The Structure of Income Residential Segregation in Canadian Metropolitan Areas

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Although interest in the measurement and description of social areas within cities has recently waned, during the 1970s and 1980s factorial ecology -- an approach that can be seen as a continuation of a long intellectual tradition that bridged the sociological and geographical study of the social character of cities -- contributed to the understanding of urban social structure and the spatial patterns of these social structures (Davies 1984). The dimensions of social variation produced in such studies area result of the *geographical variation* of neighborhood-level social characteristics in cities. These studies have consistently shown that in addition to family and ethnic characteristics, socioeconomic status, for which income is one surrogate measure, is one of the main sources of social variation, inequality, or segregation in the residential areas of cities (Murdie and Teixeira 2000; Knox and Pinch 2000; White 1987; Harris 1984). Researchers focusing on the specific measurement of segregation characteristics often overlook this link between key dimensions of urban social variation and residential segregation (Harris 1984).

Since the 1980s, interest in the socio-economic differentiation of cities has shifted to more detailed studies of the geography of social inequality, social polarisation, income distributions, income disparities, the spatial concentration of poverty, and the presence of an urban underclass. Most of these studies point to increasing urban expressions of social and economic disparity and disadvantage -- in other words, changing degrees and characteristics of income segregation.

In the US, Winsberg (1989), for example, has shown that considerable income polarisation between central cities and suburbs occurred between 1950 and 1980. Abramson et al (1995) found that despite decreasing racial segregation, the segre-

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gation of the poor increased between 1970 and 1990 -- a feature that was strongly associated with the segregation of female-headed households. Massey and Eggers (1990,1993) have also identified the simultaneous geographical segregation (concentration) of poverty and affluence in American metropolitan areas -- a spatial reflection of growing class polarisation. Neighborhood-level income disparities appear to be most extreme in central cities and inner suburbs, and decrease toward peripheral suburban areas (Chakravorty 1996), although the degree of central city concentrated urban poverty is also typically a function of the degree of racial and ethnic segregation (Coulton et al 1996).

Research on Canadian cities also points to increasing levels of poverty (Chekki 1999) and socio-economic or income-based residential segregation, although the spatial pattern of this kind of segregation is somewhat different to what may be occurring in the US. MacLachlan and Sawada (1997) argued that the distribution of household income among Canadian metropolitan census tracts is generally becoming more unequal. They suggest that these "intertract disparities in income have perhaps the greatest meaning for urban Canadians as they provide visible images of wealth and poverty in the landscape"(p.379). Bourne (1989) showed that the degree or visibility of this segregation is also a function of city size -- large places are generally more income-segregated. Moreover, Bourne also showed that the pattern of changes in income-segregation does not reflect a simple central city to suburban gradient nor an intensification of sectoral-like distinctions (Bourne 1989, 1996, 1997). Rather, the degree of *intra*-zonal variability around average income gradients has widened, suggesting a higher level of social polarisation within concentric distance zones and even within neighbourhoods (Walks 2001). This polarisation is most apparent within the older inner city and the newer outer suburbs -- both areas are simultaneously becoming richer and poorer, at the same time that there has been a relative decline in median income levels of middle and older suburbs (Bourne 1997, 1989; Bourne and Lorius 1999; Walks 2001).

Hajnal (1995) has argued that the problem of concentrated urban poverty is relatively worse in Canada than it is in the US, and reinforces the continued spatial representation of an underclass (Wilson 1987; Chekki 1999) that is not necessarily a racial minority, but white. Kazemipur and Halli (2000) and Kazemipur (2000) have charted the increasing and alarming trend, though somewhat city-specific, toward extreme poverty ghettoes in Canada -- neighbourhoods with more than 40 % of the population with income below the official Low Income threshold.

Although Canadian inner cities contain disproportionate concentrations of less educated, low income, and unemployed persons, Broadway (1992) has shown that levels of inner city deprivation have declined in those cities favored as national and regional service centres (p.192). Bourne (1993) has also pointed out that while the households of central cities in Canada have, on average, become poorer (despite gentrification), these areas have not necessarily become more polarised since there has been a substantial reduction in the proportion of families in the lowest (< $20,000/annum) income category in these areas.

In terms of a generalised "pattern" of income differentiation within Canadian cities, the traditional Burgess concentric zonal model of a social status gradient

increasing from the inner city to the suburbs still seems to dominate, as it does in the US (White 1987), although Walks (2001) has demonstrated for Toronto that complex changes to these social ecological patterns are emerging in the post-Fordist metropolis. Balakrishnan and Jarvis (1991) claim that this gradient is becoming more entrenched, although not to the same degree as a Family Status gradient. Bourne (1993) concurs, but emphasizes that the shape of this gradient has also become more complex through time.

Most of the studies described above can be seen as a continuation of the factorial ecology emphasis on socioeconomic differentiation, although they have attempted to address the process, theoretical, and policy limitations of much of the early factorial ecologies (Gottdiener 1985). They are, indirectly, concerned with the changing patterns of residence and segregation of income groups – the spatial manifestation of broader forces of structural cleavage. None, however, has explored the utility of recent conceptual and methodological advances in the study of residential segregation. There has been limited response to Bourne's conclusion that "the now rather sterile debate on inner-city-suburban contrasts must give way to more sophisticated analyses of the multiple dimensions of income variations" (Bourne 1993:1313), nor to his suggestion that there is an urgent need to further investigate the geographical importance of income segregation at a neighbourhood level (Bourne 1996). Recent conceptual and methodological advances in our understanding of residential segregation may shed some light on the dimensionality of income variations in Canadian cities.

Methodological debates over the most appropriate ways to conceptualise, measure, and understand residential segregation have continued since the 1940s. Massey and Denton's (1988) exhaustive review of the conceptual and measurement issues revealed a state of methodological disarray. This debate was virtually silenced by their own empirical analyses of the behaviour of some *twenty segregation* measures (indices), in which they argued that "residential segregation" is a five-dimensional phenomenon, consisting of Unevenness, Exposure, Concentration, Centralisation, and Clustering (Table 1).

Massey and Denton's (1988) analysis seems to have brought order to the field of segregation studies. Their study had three important methodological implications. First, their analysis revealed that segregation was a multidimensional construct. Second, it demonstrated that the vast array of indices previously employed in segregation studies could generally be seen to be complementary rather than competitive -- comprising a suite of indices, all of which summarise unique features of a larger construct of residential segregation. Third, their study pointed to key indicators or specific indices that best summarised the five dimensions, meaning that researchers could potentially achieve some parsimony when measuring these different aspects of segregation. For instance, the re-affirmation of the Dissimilarity Index (the most widely used index of segregation) as the key indicator for Unevenness showed that its extensive use in past studies was not

TABLE 1 Summary Characteristics of Dimensions of Segregation[1]

Dimension	Summary Attributes
Evenness / Unevenness	- The differential spatial distribution of two social groups (minority vs majority) among the areal units (e.g. census tracts) within a city. - A minority is segregated if it is *unevenly* distributed across the set of census tracts. - Segregation is maximised when no minority and majority members share a common area of residence.
Exposure / Isolation	- The degree of potential contact or probability of interaction between minority and majority group members within geographic areas of a city. - The extent to which minority and majority members physically confront one another through sharing the same residential area. The "experience" of segregation felt by the average minority or majority member. - *Exposure* summarises the residentially based probability of minority members interacting with majority members. - *Isolation* summarises the residentially based probability of minority members interacting with fellow minority members. High degrees of segregation occur when minority members have a high probability of spatially interacting with fellow minority members.
Concentration	- The amount of urban *physical space* occupied by a minority. - The relative density of minority members. - High degrees of *absolute concentration* occur when a minority occupies a very small share of the total urban physical space. - High degrees of *relative concentration* occur when a minority occupies a very small share of urban physical space relative to the majority.
Centralization	- The degree to which a minority group is spatially located near the centre (Central Business District) of an urban area. - *Absolute centralisation* summarises a minority's spatial distribution compared to the distribution of land area around the CBD. High degrees of segregation (absolute centralization) occur when a large proportion of a minority would be required to change area of residence in order to achieve a uniform distribution around the CBD. - *Relative centralisation* summarises the relative share of minority members that would have to change their unit of residence in order to match the degree of centralisation of majority members.
Clustering	- The degree of spatial clustering of a minority. - The spatial contiguity of minority-rich areas. - A high degree of clustering implies a residential structure where minority areas are contiguous and closely packed, creating a single large enclave. - *Absolute clustering* summarises the degree to which minority members are found in nearby as opposed to spatially distant tracts. - *Relative clustering* compares the average distance separating minority members in relation to the average distance separating majority members -- the degree to which a minority exhibits more or less spatial clustering than the majority.

