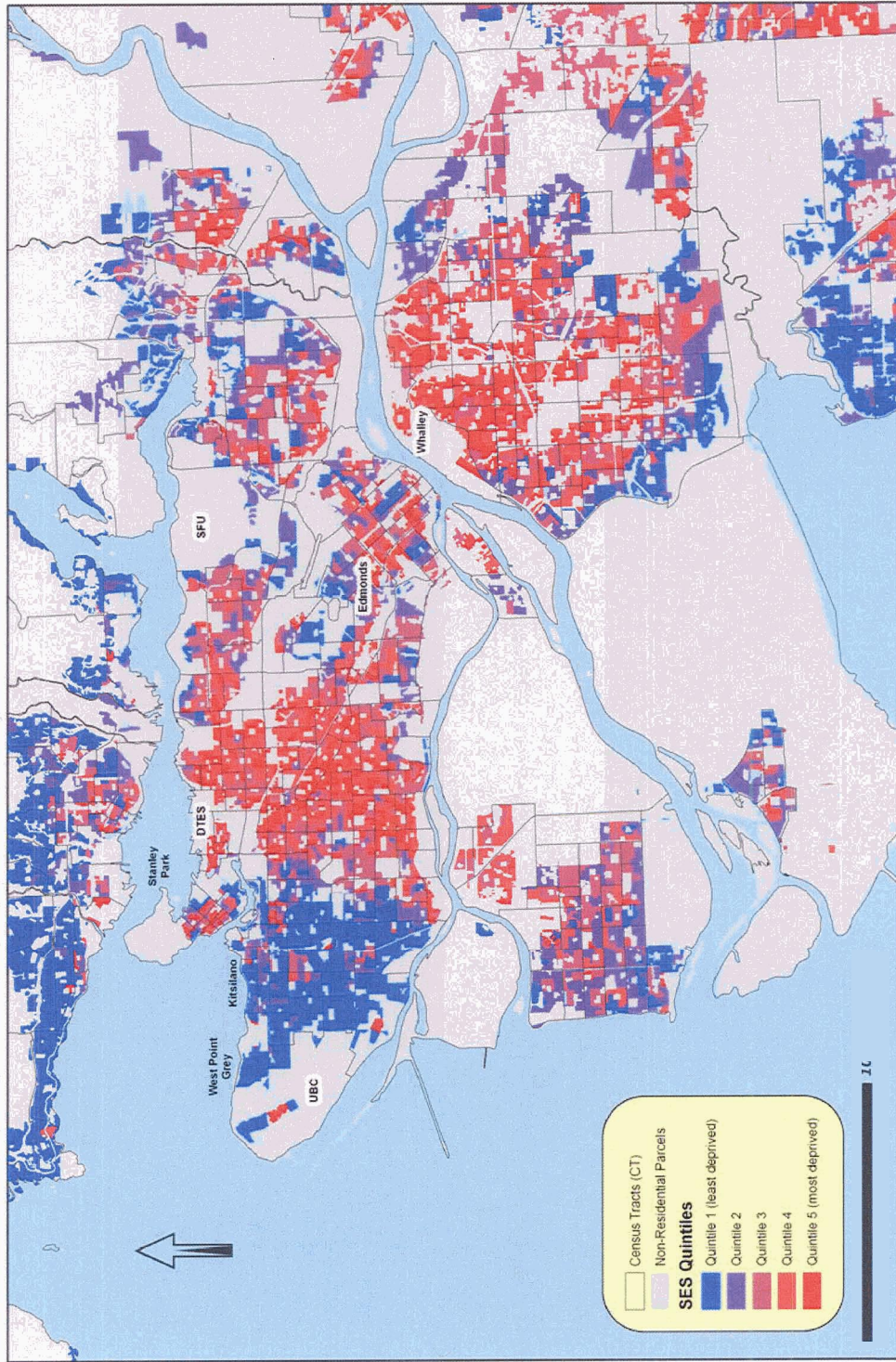
Source: Statistics Canada, 2001 Dissemination Area Census data

Figure 3.12 - Greater Vancouver Dissemination Area (DA) SES quintile rankings - OWA Max (a) Index

Census Tracts (CT)
Non-Residential Parcels

SES Quintiles
Quintile 1 (least deprived)
Quintile 2
Quintile 3
Quintile 4
Quintile 5 (most deprived)

