Term Paper:

Land Use, Income, Housing Typology and Gender as Related to Travel Behaviour in the Greater Montreal Area

Peter Szilagyi

CIVE 540 – Urban Transportation Planning – Fall 2004

Professor Murtaza Haider

December 24, 2004

Revised January 4, 2005

ABSTRACT

This paper presents a study of transit mode spilt in the Montreal Census Metropolitan Area using Census Tract (CT) data extracted from 2001 census. The purpose of this paper is to study the relationship between various attributes and travel behaviour in the Montreal CMA. The paper examines land use (population density), average individual income, housing typology (percent single-detached, percent apartment…) and gender as related to travel behaviour in the Greater Montreal Area. This analysis reveals that population density is the strongest predictor of mode choice. It is followed by housing typology, and then by income. This study also depicts a visual guide to the relationships between the various attributes. As well, gender is shown to be an important factor in mode choice. In addition, the study demonstrates that other attributes must also be considered due to the inherent problems with the given attributes.

Land Use, Income, Housing Typology and Gender as Related to Travel Behaviour in the Greater Montreal Area

INTRODUCTION

Studying travel behaviour, specifically how people travel to work, is key in urban transportation planning. Knowing how people travel to work, allows for the planning and solution of problems that affect a city's economy, health, and social well-being. Road congestion causes losses in time and money, and increased stress, thus being detrimental to health, while creating environmental issues due to carbon monoxide emissions. Remedying this situation by building white elephant transit projects, only makes the problem worse, and makes taxpayers unsatisfied. Travel behaviour studies help make the right decisions about transit and road planning in order to suit the needs of the population.

This paper presents a study of the determinants of travel behaviour related to work trips in the Montreal Census Metropolitan Area. It offers a detailed analysis of transit behaviour such as automobile driver, automobile passenger, transit, bicycle and walk work trips in relation to certain attributes that may affect mode choice in Montreal.

The following section presents a review of relevant literature. This is followed by data description and methodology. A detailed descriptive analysis of travel behaviour is then presented, followed by two different regression models. This paper ends with conclusions on the study.

LITERATURE REVIEW

This paper studies the impact of local attributes on travel behaviour in the Greater Montreal Area or Montreal CMA, using data obtained from the 2001 census, conducted by Statistics Canada, on a census tract (CT) -level. A Census Metropolitan Area (CMA) is generally formed when a number of adjacent municipalities form an urban core. “The urban core must have a population greater than 100,000 and a population density of at least 400 persons per square kilometre” (1). “A Census Tract (CT) is a small, geographically restricted area”, “is not restricted in size, and can encompass quite a large geographic extent” (1). “The census is conducted once every five years, and offers an in-depth exploration of the health and vitality of the Canadian urban landscape” (1).

DATA

This paper uses the 2001 Statistics Canada Census data for the Montreal CMA. For the purposes of this paper, travel behaviour was split into transit, driver, passenger, bike and walk work trips. Census data also contains taxi and motorcycle trips, but these were deemed insignificant compared to the selected modes of travel. A number of local attributes available through census, such as land use (population density), income and housing typology (single detached, semi-detached, and row housing, as well as, duplex, low and high apartments) can be considered in order to gain an understanding of travel behaviour in the Montreal CMA. Furthermore, it is beneficial to observe the differences between the travel behaviour by gender based on these attributes because in certain cases there are significant differences in the travel behaviour of men and women as will be seen

in the analysis to follow. There are many other attributes that affect travel behaviour, however, time and space restrictions limit this paper to the above.

The first factor to be studied is population density, which describes the number of people living per square kilometre for a given CT. This data is not directly available from census, but can be easily obtained by dividing population data by CT Area data.

Next, Average Individual income is analysed as an economic indicator to travel behaviour. This paper does not study the affect of low-income on travel behaviour, although there are several studies suggesting that areas of low-income are higher users of transit. (2) The question asked in this paper is: Does the average income of a CT affect the mode split for that CT? Male and female individual incomes are also studied separately in the analysis.

Finally, housing typology is studied to see if there is a relation between the type of dwellings in a CT and the mode split for that CT. Census data splits housing typology into single-detached housing, semi-detached housing (where two houses share a common wall), row housing (where both sides of a house shares a common wall with the next house), duplexes apartments (where there are usually two dwellings next to and on top of each other), apartments with less than five stories, (further referred to as low-rise apartments), apartments with more than 5 stories (further referred to as high-rise apartments), and movable houses. For the purposes of this study, movable houses were not studied. In order to better relate housing typology to travel behaviour, certain housing types were chosen to be combined. Generally, it is sufficient to separate housing typology into single detached housing and apartments. Because of the large number of duplex apartments and apartments less than 5 stories in the Montreal CMA, these were chosen as

additional data sets. Semi detached and row housing are thus combined into one data set, and duplex and low-rise apartments are combined into another dataset. All apartments were also combined into one dataset for study. The number of a certain type of housing unit per CT, would not have much relation to travel behaviour, however, the percentage has a much better relation. Each dwelling type, or group of dwelling types, is thus divided by the total number of dwellings for that CT to find the percentage. All datasets can be seen in Table 1.

Another housing spilt that is used in this study is the percentage of rented dwellings and the percentage of owned dwellings. Although these factors are related to income and because average individual income can be misleading, it is useful to have another economic indicator to study travel behaviour related to housing in this case. It is assumed that generally home renters are of lower income than homeowners.

All these attributes are compared to travel behaviour split into transit, driver, passenger, bike and walk work trips. Initially, the passenger mode was not looked at in this study. Upon inspection, there were more passenger trips than transit trips, so the passenger mode could not be neglected if a proper picture of Montreal CMA travel behaviour was to be developed. Datasets were developed for each of these modes based on male, female and total data for the number of trips as well as for the percentage of trips. To develop the percentage datasets, the census data for each mode was taken and divided by the total employed labour force over 15 years of age. Because it is assumed that each employed individual over the age of 15 makes one work trip per day, this is equivalent to dividing by the total number of work trips. For the gender-based data, the total employed labour force for that gender was used as the denominator.

Because there are over 900 CT in the Montreal CMA, and because 26 different variables, listed in Table 1, are studied for each CT, full tables of relevant data for this paper cannot all be shown. Relationships between data are studied and summarized in tables 2-5 using regression modelling.