Note: 1. See Massey and Denton (1988) for additional detail, and for references to related measurement issues. See Massey and Denton (1998) for clarification of relative concentration.

problematic -- a transition to a multidimensional framework did not involve a wholesale rejection of previous segregation findings based on the Dissimilarity

Index alone. The five-dimensionality of residential segregation is now often assumed *a priori* (Massey and Denton 1989,1993; Massey 1990) and seems to be widely accepted as a comprehensive structural summary of residential segregation characteristics (Massey et al 1996).

Unfortunately, all of the empirical analyses that have produced this reconceptualisation of residential segregation have been based on ethnic or racial groups in American metropolitan areas. No attention has been given to the question of whether or not residential segregation exhibits the same five-dimensional structure amongst other social groupings, in different societal contexts, and at different times. If residential segregation is universally comprised of five dimensions, then these dimensions should be apparent in other forms of social segregation in the city -- such as income segregation.

This exploratory study addresses this hypothesis by investigating the structure of income residential segregation for income groups in Canadian Census Metropolitan Areas (CMAs). The paper is structured around four questions:

- Is income-based residential segregation in Canadian CMAs five-dimensional?
- If not, how many dimensions more properly define income-based residential segregation, and what are the characteristics of these dimensions?
- What can the structure of income segregation tell us about the geography of specific income minorities, income segregation within specific CMAs, and the spatial patterns of income segregation throughout the metropolitan system?
- What is the benefit of measuring and identifying income segregation on multiple dimensions?

Operationalisation, Data, and Methods

To date, the justification for a five-dimensional structure of residential segregation has been based on ethnic and racial segregation in US cities -- in which the *degree* of segregation is relatively high, particularly so for Blacks. However, the *structure* of residential segregation that Massey and Denton (1988) described should not be dependent on the magnitude of segregation -- the correlations of the specific indices used should be consistent for both high levels of segregation as well as low levels of segregation. Indices such as the Dissimilarity Index, Gini Index, Entropy Index, and the family of Atkinson's Indices, that were found to define the same properties of "unevenness" in terms of ethnic or racial groups, should also collectively define unevenness in terms of income segregation in the city. Moreover, similar-magnitude correlation coefficients would be derived for these indices from a minority that exhibited, for instance, one tenth the degree of unevenness of blacks in US cities. This means that the structural properties of segregation, or the variables that define particular features, should be independ-

TABLE 2 Segregation Indices Used to Index Dimensions of Segregation[1]

Measures of:	Abbreviation	Index Name[2]
Evenness / Unevenness	DIS	Dissimilarity Index
	GINI	Gini Index
	ENT	Entropy Index
	ATK1	Atkinson's Index (shape parameter = 0.1)
	ATK5	Atkinson's Index (shape parameter = 0.5)
	ATK9	Atkinson's Index (shape parameter = 0.9)
Exposure	XPY	Interaction Index (interaction of minority with majority)
	XPX	Isolation Index (exposure of minority to fellow minority members)
	ETA2	Correlation Ratio
Concentration	DEL	Delta Index
	ACO	Absolute Concentration
	RCO	Relative Concentration
Centralization	ACE	Absolute Centralisation
	RCE	Relative Centralisation
	PCC[3]	Proportion Central City Index[3]
Clustering	ACL	Absolute Clustering
	SP	White's Index of Spatial Proximity
	RCL	Relative Clustering
	DPXY	Distance-based Interaction
	DPXX	Distance-based Isolation

Note: 1. This grouping of indices as measures of specific dimensions of segregation follows Massey and Denton (1988).
2. Refer to Massey and Denton 1988 for discussion and formulae for these indices. See Massey and Denton (1998) for correction to the RCO index.
3. Index not used (see text).

ent of the magnitude of segregation. Thus, comparisons of the structural characteristics of residential segregation can be made for a range of different types of "minority" groups (e.g. income groups, ethnic groups, family groups) exhibiting very different levels of segregation in the city.

Following Massey and Denton (1988), this study is based on the use of nineteen separate segregation indices (Table 2). Although Massey and Denton (1988) included the Proportion Central City (PCC) index, definitions of central city in Canada have no statistical or census definitional basis, and so the PCC index was not included. Nevertheless, the range of indices is broad enough to provide extensive insight into the character of income residential segregation in Canadian CMAs, and is comprehensive enough for an empirical investigation of how the battery of segregation indices described by Massey and Denton (1988) behave for income segregation in Canadian cities.

The segregation analysis includes all 25 CMAs in Canada. Metropolitan measures of residential segregation generally require data inputs based on dichotomised tract populations. For example, indices such as DIS typically require tract-

level counts of the particular minority of interest (e.g. tract level count of "Blacks") as well as the non-minority count (e.g. tract-level count of "non-Blacks"). Some indices, such as those that incorporate distance-based measures (RCE, ACE, ACL, SP, RCL, DPXX, DPXY) require tract-level spatial data inputs (e.g. centroid coordinates) in an appropriate form (e.g. UTM Coordinates or some other suitable metric) for the derivation of Euclidean distance coefficients. Some (DEL, ACO, RCO) also require tract areas for their calculation (Massey and Denton 1988).

Income data for all metropolitan census tracts were derived from the 1991 Census of Canada. Annual household income data were assembled for four household groups: a) less than $20,000; b) $20,000 to $34,999; c) $35,000 to $49,999; and d) $50,000 or higher. Spatial data for each tract were derived by a GIS from Statistics Canada CMA census tract digital cartographic files. After projecting each CMA digital cartographic file to an appropriate UTM coordinate system (e.g. UTM zone 17 for Toronto) tract centroid eastings and northings were derived and tract areas calculated. Because tract-to-tract and tract-to-CBD Euclidean distance calculations were required for some of the spatial segregation measures (RCE, ACE), the coordinates of the centre of the CBD, or peak value intersection (or dominant CBD in multiple nuclei cases) were identified with the assistance of local planners, from knowledge of the areas, city maps, or from inferences drawn from Nader (1976).

Given that most segregation indices are calculated, and interpreted, based on "minority" groups, in this analysis a group was excluded from metropolitan-specific calculations if it represented a majority of the households. This process eliminated the $50,000+ income category from Oshawa and Toronto where more than 50% of households were within this income group. The metropolitan system characteristics for the different income minorities are summarised in Table 3.

CMA by income-minority-specific indices were computed according to the equations defined by Massey and Denton (1988). The analysis therefore replicates Massey and Denton's (1988) methodology, but differs in that an attempt is made to identify what may be a more appropriate structure of income segregation. Two separate analyses were carried out -- initially, and for comparative purposes, a principal components analysis (PCA) of the segregation indices using Promax rotation with the solution forced to five dimensions (following Massey and Denton 1988); and second, Promax rotation without the solution forced to five dimensions in order to identify what may be a more appropriate dimensionality of income segregation. For each of the analyses, the input data file was a concatenated file of CMAs and income minority group (n=98 cases x 17 variables).

TABLE 3 CMA Population and Income Group Characteristics

Metro Area	1991 Metro Area Pop[1]	# Households Reporting Inc.[1]	% of Households <$20,000	$20,000-$34,999	$35,000-$49,999	$50,000+
St. John's	171.9	53.2	21.8	19.4	19.4	39.5
Halifax	320.5	114.0	20.2	20.4	20.8	38.6
Saint John	125.0	43.4	25.7	21.8	20.3	32.1
Chic. - Jonquière	160.9	55.5	24.8	20.9	21.4	32.9
Québec	645.6	244.0	25.0	21.6	20.1	33.3
Sherbrooke	139.2	54.4	32.5	24.1	18.7	24.8
Trois-Rivières	136.3	53.0	31.8	22.1	18.3	27.8
Montréal	3127.2	1185.6	26.2	21.4	18.7	33.8
Ottawa - Hull	920.9	337.7	17.1	17.1	17.6	48.2
Oshawa	240.1	81.4	14.8	15.2	17.3	52.6
Toronto	3893.0	1311.4	15.9	16.4	16.8	50.9
Hamilton	599.8	214.3	19.7	19.0	18.5	42.8
St Cath. - Niagra	364.6	132.6	22.2	21.4	20.2	36.1
Kitchener	356.4	123.2	17.8	19.8	20.3	42.2
London	381.5	140.9	21.3	21.0	19.3	38.4
Windsor	262.1	94.6	23.1	18.7	19.7	38.6
Sudbury	157.6	55.5	22.8	18.2	16.9	42.1
Thunder Bay	124.4	45.2	21.6	18.3	19.2	40.9
Winnipeg	652.4	244.3	25.0	22.2	20.1	32.7
Regina	191.7	69.6	22.1	21.3	19.5	37.1
Saskatoon	210.0	76.3	26.2	21.8	20.0	32.0
Calgary	754.0	266.4	18.1	19.3	18.3	44.4
Edmonton	839.9	293.0	21.6	19.8	18.9	39.7
Vancouver	1602.5	573.5	20.3	19.2	18.4	42.1
Victoria	287.9	114.5	22.5	22.1	19.6	35.8
	--	Min	14.8	15.2	16.8	24.8
	--	Max	32.5	24.1	21.4	52.6
	--	Mean	22.4	20.1	19.1	38.4
	--	SD	4.2	2.0	1.2	6.5

Note: 1. Figures are in thousands.