10 Kilometers

Source: Statistics Canada, 2001 Dissemination Area Census data

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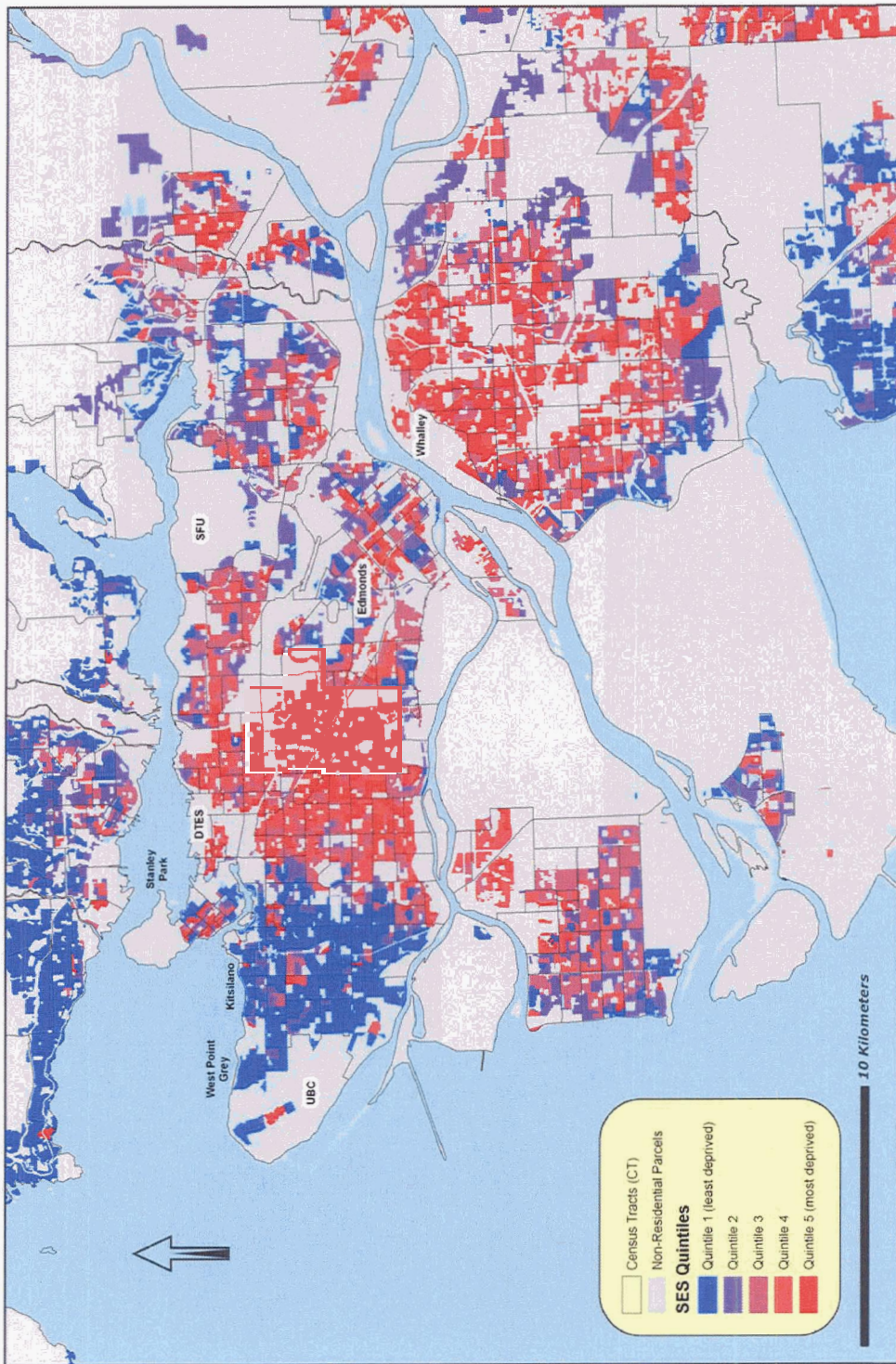
At the CT geography (n = 385), 55% of the OWA Boolean *intersection* (MIN) SES quintiles were measured against self-rated health using only the areas unemployment rate. In Greater Vancouver, there are noticeably high unemployment concentrations in areas within Kitsilano, and Shaughnessy neighbourhoods compared to the CMA average (7%). A similar rate was found at the DA geography, with a slightly higher percentage of 61%. The remaining MIN (a) quintiles at the CT geography were dispersed between the remaining six Census variables. The majority of the remaining correlations at the DA geography were based on the proportion of lone parent families. At the opposite end, 56% of the CT MAX (a) quintiles were based on the areas average income, which was again the dominant reference variable at the DA level, with 72% of prevalence scores associated with the areas average income.