METHODOLOGY

In order to visualize the above data attributes and to observe the relationships amongst them, maps were made using TransCAD software. These maps paint a picture of the Montreal CMA divided by CT, to analyze how people travel to work and identify differences between genders and between urban and suburban areas. See the list of maps. Two types of maps are used. The first are colour maps that illustrate CT areas based on incremental values (usually a total of 5 colour increments are used). The second type of map is known as a prism map. It is a three dimensional rendition of the attribute being mapped based on the relative values from one CT to the others. Prism maps do not have increment legends and are not great for making regional relationship observations, however, they are useful in giving relative perspective to the magnitudes of the relationships and seeing maximum and minimum CT peak values in the CMA.

Following the descriptive analysis of the Montreal travel behaviour profile, two distinct sets of ordinary least squared regression logit models were estimated. Each model was then split into two sets of models. The first model was a trip end mode split model using the trip-end modelling approach with the number of auto drive and transit modes as dependant variables. The second model used was the linear probability model with the

percentage of auto drive trips and the percentage of transit trips as the dependant variables.

Numerous variables as described in the data section preceding the methodology section, describing CTs were selected as explanatory variables. As explained the variables were selected based on how well they were thought to influence travel modes. Descriptions of these variables are listed in Table 1.

DESCRIPTIVE ANALYSIS

In order to analyze the chosen datasets, it would be impractical and irrelevant to analyze the many census tracts, tract-by-tract or region-by-region, using only the raw census data. For this reason, visual analysis is made using maps created with the datasets for the Montreal CMA. In the following paragraphs, observations on the maps presented and relationships among the datasets will be analysed. These analyses are merely based on observations and are not statistically valid relationships, however, they greatly help to understand the makeup of the Montreal CMA travel behaviour by region and by gender based on the given attributes. Colour maps are used to represent each dataset in increments, while the prism maps shed great light onto the magnitude of the differences from one CT to another, and help localize special regions in Montreal for the given variables. For all the maps, some holes exist in the census data where information was not available. These are visualized as blank spaces on the maps, not to be confused with the light beige areas.

The first attribute examined is population density. It can be seen in Map 1. As shown by the blue colours on the map, population density is highest in the central core of

the Island of Montreal. It is interesting to note that the greatest densities are not homogeneous, not fully concentrated in the very core, but are scattered throughout the central area. Certain areas outside the central core with high densities are in Longueil, in Montreal North or RDP, and in one CT on the southern coast of Laval. The highest population density, clearly visible on Map 2, is in the downtown core bounded by the streets of Sherbrooke, Maisoneuve, Guy and St. Mathieu.

Average individual income maps reveal that most of the Montreal CMA is in the $20,000-$30,000 average income per CT brackets. Unfortunately this has little meaning, because incomes within a CT can very so much. The most densely populated areas in Montreal also correspond to some of the lowest average incomes, mostly in the central core of the Island. Directly adjacent to these areas are the peaks of reported individual incomes in Westmount and Outremont. Other peaks of high income are in the Montreal harbour Expo 67 region, Nun's Island, and in the West Island in Senneville and Baie D'Urfe. In the exclusive average income above $100,000 is also the CT at the very western tip of Laval. These can be seen on Maps 3 and 4. Average male incomes depicts a similar picture to average incomes with the exception of a few CTs that are bumped up by one income category as can be seen on Map 5. Average female income depicts a drastically different picture with most of the Island's most populated areas reporting female incomes of less than $20,000 and the rest showing $20,000-$30,000 as can be seen on Map 6. Only Westmount and Old Montreal are shown in the high-income range, with no CT in the greater than $100,000 range, unlike the male average income. Therefore, despite progress in female incomes, there is still a wide gap. Also, as will be

pointed out later, the low female income-corridors in the central core of the Island also correspond to the highest transit use corridors.

Another economic indicator is the percentage of owned dwellings. Map 7 depicts the Montreal CMA in a sea of 80-100% owned dwellings, mostly off the Island of Montreal, in the West Island, and in Westmount and Outremont. This is much like the higher average individual income CTs. As will be seen, this corresponds to the CTs with single-detached housing as well as the CTs with the highest percentage of Auto Drivers and Passengers.

The high-percentage of rented dwellings CTs (Map 8) are closely related to the lower-income CTs. Also, the high-percentage transit CTs corresponds almost perfectly with high-percentage apartment dwelling CTs, concentrated in the central core and centre-east of the Island.

Starting with single detached dwelling percentage in housing typology, it is immediately evident from Map 9 that single detached housing is concentrated mostly off the Island, except in the western tip of the Island and Westmount, which consist almost entirely of single detached housing. Again, these CTs correspond closely to the high-owned dwelling percentage as well as the higher income, although the relationship is more loosely related in the latter case. The best relationship to single detached housing definitely appears to be the percentage of drivers for those CTs, as will be seen. This also corresponds to the areas with the lowest population densities.

Semi-detached and row housing are not at all predominant in the Montreal CMA, with most CTs in the 0-20% category as seen on Map 10. The highest percentage of such housing is found in some parts of the West Island and at the Eastern tip of the Island, as

well as Ville Saint-Laurent (Map 10). There seems to be little or no correlation to income or house ownership.

Duplex and apartments less than 5 stories are abundant strictly and uniquely in the central core of the Island, again unsurprisingly (Map 11). This corresponds to the high population density CTs; the high rented percentage CTs, and generally to the high transit use CTs.

Apartments greater than 5 stories are relatively scarce in the Montreal CMA compared to the Toronto or Vancouver CMAs (Map 13). There are, however, a few CTs with 80-100% of such housing. These can be seen on Map 14. There is one such CT in the Longueil region, as well as a few scattered around the central core of the Island, and Nun's island, known for its high-rise apartments. Not surprisingly, these CTs with a high percentage of high-rise apartments correspond to the population density peaks. It is difficult to note from this map if there is any real evidence of high transit use in those CTs, although, hypothetically, there should be. There is also no real correlation to income here or owner percentage.

Looking now at apartment percentage in general with all apartment types combined, a clear picture is seen as a mirror image to single-detached housing (Map 15). There is clearly a positive relationship between apartment percentage and population density, as well as with general transit use, although not as directly. Income is also generally lower in apartments and rented percentage generally higher, but this is not always the case. Clearly, the high apartment percentage is practically restricted to the core of the Island.