Results

Index Characteristics of Income Segregation

The average characteristics of the indices throughout the metropolitan system are briefly summarised before describing the structural characteristics of income segregation. Descriptive statistics for the nineteen segregation indices for the four income categories are presented in Table 4 and the correlations between the

TABLE 4 Index-Specific Income Minority Segregation Characteristics

		Income Minority Group																			
		< $20,000				$20,000 - $34,999				$35,000 - $49,999				>= $50,000				Total			
	Index	Min	Max	Mean	St Dev	Min	Max	Mean	St Dev	Min	Max	Mean	St Dev	Min	Max	Mean	St Dev	Min	Max	Mean	St Dev
Uneveness	DIS	.219	.325	.276	.031	.083	.214	.145	.035	.082	.139	.109	.017	.187	.334	.287	.040	.082	.334	.203	.085
	GINI	.292	.452	.379	.045	.120	.285	.200	.047	.119	.192	.153	.024	.269	.453	.390	.052	.119	.453	.279	.114
	ENT	.047	.113	.079	.018	.008	.042	.022	.010	.007	.020	.013	.004	.043	.120	.088	.021	.007	.120	.050	.036
	ATK1	.014	.040	.027	.007	.002	.019	.008	.005	.002	.007	.004	.001	.014	.036	.027	.007	.002	.040	.016	.012
	ATK5	.071	.169	.120	.028	.012	.072	.036	.017	.012	.034	.021	.007	.063	.165	.126	.030	.012	.169	.075	.052
	ATK9	.122	.278	.199	.043	.021	.115	.061	.026	.020	.057	.036	.011	.107	.281	.212	.050	.020	.281	.125	.087
Exposure (Isolation)	XPY[1]	.555	.775	.696	.056	.750	.823	.778	.018	.786	.829	.804	.012	.450	.714	.573	.059	.450	.829	.716	.098
	XPX	.225	.445	.304	.056	.177	.250	.222	.018	.171	.214	.196	.012	.286	.550	.427	.059	.171	.550	.284	.098
	ETA2	.051	.131	.085	.022	.009	.036	.021	.008	.006	.017	.012	.003	.052	.156	.109	.027	.006	.156	.056	.045
Consideration	DEL	.350	.876	.548	.110	.342	.877	.491	.116	.278	.869	.439	.126	.258	.846	.414	.137	.258	.877	.474	.131
	ACO	.663	.928	.779	.066	.642	.915	.744	.059	.586	.870	.708	.055	.237	.623	.475	.082	.237	.928	.680	.134
	RCO	.000	.737	.328	.171	-.015	.642	.145	.137	-.785	.420	-.063	.204	-3.334	.063	-.535	.662	-3.334	.737	-.021	.472
Centralisation	ACE	-.173	.838	.492	.212	-.132	.762	.418	.187	-.080	.698	.336	.168	-.020	.678	.251	.175	-.173	.838	.377	.204
	RCE	-.121	.399	.230	.123	-.035	.193	.090	.054	-.143	.061	-.035	.046	-.353	.160	-.216	.127	-.353	.399	.022	.188
Clustering	ACL	.040	.195	.115	.036	-.049	.083	.035	.035	-.098	.033	-.003	.031	-.453	.079	-.046	.106	-.453	.195	.027	.083
	SP	1.026	1.111	1.059	.021	1.003	1.023	1.011	.005	1.003	1.011	1.006	.002	1.030	1.102	1.072	.020	1.003	1.111	1.036	.032
	RCL	.088	1.086	.542	.249	.006	.404	.180	.121	-.182	.081	-.027	.057	-.398	.017	-.183	.125	-.398	1.086	.135	.312
	DPXY[1]	.571	.799	.714	.057	.753	.829	.783	.018	.793	.835	.809	.012	.483	.740	.600	.059	.483	.835	.729	.090
	DPXX	.201	.429	.286	.057	.171	.247	.217	.018	.165	.207	.191	.012	.260	.517	.400	.059	.165	.517	.271	.090

Note: 1. Not used in Principle Components Analysis

TABLE 5 Correlations Between Segregation Indices for Four Income Groups in 25 Canadian CMAs (valid n = 98) [1,2]

	DIS	GINI	ENT	ATK1	ATK5	ATK9	XPY	XPX	ETA2	DEL	ACO	RCO	ACE	RCE	ACL	SP	RCL	DPXY	DPXX
DIS	--	1.00	0.98	0.98	0.99	0.99	-0.79	0.79	0.96	0.10	-0.42	-0.24	0.01	-0.18	-0.03	0.95	0.05	-0.76	0.76
GINI	1.00	--	0.99	0.98	0.99	0.99	-0.79	0.79	0.96	0.11	-0.41	-0.24	0.03	-0.16	-0.03	0.95	0.06	-0.76	0.76
ENT	0.98	0.99	--	0.99	1.00	1.00	-0.83	0.83	0.99	0.10	-0.46	-0.29	0.00	-0.23	-0.09	0.97	-0.01	-0.80	0.80
ATK1	0.98	0.98	0.98	--	0.99	0.99	-0.75	0.75	0.95	0.16	-0.37	-0.24	0.07	-0.13	-0.02	0.94	0.09	-0.72	0.72
ATK5	0.99	0.99	1.00	0.99	--	1.00	-0.78	0.78	0.97	0.12	-0.41	-0.26	0.03	-0.17	-0.05	0.96	0.05	-0.75	0.75
ATK9	0.99	0.99	1.00	0.99	1.00	--	-0.79	0.79	0.98	0.11	-0.42	-0.26	0.02	-0.19	-0.06	0.96	0.03	-0.77	0.77
XPY	-0.77	-0.77	-0.81	-0.73	-0.77	-0.78	--	-1.00	-0.89	0.10	0.71	0.39	0.25	0.53	0.27	-0.85	0.38	1.00	-1.00
XPX	0.77	0.77	0.81	0.73	0.77	0.78	-1.00	--	0.89	-0.10	-0.71	-0.39	-0.25	-0.53	-0.27	0.85	-0.38	-1.00	1.00
ETA2	0.96	0.96	0.99	0.95	0.97	0.98	-0.89	0.89	--	0.04	-0.55	-0.34	-0.07	-0.34	-0.16	0.98	-0.13	-0.87	0.87
DEL	0.17	0.18	0.16	0.22	0.19	0.17	0.03	-0.03	0.11	--	0.43	0.08	0.76	0.36	0.32	0.07	0.44	0.11	-0.11
ACO	-0.31	-0.30	-0.36	-0.26	-0.31	-0.32	0.65	-0.65	-0.46	0.47	--	0.81	0.50	0.82	0.55	-0.49	0.75	0.71	-0.71
RCO	-0.15	-0.14	-0.20	-0.15	-0.17	-0.17	0.35	-0.35	-0.26	0.16	0.82	--	0.23	0.66	0.44	-0.28	0.59	0.37	-0.37
ACE	0.10	0.11	0.08	0.14	0.11	0.10	0.16	-0.16	0.02	0.76	0.49	0.27	--	0.51	0.29	0.00	0.50	0.26	-0.26
RCE	-0.01	0.01	-0.07	0.04	0.00	-0.02	0.42	-0.42	-0.18	0.36	0.78	0.68	0.49	--	0.70	-0.27	0.87	0.53	-0.53
ACL	0.11	0.12	0.06	0.13	0.10	0.09	0.19	-0.19	-0.03	0.34	0.56	0.49	0.31	0.73	--	-010	0.79	0.26	-0.26
SP	0.94	0.95	0.97	0.94	0.96	0.96	-0.85	0.85	0.98	0.14	-0.39	-0.20	0.08	-0.11	0.04	--	-0.04	-0.83	0.83
RCL	0.24	0.25	0.17	0.27	0.24	0.22	0.24	-0.24	0.05	0.44	0.71	0.60	0.49	0.87	0.81	0.14	--	0.38	-0.38
DPXY	-0.74	-0.74	-0.78	-0.70	-0.73	-0.75	1.00	-1.00	-0.86	0.04	0.65	0.33	0.17	0.42	0.19	-0.83	0.25	--	-1.00
DPXX	0.74	0.74	0.78	0.70	0.73	0.75	-1.00	1.00	0.86	-0.04	-0.65	-0.33	-0.17	-0.42	-0.19	0.83	-0.25	-1.00	--