The histograms in figures 3.13 and 3.14 illustrate that all indices demonstrate a step-wise gradient against self-rated health at varying degrees throughout the geographies. However, there was substantial variation in the degree to which the various indicator weights correlated with the health survey. Figure 3.13 also illustrates that compared at the CT geography, gradients in prevalence rates for residents reporting fair or poor health self-rated health and living within the *least* through *most* deprived quintile were substantially wider using all but two of the local deprivation indices. Prevalence of reporting fair or poor self-rated health corresponding with the *least* deprived quintile were greater using the SEFI (6.2%) and DIHWPQ (6.3%) indices than when using the VANDIX, TOPSIS and eight of the nine OWA models (4.4% - 6.1%). Only the full *AND*

(∩) recorded larger prevalence rates corresponding to the *least* deprived quintile and prevalence of reporting fair or poor self-rated health (6.7%).

Similar variations were found at the same geographic scale in respect to prevalence of reporting fair or poor self-rated health living within the *most* deprived SES quintiles, but with varying correlations using the OWA weights. Prevalence scores were 14.8% and 15.1% for the SEFI and DIHWPQ indices. Prevalence rates using the original VANDIX and TOPSIS indices were 15.6% and 15.8%, respectively. Only two of the seven OWA operators generated greater prevalence rates than either the SEFI or DIHWPQ indices at the CT geography. The OWA scores range from 13.7% using the full Boolean *OR* (∪) to 15.7% using a complete trade-off of the order weights. At the CT geography, the TOPSIS compensatory weights produces the widest separation between the least and most deprived quintiles.

Figure 3.13: Census Tract (CT) geography prevalence rate of reporting fair or poor self-rated health corresponding the socio-economic (SES) quintiles. SES 1 (least deprived), SES 2 (most deprived).