Looking at mode choice by starting with percentage of transit trips per CT (Map 16), the greatest transit use is located in the central core and along corridors in the central-eastern core of the island. There is also fairly high transit use along a corridor on the south shore, presumably where bus service is abundant. There is clearly a relationship between population density and transit use, though it is by no means perfectly corresponding. Income surprisingly shows little correlation to transit use. Some of the lowest income areas have high transit use, which some do not. It is possible that this suggests a lack of transit availability in those CTs. The highest percentage of transit use at 62% is in the CT bounded by Jean Talon, Van Horne, Parc and Clark. This CT is closely followed at 61% transit use in the CT bounded by Sherbrooke, Maisoneuve, Decarie and Saint-Catherine, also known as the Metro Vendome area, which has a metro station, a commuter rail station, and many bus lines. Transit availability is thus a notable factor in transit use, perhaps far more than any of the factors examined in this paper (Map 17). Male Transit percentage in contrast to total transit percentage is low as can be seen in Map 18. Immediately noticeable is the fact that there are no longer any CTs with 60-80% transit use. The highest transit use CTs appear to be the ones around major transit hubs. The extremities of the orange line are also noticeable, further proving the point about transit availability and transit use. Female Transit percentage (Map 19) in stark contrast to male transit percentage, still has 60-80% transit use CTs, and shows generally greater transit use across the board, specifically in the central core of the Island.

Driver percentage is much the opposite of transit use percentage. It is still very much the undisputed highest mode split percentage in the Montreal CMA as can be seen by the sea of red in Map 20, representing 80-100% driver mode split. There is a clear

correlation between single-detached housing and driver percentage. There also appears to be strong relationship to population density and generally to income, but again not as much in the case of income. Male driver percentage (Map 21) simply fortifies the sea of red in the previous map, with even more CTs with 80-100% driver mode split. Naturally, these CTs are also generally suburban, off the Island, or in the West Island. Female driver percentage (Map 22), shows the same picture, but with less 80-100% housing, but still lots around the boundaries of the Montreal CMA.

Passenger percentage mode split is a very heterogeneous mixture in the Montreal CMA. (Map 23) There is generally a greater percentage of passengers in the same CTs with a high percentage of drivers, but little more can be said for this variable. There seems to only small correlation to population density, but in many of the rural areas in the Montreal CMA off the Island, there seems to be no correlation to density or housing typology. There may be somewhat of a correlation with income, but because of the heterogeneous map, it is difficult to see. The peaks in passenger percentage can be seen in map 24 and are located in the Boucherville areas towards the eastern townships, as well as on the south shore near the Mercier Bridge. Male passenger percentage (Map 25) is not surprisingly lower than female passenger percentage. Female Passenger percentage (Map 26) is very high in the suburban areas, almost across the island and throughout the south shore. This fact along with women's higher transit use explains why men have such a high driver percentage in the Montreal CMA. Reasons for this can only be hypothetical, but may be related to behavioural patterns or historical patterns.

Although bike and walk percentages are very low in comparison to the other mode splits, it is interesting to note the location and gender behavioural patterns of these.

Higher bike percentages are concentrated in the absolute core of the island (Map 27). This is not surprising considering that there is also higher residential density in that area and it is the economic core of the city. There is also a relatively higher percentage of bike trips in the Longueil region and in the Saint-Anne-de-Bellevue region in the West Island. This can possibly be explained by the availability of bike paths, and local home to work trips. Bike percentage peaks can be seen in Map 28. Unlike many Asian cities, bike percentage does not seem to be linked to low-income CTs necessarily. There is more male bike percentage than female bike percentage as can be seen in Maps 29-30, which again is likely a behavioural pattern.

Walk percentage is surprisingly higher than bike percentage and is located similarly in the central core of the Island, but this time the highest percentage CTs creates a much larger footprint then the bike percentage (Map 31). It appears that 35-100% of the people living in the downtown core go to work by walking (Map 32). This is not shocking, considering that parking in the central core is expensive or impossible. Interestingly, it appears that parts of Dorval are also relatively high walk percentage. It is notable that the centre of the walking radius is still around Old Montreal. This can be a clue to how Montreal evolved from the 45-minute maximum walking distance radius starting from Old Montreal. Then further developed with the streetcar, then highways and so on. It is difficult to say whether more men of more women walk to work based on Maps 33 and 34, however it does appear that the high percentage of male walk CTs are more concentrated then female walk CTs. Female walk CTs seem far more dispersed and less homogeneous, though still located in the general core of the Island. There are also

interestingly some regions on the north shore where male walk percentage is relatively high.

The following sections take a mathematic approach to analysing these relationships through regression models.

MODEL 1 RESULTS

Table 2 presents the results of the trip end mode split model using the trip-end modelling approach with the number of auto drive the dependant variable and given attributes as explanatory variables.

The model fit (R^2) ranges between 0.02 and 0.4199, suggesting poor fits. Furthermore, constant values for the models range from 93 to 2482, suggesting that factors other than the independent variables are explaining variations in transit use. This all suggests that there is only a weak linear relationship between transit use and income when using aggregated census data. It is assumed that the linear relationship will improve greatly when using percentage data as the dependant variables.

The general relationships still hold and make sense when looking at the signs of the constant values. For example, as seen in the regression number 4, auto drive goes up as average individual income goes up. This is expected.

For regression numbers 21-26 in Table 2, where density, income and percentage owned or rented are taken as explanatory variables, the sign for income is counter intuitive, suggesting multicolinearity. This is probably because there is a strong relationship between owned percentage and density as well as with income.

The same argument holds for Transit trips as the dependant variable as can be seen in Table 3.

Essentially, aggregate census data, where populations and areas vary widely from one CT to another, make it difficult to compare the total number of trips per given mode to any variables, because the total number of people changes too widely from CT to CT. Better relationships can be made when the percentages are taken by dividing the number of work trips per mode by the total number of work trips.

MODEL 2 RESULTS

Table 4 presents the results of the linear probability model with the percentage of auto drive trips as the dependant variable and given attributes as explanatory variables.

The model fit (R^2) ranges between 0.06 and 0.752, suggesting relatively good fits for most regressions except a few.

The best fit is represented by the multivariate relationship between population density, average individual income, rented dwellings and percentage auto trips. Interesting to note in that case is that the percentage of rented dwellings is the most correlated variable to the percentage of auto drive trips. Population density follows after it. Surprisingly, the average individual income is last with a relatively insignificant correlation to the percentage of auto drive trips. Upon closer inspection it is discovered that the constant values for income are negatively related to the percentage of auto drive

trips. This is clearly incorrect and means that there is multicolinearity as in the first model between density income and the percentage of rented dwellings.

The best fit without multicolinearity, with an R^2 of 0.7457 is achieved by the multivariate relationship between density, income and the various housing types with percentage drive trips. In this case, population density has the greatest correlation to percentage auto drive, however income, low and high rise apartments have a t-stat value below 2 meaning that they do not have a large enough correlation to percent drive trips in this regression. The R^2 for the percentage of male drive trips is lower than that for female drive trips for the same list of multivariate explanatory variables as above, meaning that females in low population density are more likely to drive then males. This is interesting because in general males have a higher percentage of drive trips than females, except for low-density areas such as suburbs of Montreal. This can be seen in the model.