Note: 1. Lower Diagonal = unweighted Pearson Product Moment Correlation Coefficient
2. Upper Diagonal = minority proportion weighted Pearson Product Moment Correlation Coefficient

indices are given in Table 5.

The *eveness / unevenness* suite of indices reveal that compared to the two middle income categories, the highest and lowest income groups are the most segregated according to our understanding of residential unevenness -- the most common interpretation and measure of residential segregation (Table 4). For instance, based on DIS, an average of 28.7 % of $50,000+ households and 27.6 % of <$20,000 households would have to be relocated to another census tract in order to be as evenly distributed as households not in these income categories. By contrast, middle income households -- the larger share of households in urban social space -- are more evenly distributed throughout the neighborhoods of the metropolitan areas. The average values of the GINI, ENT, and ATK family of indices, which can be interpreted in similar ways and which are highly correlated with DIS (Table 5) point to the same generalisation.

The experiential aspects of income segregation are partly summarised by the *exposure* indices (Table 1, Table 2) -- particularly the isolation index (xPx) which measures the geographically based, and relative minority size probability of within-group interaction (Massey and Denton 1988; Lieberson 1981). Again, the highest income groups are generally most segregated with the highest level of exposure to same-income-category households (Table 4). For instance, there is (on average) a 42.7 % chance that a randomly chosen household with >$50,000 income in any Canadian CMA shares a tract or neighborhood with another household of the same income class. Low-income households also have relatively high levels of within-group contact (isolation), and again, because of both geographical dispersal and relatively large share of the population, middle income households reside in more heterogeneous tracts -- meaning that the probability of contact with same-income households is considerably lower. There is, on average, a 19.6 % chance that a randomly chosen household with $35,000-$49,999 income in any Canadian CMA shares a tract with another household of the same income class.

Concentration is a feature of residential segregation concerned with the relative density or relative amount of physical space occupied by the minority (Massey and Denton 1988; Duncan et al 1961). The suite of concentration measures (Table 2, Table 4) point to the following average profile in Canadian CMAs: Highest-income groups are *not* the most but least segregated according to these features. This group typically resides in neighbourhoods with the lowest densities of high income households -- a feature that is not surprising given the large housing and sprawling subdivision characteristics for this highest socio-economic status group. In contrast, lowest income households are not only unevenly distributed and have high probabilities of interacting with other low income households, they are also most spatially concentrated in tracts with above average shares and densities of other low income households. The RCO index points to some further generalisation of the geometry of income segregation. On average, low income groups have positive RCO scores and high income groups have negative RCO scores. Thus, the degree of concentration in physical space of low income households considerably exceeds the concentration of high income groups.

Centralisation indices (Table 2) quantify the degree to which a minority is

geographically located near the centre of the urban area (Massey and Denton 1988; Duncan and Duncan 1955). The absolute centralisation index (ACE) measures the group's spatial distribution compared to the distribution of land around the city centre. Positive ACE values indicate a tendency for residence closer to the city centre while negative ACE statistics indicate a tendency toward residence in outlying areas. According to this measure, highest income groups are the most decentralised or suburban, and conversely, lower income groups the most centralised (Table 4). This feature is reinforced by the RCE measures which index centralisation of one group relative to others. Average RCE values (Table 4) show that the two higher income classes are typically segregated in spaces further from the central city than are the two lower income groups. Both of these centralisation measures reinforce the continued interpretation of the concentric zonal character of income in Canadian cities (Bourne 1993; Balakrishnan and Jarvis 1991).

Clustering indices (Table 2) tap into the spatial properties of residential adjacency or contiguity of a minority (Massey and Denton 1988; White 1986; Duncan et al 1961; Morgan 1983). The higher the ACL index, the greater the number of same-class minority members that can be found in nearby as opposed to distant neighbourhoods. From this perspective, lowest-income households are typically the most spatially clustered, and the index declines to the lowest value for highest income groups (Table 4). The relative clustering index (RCL) also reveals that lowest-income groups are considerably more clustered in contiguous tracts than any other income class, and highest-income classes exhibit the least contiguous or clustered spatial segregation.

The generalisation above suggests the following "average" profile of income segregation in Canadian CMAs: Despite relatively low absolute values of the segregation measures compared to other forms of social segregation such as race or ethnic status, income segregation can be identified and measured in a number of distinctive ways in Canadian CMAs. Typically, both low income and high-income groups are relatively unevenly distributed in metropolitan space. Both groups also have the greatest probabilities of neighbourhood-level social contact with members of the same-income class. These similar features of segregation are occurring in different spatial contexts, however. Low income segregation and social interaction is spatially concentrated in smaller communities with much higher densities of fellow low-income households, is occurring in inner city and middle suburban neighbourhoods rather than new or peripheral suburban areas, and is characterised by considerably higher tendencies towards contiguous regionalisation of poor communities. Upper-income segregation, although highest on unevenness measures, occurs in considerably larger, low density areas that are more suburban and less regionalised (discontiguous) than poorer CBD-proximate communities.

System-Wide Structure:
Is Income Residential Segregation Five-Dimensional?

Does the residential segregation of income minorities in Canadian cities conform to the five-dimensional structure of segregation proposed by Massey and Denton (1988)? In order to address this question, the data were first subjected to a PCA analysis with the solution forced to five dimensions and subjected to Promax (oblique) rotation to increase the interpretability of results. Component loadings and inter-factor correlations for this solution are shown in Table 6 (Components A1 through A5).

An interpretation of the component loadings for A1 - A5 (Table 6) suggests that the dimensions of segregation do not neatly separate into the distinctive features identified by Massey and Denton (1988), although there are some similarities with the five-dimensional structure they described. The first axis is recognisable as an *evenness/ unevenness* dimension although some features of spatial clustering are associated with this. *Clustering* generally defines the second component, although relative centralisation is conflated with this feature. The third axis, which can be summarised as *absolute centralised density* taps into the unique locational characteristics of low-income minorities. The fourth component is recognisable as a *concentration* axis, although not all of the expected concentration indices exhibit high loadings. The fifth factor is an *exposure (isolation)* index, collapsing within-group exposure (i.e. isolation) with distance-based isolation measures.

The difficulty in interpreting these features is compounded by the fact that the components have resulted from over-factoring and are generally highly correlated (Table 6). Both the fourth and fifth components have Eigenvalues lower than one, meaning that rather than "generalising" the structure or behaviour of the indices, less information is collapsed or contained in each of the 4th and 5th components than that provided by one measure in the original suite of indices. Although it is preferable to employ oblique rotation methods in this instance, large numbers of high inter-factor correlation coefficients suggest that the components are not in fact unique enough to be interpreted as distinctive. The aim of oblique rotation is to allow the axes to become partially correlated, in order to reflect the empirical reality that the features are not completely independent of each other, but not so correlated that the structural distinction becomes meaningless. In the case of the five component income solution, Table 6 shows that component A2 (clustering) and component A4 (concentration) are highly correlated (r=0.61). Similarly, component A4 (concentration) and component A5 (isolation) have a strong inverse association (r=-0.66). Detailed interpretation of this solution is not warranted, since in reality these features are empirically collapsed. Thus income segregation should not be considered five-dimensional -- the "geography" of some features of income segregation cannot be separated from the "geography" of others.