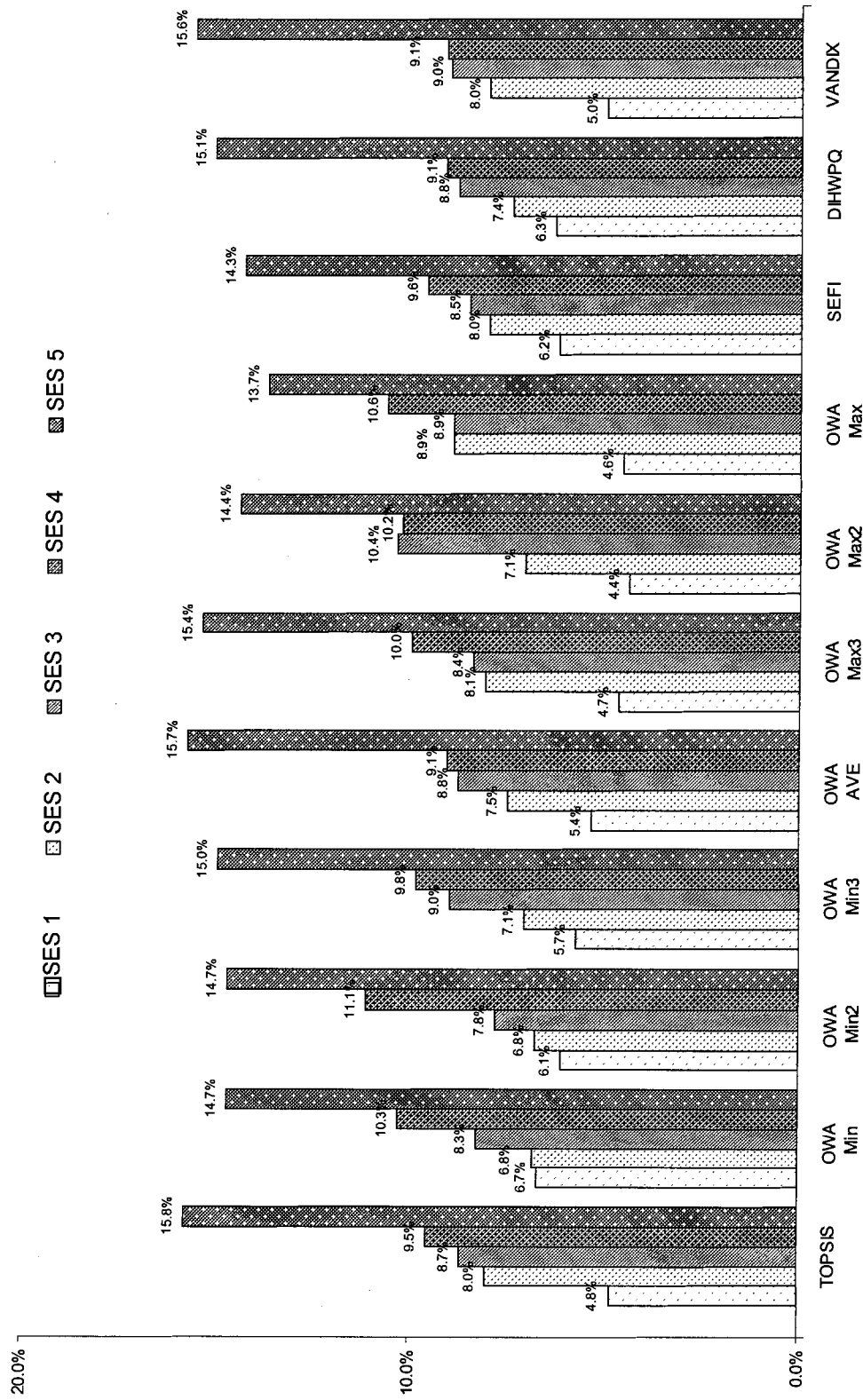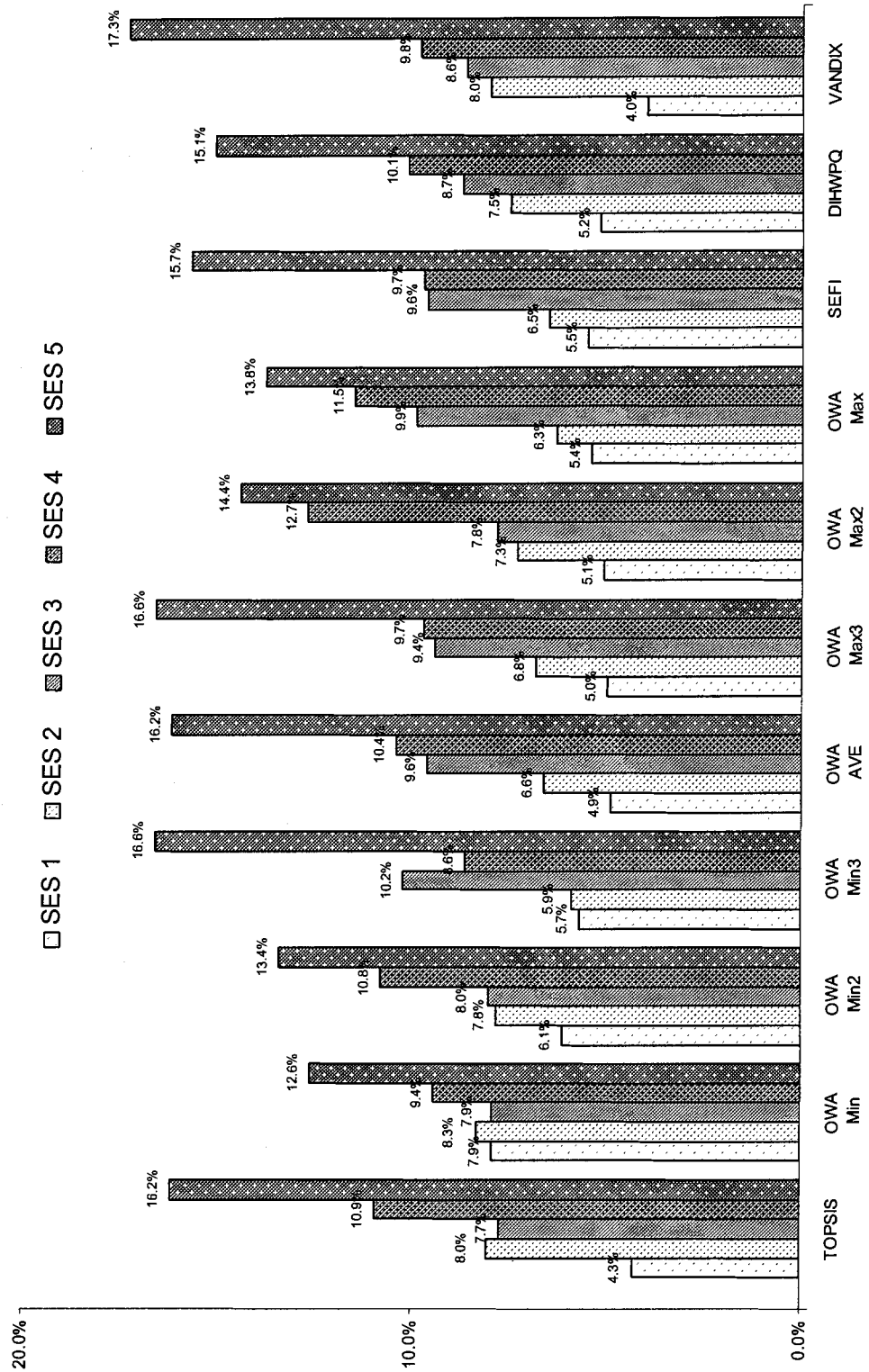Legend: □ SES 1   ▣ SES 2   ▨ SES 3   ▨ SES 4   ▨ SES 5

Figure 3.14: Dissemination Area (DA) geography prevalence rate of reporting fair or poor self-rated health corresponding the socio-economic (SES) quintiles. SES 1 (least deprived), SES 2 (most deprived).