In the relationships between population density and average individual income as the only explanatory variables, an R^2 of 0.5731 is achieved. This is passable, but not a great linear fit. Population density once again takes the lead having the greatest correlation to percent drive trips, with income having only a small correlation. The signs are correct, with drive percentage going up as income increases, and as density decreases, as expected based on the descriptive analysis from before. Once again female drive percentage increases more with a decrease in density than for male drive trips as explained previously.

As far as housing typology is concerned, when all housing typologies are set as explanatory variables against drive trips, the R^2 obtained is 0.6. This suggests a good fit. Single detached, semi-detached and row housing percentages, representing low-density

housing, all have a positive correlation with drive trips as expected. Apartments have a negative correlation also as expected. In this model, only single detached housing percentage really hold any correlation value because the t-stat for the other types of housing are all below 2. For male drive trips in this model row and semi-detached housing also have a correlation, and for females all but semi-detached and row housing have a correlation. This suggests that men and women are affected differently by housing typology when deciding what transport mode to use to get to work.

In single variable models, the percentage of rental or percentage of owned housing has the best fit to drive trips, followed by population density, and lastly by income.

Table 5 presents the results of the linear probability model with the percentage of transit trips as the dependant variable and given attributes as explanatory variables. The R^2 values for this model are slightly lower then the ones for auto drive percentage, peaking at 0.68, but this is only expected because percent transit trips is lower than auto drive trips. The same models were run for percent transit as were for percent drive trips. Almost all relationships are the same, but with opposite signs for the constants, as expected. Again population density is the greatest indicator, though still not an incredibly good fit. This time the percentage of transit trips increases as density increases. Income is still a very weak correlation according to these models.

In summary, it can be argued that income should be the best fit, but because for this case average individual income of a CT does not represent the economic well-being of the people in the CT and thus cannot properly represent the travel behaviour, percentage of owned dwellings gives a better economic indication of the CT and thus a

better idea of travel behaviour for the CT. Finally, unfortunately none of the selected variables for this study are truly great indicators of travel behaviour. A study of transit availability and other such characteristics might be much better indicators of travel behaviour. As will be discussed, work density would also be a much better indicator than home population density in modelling work trips.

DISCUSSION

Throughout the analyses, whether visual or through modelling, certain issues regarding the modelling and the choice of variables to describe travel behaviour are raised.

First, population density, which is seemingly the greatest indicator of travel behaviours according to the regression models, can help to identify these, but because both CT populations and areas vary wildly within the Montreal CMA, population density loses some of its meaning. If a given CT is very small, and there happens to be a large building in that CT, then the density of that CT is shown to be high. A CT with a much larger area, but with an equally densely populated large building will not be shown to be a high density CT, despite the fact that the population density around a particular area that does not correspond to a CT boundary, is actually very densely populated. The problem lies in the fact that for determination of road, bus stop or metro stop locations, CT population densities could be misleading. Furthermore, it is important to remember that the population density represents the number of people living in a CT, not working in a CT. If work population densities were also available for study, there may be a better opportunity for work trip planning. It would be logical to study work density because the travel behaviours being studied is work trips not home-based trips. Also, due to the nature

of economic centres, and the advent of urban sprawl, chances are that work density will be higher than home density in most CMAs, including Montreal. The high work densities could then be used for better transportation planning, especially in the case of transit planning, where the chances to increase transit readership greatly increases with the availability of transit near high density work centres.

There are problems with average individual income as the economic indicator. Within a CT, there can be some people with a very high income and many with lower income. This causes the average income of that CT to be skewed and does not truly represent the income of most people in that CT. This makes it impossible to render judgements and observations about travel behaviour from skewed incomes. Such is the case in a CT in Place Saint-Henri, now called the borough of Sud-Ouest, where most housing is relatively low income, with the exception of the construction of new ultra-luxurious apartments along the Lachine Canal next to the Atwater Market. The result is a cluster of super high income amongst a low-income neighbourhood. Travel behaviour for this CT would be expected to be heavily transit oriented because it is relatively close to the core and has one of Montreal's largest metro stations, Lionel-Groulx, within 500m. Most of the lower-income individuals will surely be using transit as their work trip mode choice. The tenants of the luxurious apartments within the CT are known to drive their cars to work. Thus, the analysis of the CT is skewed. Discrepancies within CTs such as this one can cause the model to fall apart slightly.

CONCLUSIONS

In this paper, through a detailed visual analysis as well as regression modeling of several attributes used to describe travel behaviours in the Montreal CMA using 2001 Census data at the CT level, a good understanding of general travel behaviour was obtained. However, it was determined that the chosen attributes did not fully represent the reasons for people's mode choice for work trips.

The maps of the Montreal CMA painted a picture of Montreal where single-detached housing is strongly correlated to low density housing, relatively high income, and very low transit mode split. Women still use transit more than men as was shown. Men drive more than women. More women are passengers.

It was discovered that modelling on an aggregate basis yields poor linear fits, however, running models based on percentage yields far better fits. Also, according to the models, population density was determined to be the greatest influencing factor on mode choice, followed by housing typology, and income.

Problems with variables such as income and population density, suggest that if the census data were available for study, work population density would be of much greater use than home population density.

REFERENCES

1. Wise, David. (2002). Montreal: A statistical Profile. http://www.milute.mcgill.ca/Research/Students/David_Wise/index.htm (last visited December 24th, 2004)

2. Haider, Murtaza and Spurr, Timothy. (2004). Equity, Accessibility and Transit Use in large American cities. McGill University, School of Urban Planning and Department of Civil Engineering.

3. Statistics Canada (2001). Socio-demographic data for the Montreal CMA at the Census Tract level.

LIST OF TABLES

LIST OF MAPS

Table 1 – Variable names and description

gory	Variable	Census Variable Name	Description
& Sex			
	Population	pop2001	Total population count in census year 2001
	Area	Area	Land area in square kilometers, 2001
ne			
	Average Individual Income	inc15+avg	Average income in dollars of population 15 years and over
ehold			
	Total Number of Dwellings	totdwl_strctyp	Total number of occupied private dwellings by structural type of dwelling
	Single-detached	dwl_sngldtchd	Number of single-detached house dwellings
	Semi-detached	dwl_semidtchd	Number of semi-detached house dwellings
	Row House	dwl_rowhous	Number of row house dwellings
	Duplex	dwl_aptdtchddup	Number of detached duplex style apartment dwellings
	Low-Rise Apartment	dwl_apt5+strys	Number of apartment dwellings (apartment building has 5 storeys or mor
	High-Rise Apartment	dwl_aptl5strys	Number of apartment dwellings (apartment building has fewer than 5 sto
uage_transport			
	Male Driver	mlab15+mt_drvr	Car, truck, van, as driver
	Male Passenger	mlab15+mt_psngr	Car, truck, van, as passenger
	Male Transit	mlab15+mt_trnst	Public transit
	Male Walk	mlab15+mt_walk	Walked
	Male Bike	mlab15+mt_bike	Bicycle
	Number of Work Trips	totlab15+mt	Total employed labour force 15 years and over by mode of transportation
	Male Work Trips	mlab15+mt	Males with usual place of work or no fixed workplace address
	Female Work Trips	flab15+mt	Females with usual place of work or no fixed workplace address
	Female Driver	flab15+mt_drvr	Car, truck, van, as driver
	Female Passenger	flab15+mt_psngr	Car, truck, van, as passenger
	Female Transit	flab15+mt_trnst	Public transit
	Female Walk	flab15+mt_walk	Walked
	Female Bike	flab15+mt_bike	Bicycle