The same data set was subsequently re-analysed to identify a more appropriate structural summary of the character of income-based residential segregation

TABLE 6 Component Structure for Dimensions of Income Segregation in Canadian CMAs

	Component						Component			
	A1	A2	A3	A4	A5		B1	B2	B3	
Eigen Value	9.5	4.6	1.2	0.6	0.5		9.5	4.6	1.2	
%	55.9	27.3	7.1	3.4	2.9		55.9	27.3	7.1	
	Component					Commu-nality	Component			Commu-nality
Uneveness										
DIS	0.98	0.04	-0.03	-0.02	0.01	0.98	*1.00*	0.12	0.00	0.97
GINI	0.98	0.05	-0.02	-0.02	0.01	0.99	*1.00*	0.12	0.01	0.98
ENT	0.97	-0.01	0.00	-0.03	0.05	1.00	*1.00*	0.04	0.02	0.99
ATK	1.00	0.04	0.01	-0.06	-0.06	0.99	*0.99*	0.13	0.05	0.97
ATK	1.00	0.02	-0.01	-0.05	-0.03	1.00	*1.00*	0.10	0.03	0.98
ATK	0.99	0.01	-0.01	-0.03	0.00	1.00	*1.00*	0.09	0.02	0.98
Exposure										
XPX	0.52	-0.06	0.04	0.13	*0.73*	0.99	*0.83*	-0.31	-0.06	0.87
ETA	0.89	-0.05	0.01	0.01	0.22	0.99	*0.98*	-0.07	0.01	0.99
Concentration										
DEL	-0.05	0.10	*1.02*	-0.11	0.19	0.92	0.07	-0.11	*0.98*	0.88
ACO	-0.17	0.21	0.22	*0.54*	-0.18	0.96	-0.33	*0.73*	0.21	0.91
RCO	-0.02	0.10	-0.11	*1.11*	0.24	0.99	-0.10	*0.88*	-0.19	0.68
Centralisation										
ACE	0.07	-0.09	*0.92*	0.00	-0.13	0.88	0.00	-0.01	*0.94*	0.87
RCE	0.09	*0.59*	0.01	0.22	-0.29	0.89	0.01	*0.92*	0.03	0.88
Clustering										
ACL	-0.16	*1.19*	-0.03	-0.14	0.23	0.97	0.17	*0.89*	-0.11	0.70
SP	*0.88*	0.00	0.04	0.04	0.22	0.96	*0.98*	-0.01	0.03	0.96
RCL	0.27	*0.71*	0.03	0.10	-0.24	0.95	0.26	*0.94*	0.05	0.92
DPX	0.47	-0.05	0.04	0.17	*0.80*	0.98	*0.80*	-0.31	-0.08	0.83

	Correlation						Correlation		
A1	1.00					B1	1.00		
A2	0.12	1.00				B2	-0.14	1.00	
A3	0.13	0.47	1.00			B3	0.05	0.52	1.00
A4	-0.20	0.61	0.41	1.00					
A5	0.39	-0.50	-0.39	-0.66	1.00				

Note: 1. Highest ranking loadings are shown in italics.

in Canadian CMAs. A series of alternate solutions were explored, employing Varimax, Oblimin, and Promax rotations for an Eigenvalue 1.0 extraction threshold, as well as for solutions with one more and one less component than derived from the latter. Results from the different rotation procedures were very similar, meaning that the findings are robust and not technique-dependent. Results from the Promax rotated, three-component solution provide a reliable summary of the structure of income segregation (see Table 6).

System-Wide Structure: The Dimensionality of Income Segregation

Table 6 reports the component loadings and inter-factor correlation matrix for the three-component income segregation model (Components B1 through B3). In this solution, all eigenvalues are >1, and the variance of all of the indices is well accounted for by three components (more than 68 % of the variance of every index). The inter-factor correlation matrix is reasonable -- only one coefficient is moderately strong (r=0.52). Income segregation in Canadian CMAs may therefore be summarised by the following three sources of differentiation.

Unevenness and Isolation

Accounting for 55.9 % of the variation in the seventeen segregation indices, Component B1 can be interpreted as an *unevenness and isolation* scale. High component loadings (Table 6) show that this axis collapses the suite of unevenness statistics with measures of within-group interaction (isolation) and distance-based isolation. Geographical unevenness in the intra-urban distribution of income classes is therefore inseparable from the probability that any given income minority will spatially interact with the same-income class. In short, spatial inequality is intimately linked with the *experiential* inequality of income segregation. This operates differently for different income minorities. Figure 1 shows the u-shaped features of the median values of this dimension with respect to income groups. The <$20,000 income households have characteristically high levels of unevenness and within-group exposure (isolation) -- this group has component scores greater than 0.0 (i.e. unevenness rather than evenness and higher than average levels of isolation) in every CMA but two (St. Catharines-Niagara and Thunder Bay). Households in the two middle income categories have component scores that are universally below average (below 0.0) in all CMAs -- meaning that they are relatively evenly distributed throughout metropolitan space and experience relatively low probabilities of interacting spatially with only the same-income class. The $35,000-$49,999 income class is the least segregated on this dimension, and given the fact that there is very little inter-metropolitan variation in component scores, can be considered to have very similar low-level unevenness and isolation characteristics throughout the metropolitan system. Although the literature tends to emphasize the segregation of low-income groups in inner cities, Figure 1 shows that on the unevenness and isolation dimension of segregation, the highest income group is the most segregated. These households are the most unevenly distributed, but are also unevenly distributed in more income-homogeneous tracts than the <$20,000 group. This accounts for the highest levels of isolation for this income minority -- and a greater experience of income similarity amongst neighbours.