Similar spatial patterns were reproduced at the DA geography, but with consistently greater separation between quintile classifications when using the finer-scale geographies. Figure 3.14 illustrates that stepwise gradients were more visible, on average, using the VANDIX and MCA-based indices than either the SEFI or DIHWPQ. However, the original VANDIX score produced the widest separation between quintiles. Prevalence rates of residents living in the *least* deprived quintile using the SEFI and DIHWPQ indices were 5.5% and 5.2%, respectively. These were significantly higher than the original VANDIX score (4.0%) and the TOPSIS score (4.3%), but with less consistency using the OWA MIN operators (6.1% - 7.9%). At the opposite end, the correlation between residents reporting fair or poor self-rated health and living within the *most* deprived DA were significantly higher using the VANDIX (17.3%) and four of the eight MCA models (16.2% - 16.6%) compared to 15.7% from the SEFI and 15.1% from the DIHWPQ. The four remaining OWA operators recorded attenuated prevalence rankings, ranging from 12.6% to 14.4%, respectively.

3.7 Discussion

All indices provide further evidence of an inverse relationship between SES and self-rated health. The TOPSIS weights produced the widest separation between the least and most deprived quintiles at the CT level, but where slightly less revealing at a finer spatial extent. At the DA geography, the original VANDIX score produced the largest separation between the least and most deprived SES quintiles. When at least five of the SES variables were assigned an *order weight* the prevalence scores were consistently wider than either the SEFI or DIHWPQ indices.

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One explanation for the varied cartographic outputs is the collection of Census variables used to construct the indices. The DIHWPQ is overwhelmingly represented by the value of persons living alone, and the percentage of the population who are single, divorced, or widowed. All four variables have high concentrations within the Kitsilano, Downtown, Westend, Yaletown, and Point Grey regions. To some effect, the MCA *intersection* indices (MIN a,b,c) produce similar geographies of SES as the DIHWPQ index, although the reasons for its dissimilarity rests in the attenuated weights assigned to the MHO variables.

Interestingly, even though the eight MCA indices and the VANDIX were constructed using identical variables only a portion of the MCA scores produced a stronger spatial association between SES and self-rated health compared to the SEFI and DIHWPQ indices. The MIN OWA models, on average, produced narrower gradients in the association between the *least* or *most* deprived quintile and self-rated health. The TOPSIS and the OWA full trade-off (averaging), Min (c), and Max (c) operators produced similar prevalence scores to the original VANDIX index at both CT and DA Census geographies.

The geographic location of the SES quintile scores varied consistently using the DIHWPQ index and the MIN (a, b) OWA indices. There were also many parallel SES classifications between the indices throughout Metropolitan Vancouver. Areas of high overlap included the encompassing neighbourhoods of the Downtown Eastside (DTES) and the Whalley and Strawberry Hill neighbourhoods in Surrey; districts that have previously shown a significantly higher association between SES and self-rated health and incidence of mortality (Burr, Costanzo, Hayes et al., 1995; Kershaw, Irwin, Trafford

et al., 2005). The SEFI, DIHWPQ, and OWA MIN (a, b) indices extended similar socio-economic classification scores into the Yaletown, Kitsilano, and West Point Grey neighbourhoods - areas which are less known to have a higher prevalence of socio-economic inequality in comparison to the surrounding neighbourhoods (Burr, Costanzo, Hayes et al., 1995, Kershaw 2005).

The OWA indices produced stronger associations with self-rated health as the order weights approached a full trade-off and Boolean *union*. This suggests that the amalgamation of numerous social and economic variables produce greater evidence of a social gradient in health status than when used singularly. This is both consistent with and confounding of the current literature on SES. The OWA models emphasize *multiple* rather than *single* deprivation, which echoes previous interpretations (Townsend, Phillimore, & Beattie, 1988; Hayes 1994). However, the OWA model does somewhat mask the conditions that characterize SES in Metropolitan Vancouver. Insofar as average income is often viewed as one of the most robust indicators of SES (Evans 2002), the OWA models produce quite interesting outcomes. Both the DA and CT MAX models, which were predominantly represented by the Census area's average income, produced some of the lowest prevalence scores against self-rated health in contrast to employment and educational variables.