Table 2 – Results for Model 1 (Number of Auto Drive Trips)

Trial #	Dependent	Independent	I tstat I	Bo	B	F-stat	Rsquared
1	Auto Drive	Population Density	18.6908	1705.78	-8.24E-02	349.346	0.2772
2	Auto Drive Male	Population Density	17.7891	9.75E+02	-4.41E-02	316.454	0.2578
3	Auto Drive Female	Population Density	19.4451	730.382	-3.82E-02	378.11	0.2933
4	Auto Drive	Avg Individual Income	4.96936	926.096	1.14E-02	24.6945	0.0264
5	Auto Drive Male	Avg Male Income	4.34143	609.054	3.54E-03	18.848	0.0203
6	Auto Drive Female	Avg Fem Income	5.26539	288.02	1.02E-02	27.7243	0.0295
7	Auto Drive	P_owned	23.9759	321.044	1812.31	574.843	0.3869
8	Auto Drive	P_rented	23.9783	2132.92	-1811.48	574.959	0.3869
9	Auto Drive			-417.097		147.997	0.3947
		P_singdet	4.44252		2473.43		
		P_semidet+row	4.52377		2656.11		
		P_low rise ap+duplex	2.00675		1117.3		
		P_high rise ap	1.59871		905.864		
10	Auto Drive Male	P_owned	22.9973	227.909	981.523	528.877	0.3673
11	Auto Drive Male	P_rented	23.0005	1209.21	-981.098	529.024	0.3674
12	Auto Drive Male			1300.27		264.222	0.3674
		P_owned	0.025981		-91.0878		
		P_rented	0.305964		-1072.13		
13	Auto Drive Male			-207.349		137.675	0.3775
		P_singdet	4.37795		1373.87		
		P_semidet+row	4.50236		1490		
		P_low rise ap+duplex	2.04924		643.089		
		P_high rise ap	1.57335		502.482		
14	Auto Drive Female	P_owned	24.6283	93.1346	830.785	606.551	0.3997
15	Auto Drive Female	P_rented	24.6295	923.709	-830.378	606.615	0.3997

16	Auto Drive Female			683.96		302.981	0.3997
		P_owned	0.086545		239.822		
		P_rented	0.213278		-590.699		
17	Auto Drive Female			-209.748		154.096	0.4043
		P_singdet	4.4144		1099.56		
		P_semidet+row	4.43928		1166.1		
		P_low rise ap+duplex	1.90377		474.209		
		P_high rise ap	1.59127		403.382		
18	Auto Drive			1669.09		174.687	0.2774
		Population Density	17.7802		-8.16E-02		
		Avg Individual Income	0.545222		1.12E-03		
19	Auto Drive Male			981.358		158.078	0.2578
		Population Density	17.0676		-4.43E-02		
		Avg Male Income	0.193606		-1.44E-04		
20	Auto Drive Female			628.586		193.242	0.2981
		Population Density	18.6599		-3.73E-02		
		Avg Female Income	2.49205		4.18E-03		
21	Auto Drive			824.243		216.968	0.4173
		Population Density	4.5389		-0.0254706		
		Avg Individual Income	4.90036		-9.72E-03		
		P_owned	14.7702		1.66E+03		
22	Auto Drive Male			468.866		201.212	0.3991
		Population Density	4.13995		-1.31E-02		
		Avg Male Income	5.39318		-3.85E-03		
		P_owned	14.6155		920.922		
23	Auto Drive Female			309.798		219.368	0.4199
		Population Density	5.07171		-1.28E-02		
		Avg Female Income	1.94236		-3.14E-03		
		P_owned	13.8184		686.798		
24	Auto Drive			2482.7		217.046	0.4174
		Population Density	4.54884		-2.55E-02		
		Avg Individual Income	4.89947		-9.72E-03		
		P_rented	14.7759		-1657.71		

25	Auto Drive Male			1389.68		201.312	0.3992
		Population Density	4.1483		-1.31E-02		
		Avg Male Income	14.6231		-3.86E-03		
		P_rented	5.39593		-920.408		

26	Auto Drive Female			996.159		219.428	0.42
		Population Density	5.0822		-1.29E-02		
		Avg Female Income	1.9365		-3.13E-03		
		P_rented	13.823		-686.188		

Table 3 – Results for Model 1 (Number of Transit Trips)

Trial #	Dependent	Independent	I tstat I	Bo	B	F-stat	Rsquared
1	Transit	Population Density	16.7673	254.247	0.0255198	281.142	0.235
2	Transit Male	Population Density	18.8556	95.5368	0.0121174	355.533	0.2807
3	Transit Female	Population Density	14.3495	158.71	0.0134024	205.909	0.1844
4	Transit	Avg Individual Income	7.63456	561.692	-0.00575804	58.2864	0.0591
5	Transit Male	Avg Male Income	7.11994	215.155	-0.00150161	50.6935	0.0517
6	Transit Female	Avg Fem Income	4.81707	326.835	-0.00413586	23.2041	0.0238
7	Transit	P_owned	16.729	638.262	-474.547	279.86	0.2342
8	Transit	P_rented	16.7093	164.049	473.872	279.2	0.2337
10	Transit	P_singdet	19.3023	538.707	-431.369	372.58	0.2895
11	Transit	P_semidet	1.60285	402.869	-212.574	2.56911	0.0017
12	Transit			-420.498		103.924	0.314
		P_singdet	2.6169		521.077		
		P_semidet+row	5.2061		1093.21		
		P_low rise ap+duplex	4.90662		977.02		
		P_high rise ap	4.25404		862.066		
13	Transit Male	P_owned	18.0785	274.555	-218.913	326.833	0.264
14	Transit Male	P_rented	18.0564	55.7952	218.602	326.032	0.2636
15	Transit Male			1497.71		164.267	0.2653
		P_owned	1.45117		-1442.35		
		P_rented	1.23101		-1222.89		
16	Transit Male			-175.492		98.985	0.3036
		P_singdet	2.4737		215.987		
		P_semidet+row	4.41282		406.324		
		P_low rise ap+duplex	4.66614		407.422		
		P_high rise ap	4.37772		389.003		