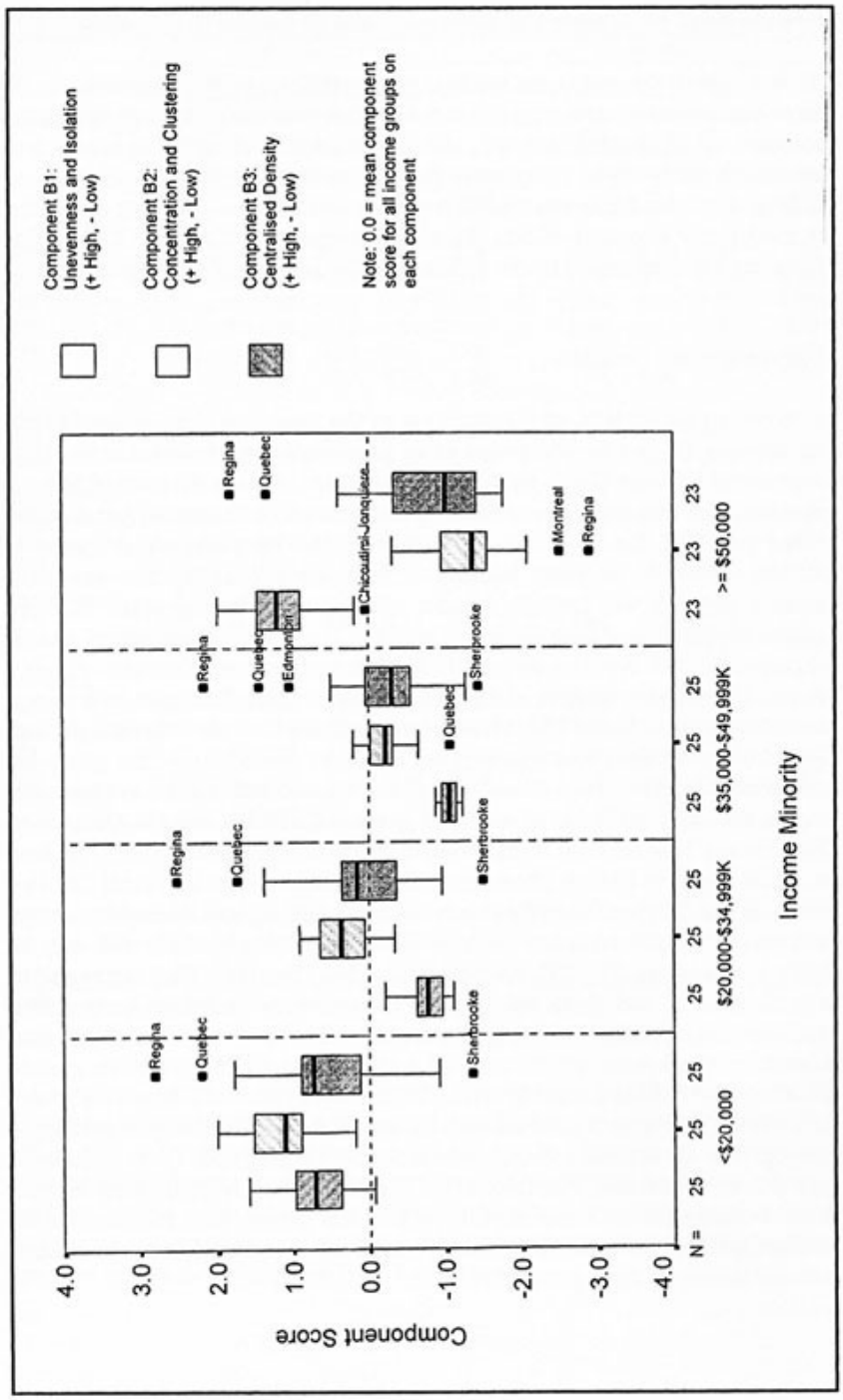

FIGURE 1 Income "Minority" Characteristics on Dimensions of Income Segregation

Concentration and Clustering

It is well known that the Dissimilarity Index cannot capture pattern effects -- identical values of the DIS can be derived from very different spatial configurations of minorities (Peach et al 1981; White 1983; Wong 1993). The same is true of Component B1 described above. However, the second dimension of income segregation (B2) does provide further information about the intra-metropolitan *patterns* of segregation. Component B2 (Table 6), accounting for 27.3 % of the variance in the indices used, can be labeled *Concentration and Clustering*. It is characterised by high loadings for absolute concentration (ACO), relative concentration (RCO), relative centralisation (RCE), absolute clustering (ACL), and relative clustering (RCL). Positive component scores for this axis index relatively high levels of concentration and high levels of spatial clustering or contiguity; negative component scores index relatively low levels of concentration and clustering. Figure 1 shows a linear trend for the median component scores for the selected income minorities. Low-income households (<$20,000) are the most segregated according to this dimension. Their patterns of residence generally exhibit concentration in small, if not the smallest, census tracts in the city. As a group they also occupy the smallest areal share of metropolitan space, and compared to other income groups, they are closer to achieving the maximum possible spatial concentration. They are also the most spatially clustered, occupying the most contiguous set of similar-income neighbourhoods. These features are coincident or inseparable—low income groups *simultaneously* occupy small, high density tracts in a relatively contiguous region. This group had higher than average degrees of concentration and clustering in every CMA.

The linear gradient noted above points to the fact that the level of concentration and spatial contiguity declines throughout the spectrum of income classes, with lowest levels of concentration and clustering evident for the highest income class. Thus, the highest income minority typically resides in larger neighbourhoods, occupies more of the physical space of metropolitan areas, and, compared to other income classes, are the least spatially concentrated. Their somewhat homogeneous high-income neighbourhoods that give rise to high levels of isolation are the least contiguous or least regionalised. In every metropolitan area, this income group had lower than average component scores for concentration and clustering (Figure 1).

Centralised Density

The third component (Table 6, Component B3), accounting for 7.1 % of the variance in the 17 indices, can be called a *Centralised Density* dimension. High loading indices defining this axis are DEL and ACE, and so the axis summarises absolute centralisation or proximity to the CBD as well as the propensity for this centralisation to coincide with higher than average proportions of minorities residing in tracts with above average densities of the same minority. This also

reveals something about the spatial pattern of income segregation. Figure 1 shows a declining linear gradient in median component scores for this axis as income class increases. Lowest-income groups have the highest levels of simultaneous centralisation and same-minority high densities -- reflecting the inner city and inner suburban patterns of low-income segregation described above. This is hardly surprising since the smallest tracts in Canadian CMAs are typically found in inner cities. Highest-income minorities are generally segregated in communities most distant from the CBD, and in neighbourhoods with low densities -- again not surprising given the housing and subdivision characteristics of high income communities.

There is considerably more inter-metropolitan variation in component scores for this axis than there is for the two previous dimensions, and within each income category a number of outlier CMAs are evident (Figure 1). Regina and Quebec stand out as two CMAs that have particularly high centralised density scores throughout the range of different income classes. Thus, the simple linear gradient from central city to suburbs is not as evident in these places, since all income classes share high scores on this axis. In Quebec CMA for instance, high concentrations of high-income households on the north and south shore of the Saint Lawrence in close proximity to the CBD parallel high concentrations of low-income households immediately north of the CBD. In Regina, the uniqueness may be accounted for by the tract-particular features, since some of the smaller tracts containing high income households are the most suburban. Sherbrooke stands in sharp contrast to Regina and Quebec. Relative to all other CMAs, it has extremely low levels of centralised density for all but the highest income class. This may be a function of minority size -- Sherbrooke has the largest share of the CMA population in the lowest income categories of any CMA -- some 32 % of households are below <$20,000 and a further 24.1 % are $20,000-$34,999. Thus, the *majority* of the households represent the lowest income groups, and these are distributed throughout a range of size and CBD-proximate areas.

The above summaries indicate that it is useful to consider income residential segregation as a multidimensional construct. These different dimensions of segregation provide deeper insights into the residential expression of horizontal forms of income inequality within Canadian cities (Bourne 1997) but also point to ways in which scores on these separate dimensions quantify something of the pattern effects that underlie much of our subjective interpretation of maps of income characteristics.

Composite Segregation: Minority-Specific Characteristics

The battery of segregation indices used above and the respective dimensions of income segregation provide a high level of detail, and allow for the comparison of income groups on the different dimensions of segregation. However, in some situations one may not be concerned with the separate features, sub-scales, or spatial patterns of each of these features. Thus, a single scale of *composite* segrega-

tion may be desirable to address the basic question: "which income group is most segregated simultaneously over all of the separate dimensions of segregation and across all CMAs (i.e. within the metropolitan system)?".

Recognising that the dimensions have differential weights (proportion of variance explained), a weighted mean component score is one way to derive such a composite index. Such a score for *each income minority* within the urban system can be computed by Equation 1:

$$MCOMP_k = \frac{\sum_{i=1}^{n} w_i S_{i,k}}{\sum_{i=1}^{n} w_i} \qquad (1)$$

Where:

$MCOMP_k$	=	the minority k composite segregation score (standardised to mean=0 and SD=1).
W_i	=	the component or dimension weight (e.g. percentage or proportion of variance explained).
$S_{i,k}$	=	the component score for minority k on the ith component
n	=	the number of components extracted for interpretation (n=3 in this example).

Table 7 shows the MCOMP scores for the CMAs. A value of 0.0 is the metropolitan system-wide mean and 1.0 is one standard deviation above average. Table 7 is graphically summarised in Figure 2. In Canadian CMAs, households with <$20,000 per year are clearly the most segregated on this composite index, and Figure 2 shows the u-shaped trend of declining median segregation characteristics for the two middle income categories and increasing segregation characteristics for the highest income group, which also exhibits above average composite segregation scores. It is worth noting that Figure 2 also identifies highest levels of inter-metropolitan variation for the lowest income class, a feature which emphasizes the tendency for extreme segregation of low income groups -- such as the concentration of urban poverty -- to be somewhat city-specific (Broadway 1989, 1992; Chekki 1999; Myles et al 2000; Kazemipur 2000). It reinforces the findings of Kazemipur (2000), for example, who has shown that Saint John, Quebec city, Montreal, and Winnipeg have high proportions of low-income-concentrated neighbourhoods. Table 7 also shows that Regina, Trois Rivières, Edmonton, Ottawa-Hull, Calgary, and Hamilton must also be considered to have relatively high levels of segregation (> 1 SD above average) of the lowest-income class.