Yet the OWA model remains beneficial validation of the original VANDIX score. The Average (trade-off), Min (c), and Max (c) OWA scores are primarily constructed from the particular position of the VANDIX variables in the Census dataset rather than the original proportional weights assigned by tallying MHO response scores. This indicates that the original variables selected by the MHOs remain stronger markers

of SES for Metropolitan Vancouver than when using either the SEFI or DIHWPQ indices.

3.8 Conclusion

A particular benefit of using MCA to combine qualitative and quantitative health approach is the wide array of weighting strategies that can be assigned to the variables selected by the MHOs – offering a number of new approaches with which to measure this caveat associated with deprivation index construction (Frohlich 1996). Moreover, MCA models are well-suited for integrating qualitative and quantitative data into a single quantitative model. Although introducing the views and viewpoints of MHOs adds an additional value of subjectivity, researchers should not overlook strategies that can integrate the opinions of local health experts into a deprivation index.

While those populations with a lower income or lower social status suffer universally higher levels of morbidity and mortality, the eleven indices collectively identify that deprivation occurs as a continuous gradient, rather than at a particular threshold (Mustard & Frank, 1994). However, blanketing previously constructed deprivation indices across spaces masks the conditions that give rise to poorer socio-economic position within communities in Metropolitan Vancouver. Provincial MHOs demonstrated that they are valuable sources of local knowledge about the socio-economic conditions that give rise to health inequalities within urban areas in Metropolitan Vancouver.

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CHAPTER 4:CONCLUSION

This thesis examined the literature on measuring socio-economic inequality and presented new ways in which researchers can construct place-specific methods of deprivation using survey-based techniques and a GIS. This thesis had three primary goals.

The first was to provide an architecture for building a deprivation index using survey-based methods to measure the degree to which provincial Medical Health Officers (MHOs) agreed on what were the most significant socio-economic variables that characterize levels inequality and relative health outcomes within urban areas in British Columbia. The deprivation index was referred to as the *Vancouver Area Neighbourhood Deprivation Index* (VANDIX). British Columbia's MHOs were used to construct the VANDIX as they are well versed in determining the relationship between status and health. The variables incorporated into the survey were chosen based on their ability to represent the broad social, cultural, and material components that influence socio-economic inequality. All SES variables had previously been used in other deprivation indices. The idea was to include the variables we thought pertinent to urban areas in BC as well as other variables commonly used to construct deprivation indices elsewhere and let the local experts decide on the ones that were most relevant.

The second goal was to outline the construction sequence of amalgamating the MHO responses (n = 10) into a single quantifiable measure of socio-economic position. A number of methods were presented. The first was a simple proportional weighting

logic assigned to the MHO variable selections based on the frequency of their Strongly Agree and Agree responses to the impact of the socio-economic variable. The next were methods based on a Multicriteria Analysis (MCA). For this, we chose a compensatory weighting logic using the *Technique for Order Preference in Similarity to Ideal Solution* (TOPSIS) and a fuzzy-based *Order Weighted Average* (OWA). Compensatory methods were selected because of their ability to measure complex interdependencies among the variables. This approach is similar to the classical (z) score method, but the final index is based on the degree to which an area score is separated from all other possible choices. The OWA strategy was selected as a means of addressing uncertainty in the importance of the variables selected by the MHOs. It is similar in scope to methods of Principal Component Analysis as the *order weight* component of OWA lets the position of the variable determine its particular importance. This strategy also enabled us to observe if the strength of the original VANDIX was due to the proportional weights assigned by the MHOs or the variables themselves.

The final goal of this thesis was to evaluate if the VANDIX was more robust in illustrating a social gradient in health status than if we were to import previously constructed measures of deprivation. The strength of the VANDIX was contrasted against two previously constructed measures of deprivation specifically designed to measure the health status of Canadians living in Manitoba and Quebec. Self-rated health data taken from the Canadian Community Health Survey (CCHS) cycle 2.1 data was used as a measuring stick for the multiple indices. At both the Census Tract (CT) and Dissemination Area (DA) administrative geographies the VANDIX produced consistently wider and more spatially accurate associations between neighbourhoods of

lower socio-economic position and health status. On average, variations of the MCA-based VANDIX followed this trend.

The results presented in this research suggest that place-specific measures of socio-economic position provide health policy makers with a more robust indication of local social gradients in health status then importing previously constructed indices.