17	Transit Female	P_owned	14.7742	363.708	-255.634	218.278	0.1933
18	Transit Female	P_rented	14.7577	108.253	255.27	217.79	0.1929
19	Transit Female			1790.34			
		P_owned	1.18442		-1682.6	109.645	0.1942
		P_rented	1.00455		-1426.33		
20	Transit Female			-245.006		95.1992	0.2955
		P_singdet	2.54529		305.09		
		P_semidet+row	5.43396		686.884		
		P_low rise ap+duplex	4.75195		569.598		
		P_high rise ap	3.87797		473.064		
21	Transit			345.331		150.633	0.2487
		Population Density	15.1139		2.38E-02		
		Avg Individual Income	3.95141		-2.78E-03		
22	Transit Male			117.909		183.097	0.2869
		Population Density	17.2894		1.16E-02		
		Avg Male Income	2.81941		-5.39E-04		
23	Transit Female			208.58		106.887	0.1902
		Population Density	13.6331		1.29E-02		
		Avg Female Income	2.56885		-2.05E-03		
24	Transit			474.326		116.438	0.2776
		Population Density	7.24039		0.0151985		
		Avg Individual Income	1.51141		-1.12E-03		
		P_owned	6.02874		-2.53E+02		
25	Transit Male			182.678		142.285	0.3195
		Population Density	8.61045		7.63E-03		
		Avg Male Income	0.352242		-7.05E-05		
		P_owned	6.59859		-116.387		
26	Transit Female			280.106		86.2393	0.2216
		Population Density	5.74492		7.46E-03		
		Avg Female Income	0.490677		-4.06E-04		
		P_owned	6.04852		-154.095		
27	Transit			221.522		116.336	0.2774
		Population Density	7.25967		1.52E-02		
		Avg Individual Income	1.51948		-1.13E-03		

		P_rented	6.00975		252.259		
28	Transit Male			66.4797		142.158	0.3193
		Population Density	8.63111		7.64E-03		
		Avg Male Income	0.359168		-7.19E-05		
		P_rented	6.57798		115.926		
29	Transit Female			126.351		86.1561	0.2214
		Population Density	5.76293		7.48E-03		
		Avg Female Income	0.499277		-4.14E-04		
		P_rented	6.0318		153.507		

Table 4 – Results for Model 2 (Percentage of Auto Drive Trips)

Trial #	Dependent	Independent	I tstat I	Bo	B	F-stat	Rsqua
1	P_Auto Drive	Population Density	34.2117	0.77899	-2.86E-05	1170.44	0.5
2	P_Auto Drive Male	Population Density	31.7337	8.37E-01	-2.61E-05	1007.03	0.
3	P_Auto Drive Female	Population Density	33.1316	0.71408	-3.11E-05	1097.7	0.5
4	P_Auto Drive	Avg Individual Income	9.84021	0.46912	5.28E-06	96.8297	0.0
5	P_Auto Drive Male	Avg Male Income	8.99063	0.58996	2.94E-06	80.8315	0.0
6	P_Auto Drive Female	Avg Fem Income	7.92261	0.337634	8.99E-06	62.7678	0.0
7	P_Auto Drive	P_owned	45.8488	0.317128	0.59289	2102.11	0.6
8	P_Auto Drive	P_rented	45.8351	0.909832	-0.592527	2100.86	0.6
10	P_Auto Drive			0.56203		486.551	0.6
		P_singdet	3.46901		0.341104		
		P_semidet+row	1.9384		0.201002		
		P_low rise ap+duplex	1.22229		-0.120188		
		P_high rise ap	1.46147		-0.14625		
11	P_Auto Drive Male	P_owned	40.0244	0.418005	0.536329	1601.95	0.6
12	P_Auto Drive Male	P_rented	40.0261	0.954193	-0.536057	1602.09	0.6
13	P_Auto Drive Male			0.741382		800.217	0.6
		P_owned	0.193392		0.212876		
		P_rented	0.293869		-0.323308		
14	P_Auto Drive Male			0.523868		343.378	0.
		P_singdet	3.9614		0.412292		
		P_semidet+row	3.18309		0.349365		
		P_low rise ap+duplex	0.14427		0.0150154		
		P_high rise ap	0.533592		-0.0565183		
15	P_Auto Drive Female	P_owned	45.0479	0.207639	0.652051	2029.32	0.6
16	P_Auto Drive Female	P_rented	45.0162	0.859447	-0.651569	2026.46	0.6

17	P_Auto Drive Female			-0.425166		1014	0.6
		P_owned	1.08084		1.285		
		P_rented	0.532428		0.632669		
18	P_Auto Drive Female			0.611457		514.588	0.6
		P_singdet	2.35215		0.250858		
		P_semidet+row	0.342393		0.0385089		
		P_low rise ap+duplex	2.57994		-0.275155		
		P_high rise ap	2.31737		-0.251524		
19	P_Auto Drive			0.718637		610.787	0.5
		Population Density	31.887		-2.74E-05		
		Avg Individual Income	4.7898		1.84E-06		
20	P_Auto Drive Male			0.802404		515.434	0.5
		Population Density	29.5414		-2.53E-05		
		Avg Male Income	3.44209		8.42E-07		
21	P_Auto Drive Female			0.613803		577.923	0.5
		Population Density	31.9794		-3.02E-05		
		Avg Female Income	5.1882		4.12E-06		
22	P_Auto Drive			0.485879		918.49	0.7
		Population Density	13.389		0.485879		
		Avg Individual Income	3.63627		-1.19E-05		
		P_owned	25.6011		-1.15E-06		
23	P_Auto Drive Male			0.574432		685.785	0.6
		Population Density	12.1619		-1.14E-05		
		Avg Male Income	3.82007		-8.09E-07		
		P_owned	21.9502		0.409654		
24	P_Auto Drive Female			0.383913		849.647	0.7
		Population Density	12.3795		-1.26E-05		
		Avg Female Income	1.78453		-1.16E-06		
		P_owned	24.7833		0.495276		
25	P_Auto Drive			0.942734		918.614	0.
		Population Density	13.4132		-1.20E-05		
		Avg Individual Income	3.63158		-1.15E-06		
		P_rented	25.6042		-0.456593		
26	P_Auto Drive Male			0.984042		686.243	0.6
		Population Density	12.1792		-1.14E-05		