The least segregated group, the $35,000-$49,999 per year income group, is well below average and exhibits little inter-metropolitan variation (Figure 2). This group is the most fully integrated into all neighbourhoods of metropolitan

TABLE 7 CMA Minoroty Compposite Scores (MCOMP)

< $20,000		$20,000-$34,000		$35,000-$49,999		$50,000+	
Most Segregated							
Québec	1.66	Ottawa-Hull	0.14	Regina	-0.36	Ottawa-Hull	0.65
Winnipeg	1.58	Calgary	0.14	Calgary	-0.54	Calgary	0.53
Regina	1.54	Regina	0.12	Toronto	-0.62	Edmonton	0.51
Trois-Riv.	1.33	Hamilton	0.00	Edmonton	-0.63	Trois-Riv.	0.51
Edmonton	1.30	Toronto	-0.01	Ottawa-Hull	-0.64	Québec	0.46
Ottawa-Hull	1.26	Edmonton	-0.08	Trios-Riv.	-0.64	Winnipeg	0.45
Hamilton	1.18	Vancouver	-0.15	Hamilton	-0.67	London	0.39
Calgary	1.18	London	-0.23	winnipeg	-0.72	Regina	0.38
Montréal	1.17	Kitchner	-0.25	Halifax	-0.72	St John's	0.37
Windsor	0.96	Winnipeg	-0.28	Vancouver	-0.74	Sherbrooke	0.34
Victoria	0.89	Victoria	-0.31	Kitchner	-0.74	Hamilton	0.30
Toronto	0.86	Québec	-0.34	London	-0.75	Windsor	0.23
Saint John	0.84	Oshawa	-0.36	Saint John	-0.75	Halifax	0.22
Oshawa	0.69	Sudbury	-0.37	Québec	-0.76	Saint John	0.21
Saskatoon	0.66	Halifax	-0.38	Sherbrooke	-0.76	Vancouver	0.19
Vancouver	0.63	Montréal	-0.40	Victoria	-0.77	Saskatoon	0.17
Halifax	0.58	Windsor	-0.46	Chic.-Jonqu.	-0.77	Victoria	0.13
London	0.55	St John's	-0.51	StCath.-Niagra	-0.79	Kitchener	0.06
Sherbrooke	0.54	Trois-Riv.	-0.62	Sudbury	-0.82	StCath.-Niagra	0.05
St John's	0.50	Saskatoon	-0.65	Oshawa	-0.83	Montréal	0.03
Sudbury	0.44	Chic.-Jonqu.	-0.67	Montréal	-0.83	Sudbury	0.00
Chic.-Jonqu.	0.40	StCath.-Niagra	-0.68	Windsor	-0.83	Chic.-Jonqu.	-0.20
Kitchener	0.40	Saint John	-0.69	St John's	-0.83	Thunder Bay	-0.21
StCath.-Niagra	0.07	Thunder Bay	-0.74	Saskatoon	-0.85	Toronto	n.a.
Thunder Bay	-0.05	Sherbrooke	-0.89	Thunder Bay	-0.90	Oshawa	n.a.
Least Segregated							
Mean	0.85		-0.35		-0.73		0.25

areas. The highest income group ($50,000+) in the majority of CMAs exhibits above-average levels of residential segregation. This is most extreme in cities like Ottawa-Hull, Calgary, and Edmonton, and least evident in places like Thunder Bay, Chicoutimi, and Sudbury (Table 7).

The MCOMP scores summarise minority-specific levels of composite segregation throughout all metropolitan areas. The values of these scores reinforce the generalisation that high levels of residential segregation are characteristic of both the richest and the poorest income minorities. With relatively low levels of segregation, middle income groups are more fully integrated into all neighbourhoods of Canadian CMAs relative to the highest and lowest income minorities.

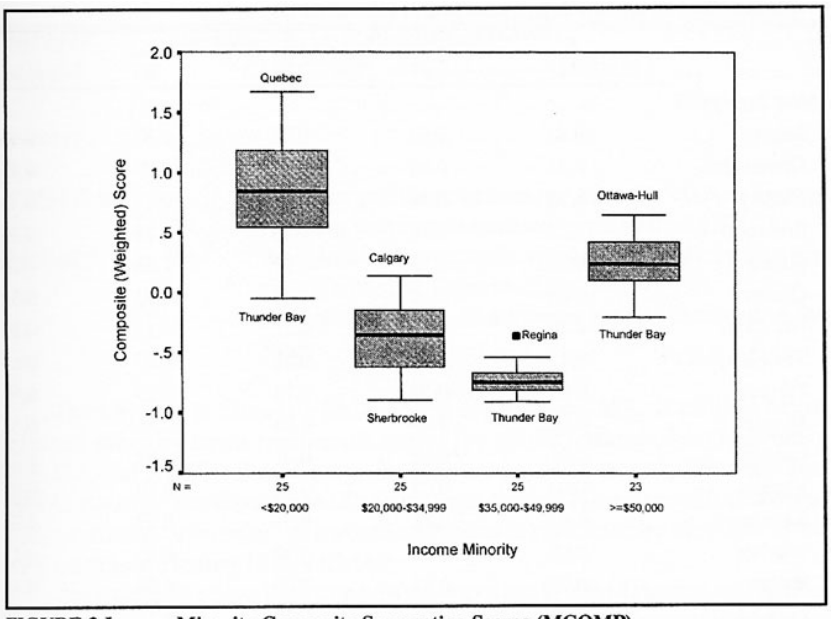

FIGURE 2 Income Minority Composite Segregation Scores (MCOMP)

Composite Segregation: Metropolitan-Specific Characteristics

Averaging the minority-specific scores by CMA allows one to answer the question: "Which CMA is most (or least) income-segregated when all dimensions of segregation are considered for all income minorities simultaneously?".

Equation 2 defines the computation of the CMA composite segregation scores (CMACOMP), and Table 8 shows the descending rank order of the CMACOMP values. Considering all income groups together for all dimensions of segregation, Regina is the most income-segregated CMA in Canada, although it must be remembered that this ranking could be produced from unique segregation features specific to Regina. This CMA ranked third behind Ottawa-Hull for minority averages in terms of *Uneveness and Isolation* (Table 8, Component B1), was fairly typical for minority averages on the *Concentration and Clustering* dimension (Table 8, Component B2), and was the most extreme of all CMAs in terms of minority averages for the *Centralised Density* dimension (Table 8, Component B3). London and Montreal are examples of the most "average" Canadian CMAs in terms of composite income segregation features -- each with a composite score of –0.01, and ranking 10th and 11th (Table 8). However, the specific segregation features that have generated these similar scores are different. In London, average income minority characteristics for *Uneveness and Isolation* are fairly typical of the metropolitan system (Table 8, Component B1), as they are for *Concentration and Clustering* (Table 8, Component B2). How-

TABLE 8 CMA Composite Segregation Scores (CMACOMP)

		Mean Minority Score on Component			Mean Min.
	CMACOMP	B1	B2	B3	DIS Index
Most Segregated					
Regina	0.42	0.38	0.00	2.33	0.23
Ottawa-Hull	0.35	0.49	0.17	-0.09	0.33
Calgary	0.33	0.34	0.24	0.58	0.23
Edmonton	0.27	0.22	0.16	1.15	0.26
Winnipeg	0.26	0.25	-0.09	1.68	0.18
Quebec	0.26	0.42	0.05	-0.22	0.31
Hamilton	0.20	0.28	0.12	-0.11	0.25
Trois-Rivières	0.15	0.21	-0.13	0.67	0.18
Toronto	0.08	-0.29	0.78	0.25	0.31
Montreal	-0.01	0.09	-0.35	0.56	0.31
London	-0.01	0.09	0.01	-0.88	0.23
Victoria	-0.02	-0.05	0.09	-0.19	0.27
Vancouver	-0.02	-0.02	0.01	-0.07	0.24
Windsor	-0.03	0.12	-0.10	-0.85	0.21
Halifax	-0.07	-0.13	-0.03	0.16	0.20
Saint John	-0.10	0.00	-0.29	-0.12	0.18
St John's	-0.12	-0.09	-0.12	-0.29	0.16
Kitchner	-0.13	-0.21	0.03	-0.16	0.22
Oshawa	-0.17	-0.43	0.43	-0.42	0.20
Saskatoon	-0.17	-0.14	-0.06	-0.81	0.19
Sudbury	-0.19	-0.02	-0.23	-1.45	0.18
Sherbrooke	-0.19	-0.23	-0.04	-0.39	0.22
Chic-Jonquière	-0.31	-0.45	-0.14	0.16	0.13
StCath-Niagra	-0.34	-0.47	-0.07	-0.34	0.19
Thunder Bay	-0.48	-0.54	-0.17	-1.18	0.18
Least Segregated					

ever, minority averages for *Centralised Density* are almost one standard deviation below the metropolitan system average (Table 8, Component B3). In Montreal minority average component scores for *Uneveness and Isolation* (Table 8, Component B1) were similar to London. However, on average, Montreal exhibits considerably less *Concentration and Clustering* of income minorities (Table 8, Component B2), and considerably higher relative levels of *Centralised Density* of income minorities than London (Table 8, Component B3).

$$CMACOMP_c = \frac{\sum_{k=1}^{p} MCOMP_k}{p} \qquad (2)$$

Where:

$CMACOMP_c$	=	the metropolitan area average minority composite segregation score (standardised to mean 0 and SD 1).
$MCOMP_k$	=	the minority k composite segregation score for the specific CMA (see Equation 1).
p	=	the total number of minority groups included in the study.