4.1 Research Contributions

There is a widely observed understanding that gradients in social and economic conditions create health inequalities (Marmot, 1994; Marmot, Shipley, & Rose, 1984). There are a number of competing strategies with which to construct measures of socio-economic inequality to illustrate this effect. Although one can dispute the predictive strength of the VANDIX variables as predictors of material and social deprivation, this research demonstrates that the variables selected by the MHOs can predict gradients in self-rated health. The research results also suggest that deprivation index methodologies can be expanded to include survey-based strategies. A weighted Kappa test statistic and two weighting logics associated with GIS-based MCA provide a framework for other researchers to explore a means of integrating qualitative and quantitative data into assessments socio-economic status (SES).

Deprivation indices are a vital component in illustrating how health is inversely tied to SES. However, relatively few analyses of aggregated geographical data similar in scope to the ones presented in this research have been created specifically for measuring a social gradient the health status of British Columbians (Kershaw, Irwin, Trafford et al., 2005). Health inequalities can be objectively measured, but this requires that the variables

used to contrast against health status reflect the current social and economic conditions representative of the population. We feel that the methods proposed in this research demonstrate that British Columbia's MHOs have a strong place in the future construction of deprivation indices given their underlying understanding of the factors that influence local health conditions. Other researchers in the health sector can build from this framework in constructing place-specific measures of socio-economic inequality specific to their locale.

4.2 Future Applications

The methods presented in this thesis lend themselves to other applications beyond Census-based aggregate analysis of socio-economic inequality. Future applications might consider the use of more robust indicators of SES through small-area statistics. Individual socio-economic data tied to health surveys or separate individual/household level survey information could also be used to construct the VANDIX. This strategy would provide a finer grain spatial distribution of the effects of place on health.

Additionally, an MCA-based deprivation index could also be constructed using multiple, and even competing, groups who may have authoritative political power associated with managing social and health care services. For example, along with the MHOs the views of politicians and health care employees, such as social workers, could also be included in the deprivation index construction. Multiple scenarios could be constructed and used as a basis for assigning health care and social expenditures to a particular locale. MCA could be used to create multiple contrasting or analogous models of each group's perception on the conditions that are necessary in establishing social and

health care services. In addition, this may stimulate future efforts to address the social and structural factors that create a social gradient in health status.

Whether researchers will choose to incorporate survey-based deprivation indices into socio-economic models of health remains to be seen. These techniques may be viewed as relatively cumbersome to a research platform that primarily relies on more robust statistical measures. Yet, this research has demonstrated that local knowledge is an excellent predictor of the SES conditions that give rise to poorer self-rated health throughout geographical areas within Metropolitan Vancouver. Although this type of strategy adds a level uncertainty to the analysis, it is this very subjectivity that allows us to better understand and evaluate socio-economic effects on health.

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APPENDIX

IHRE Population Health Survey

Background:
Population health highlights the influence of socioeconomic factors in shaping the health outcomes of entire populations. The known relationship between social characteristics and health outcomes forms the basis of a number of health indices. Most of these have been developed in other countries. We are exploring the prospect of developing an index for BC based on Census variables and seek the support of health experts around the province to help us identify which factors from the list below they believe to most strongly influence the health of the population.

The survey is organized into sections consisting of several questions in each. The questions relate to the rating of variables based upon your opinion of its influence to population health. The five-point rating scale is used to provide a simple method for evaluation. The numerical value of '1' indicates a strong agreement that the variable is very influential, and a value of '5' indicates that the variable is not very influential. Values between 1 and 5 denote the positions in between the extremes. The questions should be answered taking into account the broad encompassing view of the problem, and each question is framed to be answered independently of each other.

The survey consists of five pages. Please fill out all questions on the first page before you move on to the next page. You have the ability to modify your responses at any time before pressing the submit button. The survey should take no more than 10 minutes to complete.

Once you have completed the survey, you have the option to leave your email along with comments regarding your experience with the survey. These comments will be kept strictly confidential, and will only be read by the survey administrators.

The survey responses will not be released or linked to a single individual. Any use of the survey responses in our study will be as an aggregate of the total responses. Your confidentiality is assured. The completion of the survey constitutes your consent to participate in this study.

Thank you for your participation!

Participate   Decline

Material Wealth

1) Average Income
Average individual income in a given census tract.

Please qualify this statement. **Average income** is an influential variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

2) Average Dwelling Value
Average value of all occupied private dwellings in a given census tract.

Please qualify this statement. **Average dwelling value** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Housing

3) Single-detached Housing
The percentage of all occupied private dwellings that are single-detached houses in a given census tract.

Please qualify this statement. **Single-detached Housing** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

4) Home Ownership
The percentage of occupied private dwellings that are owned in a given census tract.