		Avg Male Income	3.82439		-8.09E-07		
		P_rented	21.9649		-0.409431		
27	P_Auto Drive Female			0.878714		849.13	0.
		Population Density	12.4072		-1.26E-05		
		Avg Female Income	1.76822		-1.15E-06		
		P_rented	24.7695		-0.494538		
28	P_Auto Drive			0.522038		442.674	0.7
		Population Density	15.066		-1.36E-05		
		Avg Individual Income	0.649035		-2.16E-07		
		P_singdet	4.39069		0.387266		
		P_semidet+row	2.56055		0.239485		
		P_low rise ap+duplex	0.569788		0.0505666		
		P_high rise ap	0.893864		0.0815066		
29	P_Auto Drive Male			0.485255		308.224	0.6
		Population Density	13.803		-1.34E-05		
		Avg Male Income	1.26266		-2.89E-07		
		P_singdet	4.86955		0.462432		
		P_semidet+row	3.93261		0.396043		
		P_low rise ap+duplex	1.93232		0.184543		
		P_high rise ap	1.77161		0.17389		
30	P_Auto Drive Female			0.54009		455.037	0.7
		Population Density	14.0356		-1.39E-05		
		Avg Female Income	2.20345		1.47E-06		
		P_singdet	2.95931		0.285512		
		P_semidet+row	0.400923		0.041092		
		P_low rise ap+duplex	1.05625		-0.102594		
		P_high rise ap	0.453786		-0.0453437		

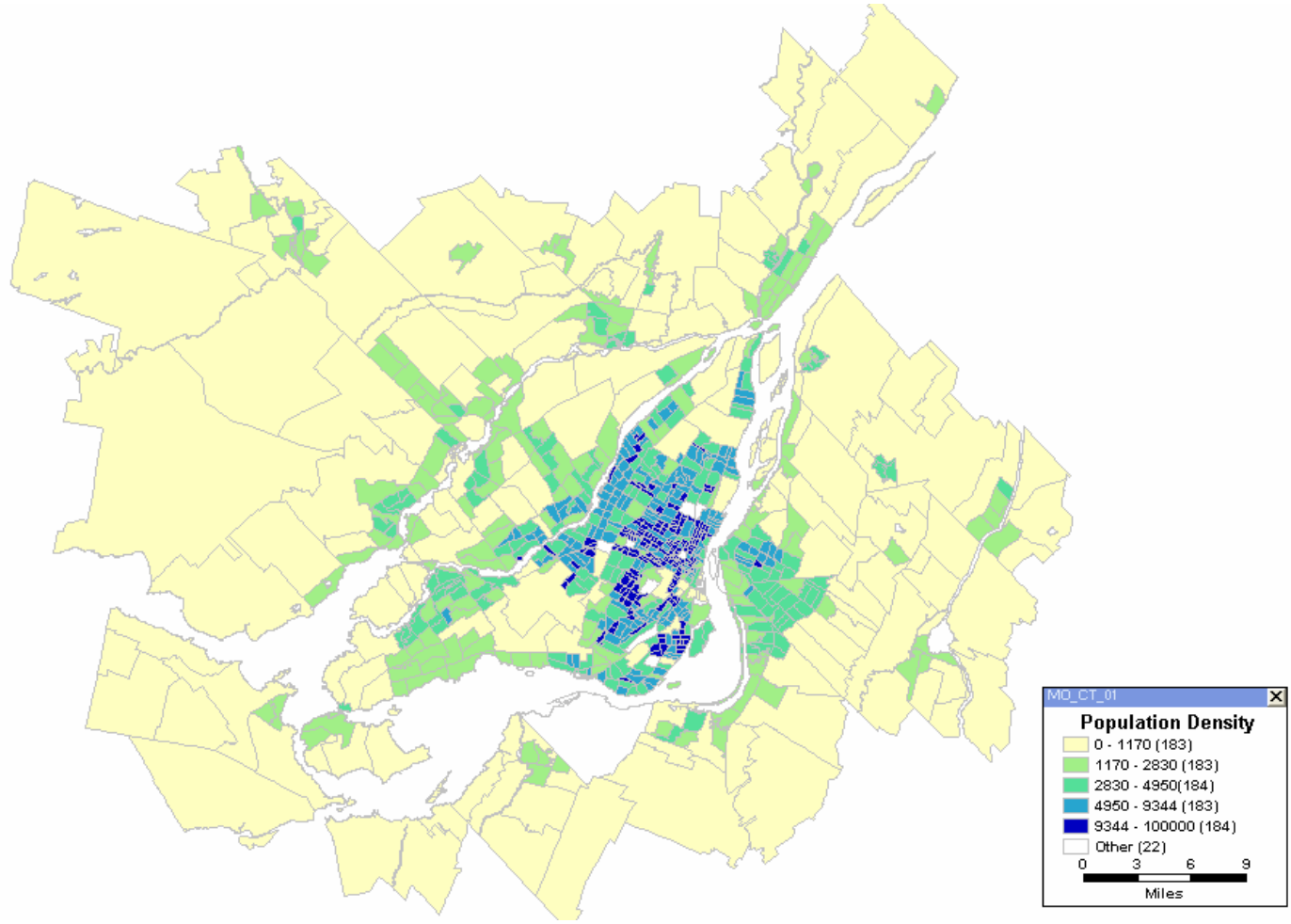
Table 5 – Results for Model 2 (Percentage of Transit Trips)

Trial #	Dependent	Independent	I tstat I	Bo	B	F-stat	Rsquared
1	P_Transit	Population Density	29.3084	0.125097	2.05E-05	858.984	0.4853
2	P_Transit Male	Population Density	29.5356	0.0901408	1.81E-05	872.353	0.4892
3	P_Transit Female	Population Density	26.1994	0.164788	2.30E-05	686.411	0.4297
4	P_Transit	Avg Individual Income	11.1227	0.369888	-4.55E-06	123.714	0.1196
5	P_Transit Male	Avg Male Income	9.73036	0.270047	-2.27E-06	94.6799	0.0941
6	P_Transit Female	Avg Fem Income	12.4575	0.427207	-3.83E-06	155.188	0.1456
7	P_Transit	P_owned	37.5358	0.457583	-0.427426	1408.94	0.6073
8	P_Transit	P_rented	37.4824	0.0303861	0.426965	1404.93	0.6066
9	P_Transit						
10	P_Transit			0.0105107		392.119	0.6333
		P_singdet	0.16272		0.0132724		
		P_semidet+row	2.13807		0.183909		
		P_low rise ap+duplex	4.56674		0.372493		
		P_high rise ap	3.61998		0.300494		
11	P_Transit Male	P_owned	35.4279	0.378614	-0.367429	1255.14	0.5794
12	P_Transit Male	P_rented	35.3852	0.0113736	0.367051	1252.11	0.5788
13	P_Transit Male			1.45304			0.5802
		P_owned	1.69413		-1.44211		
		P_rented	1.26258		-1.0742		
14	P_Transit Male			-0.00477672		308.729	0.5763
		P_singdet	0.239844		0.0185083		
		P_semidet+row	1.57957		0.128544		
		P_low rise ap+duplex	4.07882		0.314759		
		P_high rise ap	3.59707		0.282494		
15	P_Transit Female	P_owned	35.0792	0.546283	-0.495833	1230.55	0.5746