Thunder Bay is Canada's least income-segregated CMA. It exhibits below average minority mean component scores for all dimensions of segregation -- 0.5, 0.2, and 1.2 SD below average for *Unevenness and Isolation, Concentration and Clustering, and Centralised Density* respectively (Table 8), and it is obvious that the spatial "evenness" of income minorities is paralleled by very low levels of Centralised Density in this CMA.

The examples above illustrate how metropolitan levels of income segregation may be, in some circumstances, a function of unique combinations of segregation features -- although scores on the *Unevenness and Isolation* dimension (the largest in terms of explained variance) seem to dominate these levels of segregation.

Are there Benefits to Indexing Multiple Dimensions of Income Segregation and Adopting Composite Segregation Scores?

The analysis described above is both data and computationally intensive and the interpretation of structures of segregation is considerably more difficult than the interpretation of a single index measure. Thus, an obvious issue is whether or not, within the context of the metropolitan system, simpler or more easily interpretable indices tell us the same thing as the battery of indices and dimensions of segregation used here. An obvious candidate is the workhorse of segregation studies -- the Index of Dissimilarity (DIS). Given that *Unevenness and Isolation* is the most important dimension of segregation (accounting for 56 % of the variation of segregation indices in this analysis), and that DIS is a high-loading variable on this axis (i.e. a key indicator or single-variable surrogate), it may be expected that little more is to be gained from a multivariate approach to segregation than simply adopting DIS to measure income segregation. This is in fact the case, especially when a composite summary of residential segregation, irrespective of pattern effects is sought, since neither the *Unevenness and Isolation* dimension nor DIS index the spatial *patterns* of unevenness. The correlation between DIS and MCOMP for the metropolitan system is 0.92 for the <$20,000 group; 0.93 for the

$20,000-$34,999 minority; 0.63 for the $35,000-$49,999 minority; and 0.84 for the $50,000+ minority. The utility of DIS as a surrogate for composite segregation is therefore weakest for the $35,000-$49,999 minority. Only 40 % of the variation in composite segregation (i.e. segregation as a multidimensional construct) can be accounted for by DIS, meaning that characteristics other than unevenness in residential pattern are more important in understanding the geographical characteristics of segregation of this specific income group than they are for other income minorities. Conversely, the utility of DIS as a surrogate for composite segregation is strongest for the $20,000-$34,999 minority, in which 86 % of the variation in MCOMP is accounted for by DIS alone. Therefore, little additional insight into the geography of income segregation for this minority at a metropolitan system scale is achieved by measuring characteristics such as centralisation, clustering, or spatial concentration.

In the main, the composite measures derived from including information from multiple dimensions of segregation tell us little more than what could be easily obtained by calculating DIS, since the dominant dimension weighting the composite measures is one that summarises the same properties as DIS. The efficiency of DIS as a tool for *generalising* and comparing income minority *segregation levels* is impressive -- although an understanding of other features of segregation would be required to summarise pattern effects such as centralisation, clustering, and concentration.

A related issue is the utility of employing DIS in summarising CMA-specific levels of segregation for all minorities--in other words, the comparative utility of CMACOMP and mean DIS indices for the income minorities within each CMA. The mean DIS index values for the income minorities in each CMA are given in Table 8. There is a very strong correlation between CMACOMP scores and mean DIS values (r=0.94). Thus 88 % of the variation in CMACOMP can be accounted for by mean DIS indices alone. Like MCOMP, therefore, employing the extensive battery of indices required to measure multiple dimensions of segregation does not significantly enhance an understanding of the overall *degree* of residential segregation of *all income minorities* in a city. The DIS is an effective, easily computed, and easily understood measure of segregation that adequately captures the overall degree of income group segregation in the city.

The general efficiencies of DIS for summarizing the *degree* of segregation of one income minority relative to others, or of one city relative to others for all income minorities, should not obscure the fact that this approach misses important insights into the spatial properties of segregation. Again, Toronto and Montreal, provide useful examples. The comparative development, differences, and similarities between these CMAs have been well documented (see Ledent et al 1999 for example). Table 8 shows that these CMAs have identical (and *relatively* high) mean DIS indices for the income minorities, as well as similar CMACOMP scores that are average within the metropolitan system. However, reliance on either mean DIS indices or on CMACOMP scores obscures an important difference between the two CMAs. This difference is *not* associated with the overall *degree* of income segregation, but with the spatial properties of segregation. Relative to other CMAs,

an important spatial feature of income segregation in Toronto is *Concentration and Clustering*, whereas in Montreal a key feature is *Centralised Density*.

The relative utility of the multiple dimension approach and the use of composite segregation scores is therefore limited if a simple index of the *degree* of segregation is desired. If data and computational intensity is not an issue, then the composite segregation measures described here provide a more detailed and more accurate measure, since they capture many different features or dimensions of segregation simultaneously. The real advantage of the multiple dimension approach is the ability to gain insights into the *spatial properties* of segregation not summarised by unevenness measures, and the ability to relate one minority to another and one city to another on a series of standardised scales. It provides a quantitative parallel to more subjective visual map comparisons. Thus, for example, one can compare the spatial concentration and clustering of income minorities in Regina and Toronto, and not only index these features for each city, but index where in relation to all other CMAs these cities, or specific minorities, are situated. The latter is impossible by visual inspections of tract-level maps of income classes. Such an approach also provides another set of tools for measuring and describing some of the characteristics of the complex social ecology of the Canadian city.

Conclusion

Factorial ecology studies have long shown that socio-economic or income segregation is one of the most important sources of social variation in the North American City, and is increasingly represented by new forms of inequality. Summarising the spatial characteristics and patterns of this kind of segregation within cities has typically relied on map distributions of component scores of Socio-economic Status, although single index measures such as the Index of Dissimilarity have also been employed to summarise the degree of residential unevenness in the distribution of households by income. Given that recent research has argued for a five-dimensional understanding of residential segregation, this paper has explored the dimensionality of income segregation within the Canadian metropolitan system. We find that current arguments for a five-dimensional structure of segregation need to be qualified with respect to the type of social segregation under consideration. Perhaps racial or ethnic segregation in US urban systems is five-dimensional, but three dimensions of variation better define income residential segregation in Canadian CMAs. Thus, some of the features that Massey and Denton (1988) hypothesized to be distinct are empirically collapsed, or spatially inseparable, within the context of income segregation.

This study has shown that there is value in adopting a multidimensional approach since it provides deeper insights into the generaliseable spatial patterns of income segregation throughout the metropolitan system. This is particularly so for dimensions of segregation that extend our understanding of minority-specific or city-specific forms of segregation that are not summarised by general measures of unevenness. By scaling each minority or each CMA on a series of standardised

scales (component scores), the *relative* segregation of groups and cities can be better described, and unique features of the geographical patterns of income segregation for specific minorities and cities can be identified.

We have identified two measures that provide composite, quantitative summaries of the *structural* character (dimensionality) of income segregation. Compared to commonly used indices such as DIS, these composite indices provide a more comprehensive and standardised relative measure of segregation since they are based on information from multiple dimensions of segregation. However, little is to be gained by employing these composite indices if researchers are only concerned with deriving a simple summary measure of residential segregation. The easily computed, easily interpreted workhorse of segregation, DIS, performs very well in this regard.

One area in which the multidimensional approach to income segregation may prove valuable in future studies is in our understanding of system-level change through time. For, instance, if future studies identify *fewer* dimensions of income segregation, then income segregation within Canadian CMAs could be considered structurally less complex -- as the geographical characteristics of unevenness, isolation, concentration, centralisation, and clustering become less distinctive features. However, increasing structural simplicity in this case may be equated with increasing social polarisation -- since Massey and Denton (1989, 1993) have argued that as the dimensions of segregation collapse or converge in structure, there is a tendency toward hypersegregation. More detailed comparative studies would be required to better understand how segregation structures are changing through time, which specific minority segregation features lie behind these changes, or how individual CMAs are implicated in such change. Likewise, there is a need to understand the structure and complexity of residential segregation for other key sources of social differentiation in Canadian cities -- such as Family Status groups (family and age groups), as well as ethnic minorities.

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