Please qualify this statement. **Home ownership** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

5) Proportion of Renters
The percentage of occupied private dwellings that are rented in a given census tract.

Please qualify this statement. **Proportion of renters** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

6) Reside in an Apartment
The percentage of total occupied private dwellings that are apartments
(all apartment types) in a given census tract.

Please qualify this statement. **Reside in an apartment** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Demographic

7) Eldery 65+ Living Alone
The percentage of the population who are elderly people 65 years and over that are
living alone in a given census tract.

Please qualify this statement. **Elderly 65+ living alone** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

8) Living Alone
The percentage of the population who are living alone in a given census tract.

Please qualify this statement. **Living alone** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

9) Single-parent Family
The percentage of families that are single-parent families in a given census tract.

Please qualify this statement. **Single-parent family** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

10) Single/Divorced/Widowed
The percentage of the population who are single, divorced, or widowed in a given census tract.

Please qualify this statement. **Single/divorced/widowed** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

11) Persons under the Age of 5
The percentage of the population under five years old in a given census tract.

Please qualify this statement. **Persons under the age of 5** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

12) Family Size Greater Than 5 Persons
The percentage of the all families that have greater than 5 people in a given census tract.

Please qualify this statement. **Family size greater than 5** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Mobility

13) Mobility Within Past 5 Years
The percentage of the population who have changed place of residence within the past 5 years in a given Census tract

Please qualify this statement. **Mobility within past 5 years** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

14) Mobility in Previous Year
The percentage of the population who have changed place of residence in the previous year in a given Census tract

Please qualify this statement. **Mobility in previous year** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Education

15) No High School Completion
The percentage of the population 15 years and over without a high school diploma in a given census tract.

Please qualify this statement. **No high school completion** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

16) University Degree
The percentage of the population 15 years and over who received a university degree in a given census tract

Please qualify this statement. **University degree** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Employment

17) Employment Ratio
The ratio of employment to population in a given census tract

Please qualify this statement. **Employment ratio** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

18) Unemployed
The percentage of the population 15 years and over who are unemployed in a given census tract.

Please qualify this statement. **Unemployed** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

19) Female Participation in Labour Force
The percentage of the labour force who are female in a given census tract.

Please qualify this statement. **Female participation in labour force** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Other

20) Non Canadian Citizen
The percentage of the population who do not have a Canadian Citizenship in a given census tract.

Please qualify this statement. **Non Canadian citizen** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

110

21) First Language
The percentage of the population whose first official spoken language is neither English nor French in a given census tract.

Please qualify this statement. **First language** is an influencial variable when modeling the relationship between socioeconomic characteristics and health outcomes within urban areas.

☐ 1 Strongly Agree

☐ 2 Agree

☐ 3 Neither Agree nor Disagree

☐ 4 Disagree

☐ 5 Strongly Disagree

Summary Page 1 of 2

Based upon those questions to which you replied as **Strongly Agree**, please rank the importance of those socioeconomic variables that you feel strongly characterizes health outcomes in urban areas. Please place a "1" next to the variable that you feel is most influential when modeling the relationship between socioeconomic characteristics and health outcomes, a "2" next to the variable that is next most influential, and so on. Remember, no two variables may have the same ranking.

Sample (Average Income)
Your Rating: Strongly Agree

[select rating] ▼

Sample (No High School Education)
Your Rating: Strongly Agree

[select rating] ▼

Summary Page 2 of 2

Based upon those questions to which you replied as **Agree**, please rank the importance of those socioeconomic variables that you feel strongly characterizes health outcomes in urban areas. Please place a "1" next to the variable that you feel is most influential when modeling the relationship between socioeconomic characteristics and health outcomes, a "2" next to the variable that is next most influential, and so on. Remember, no two variables may have the same ranking.

Sample (University Degree)
Your Rating: Agree

[select rating] ▼

Sample (Employment Ratio)
Your Rating: Agree

[select rating] ▼

INSTITUTE FOR HEALTH RESEARCH AND EDUCATION IHRE **SIMON FRASER UNIVERSITY**

Background Information

Thank you for taking time to complete this survey. Please let use know if you are a Health Committee Member from an urban or rural/remote area in BC.

☐ Urban Area

☐ Rural / Remote Area

E-Mail Address
(optional)

Comments
(optional)

Thank you
for participating in
IHRE Population Health Survey!

For additional questions please contact

Dr. Michael Hayes

Associate Dean, Faculty of Health Sciences, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia, V5A 1S6, mhayes@sfu.ca (604) 291 – 6648.

Thank you for your participation!

Submit the Survey