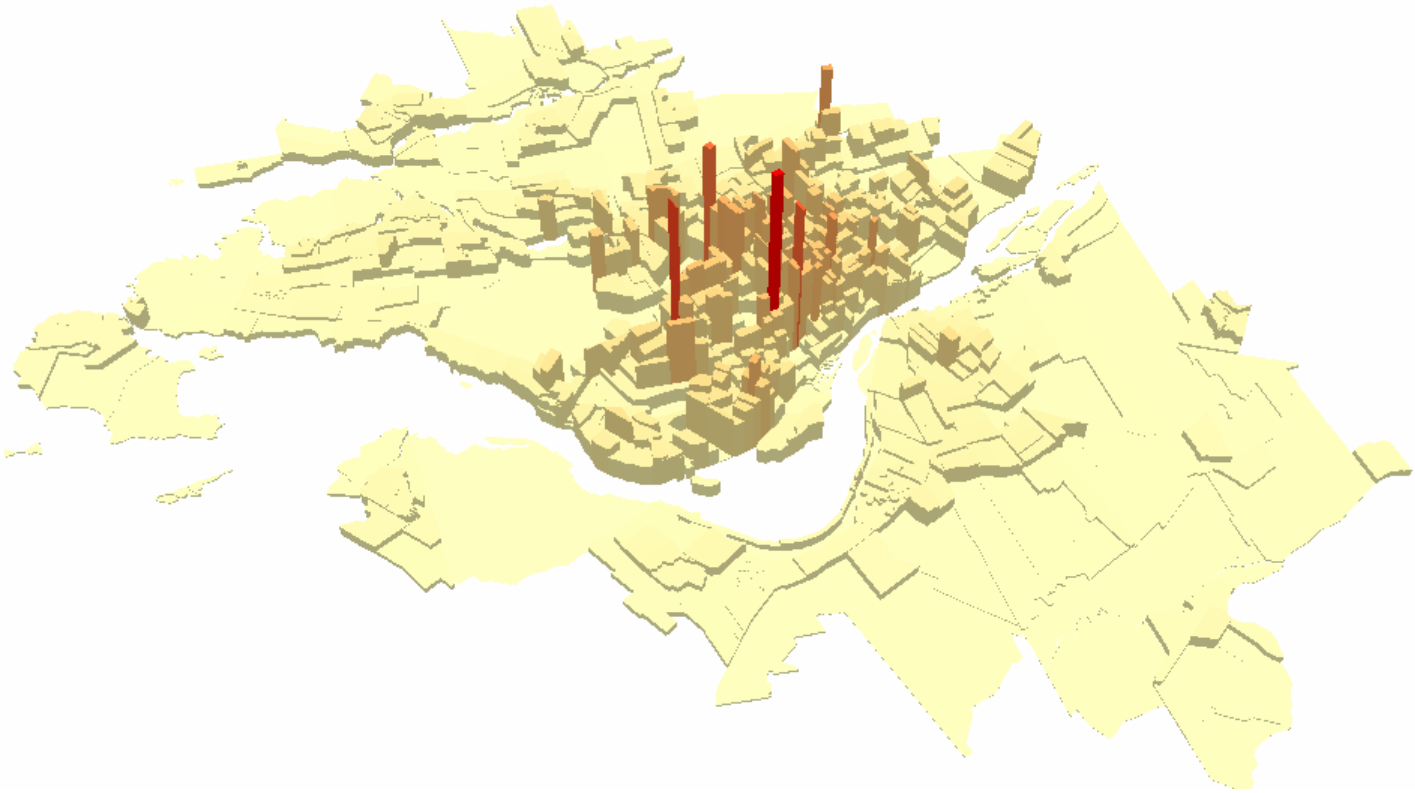
16	P_Transit Female	P_rented	35.0267	0.0507356	0.495258	1226.87	0.5739
17	P_Transit Female						
		P_owned			-		
		P_rented			-		
18	P_Transit Female			0.0478747		363.848	0.6158
		P_singdet	0.112628		-0.011215		
		P_semidet+row	2.04984		0.215251		
		P_low rise ap+duplex	4.16499		0.414735		
		P_high rise ap	3.0703		0.31114		
19	P_Transit			0.195497		473.262	0.5098
		Population Density	26.9175		1.92E-05		
		Avg Individual Income	6.74842		-2.15E-06		
20	P_Transit Male			0.124861		456.552	0.5009
		Population Density	27.2299		1.73E-05		
		Avg Male Income	4.61588		-8.37E-07		
21	P_Transit Female			0.284215		381.877	0.4563
		Population Density	25.0391		2.19E-05		
		Avg Female Income	6.67373		-4.91E-06		
22	P_Transit			0.354546		562.01	0.6497
		Population Density	10.4861		8.58801E-06		
		Avg Individual Income	0.364269		-1.05E-07		
		P_owned	19.0523		-3.12E-01		
23	P_Transit Male			0.272113		520.576	0.6321
		Population Density	11.2611		8.31E-06		
		Avg Male Income	1.37406		2.29E-07		
		P_owned	18.0072		-0.264604		
24	P_Transit Female			0.45887		462.011	0.6039
		Population Density	8.18498		8.53E-06		
		Avg Female Income	1.34791		-8.96E-07		
		P_owned	18.406		-0.376277		
25	P_Transit			0.0425912		561.056	0.6493
		Population Density	10.5168		8.61E-06		
		Avg Individual Income	0.378182		-1.10E-07		
		P_rented	19.0154		0.311544		

26	P_Transit Male			0.00772603		519.886	0.6318
		Population Density	11.2884		8.33E-06		
		Avg Male Income	1.36599		2.28E-07		
		P_rented	17.9785		0.264034		
27	P_Transit Female			0.0831972		461.134	0.6035
		Population Density	8.21784		8.56E-06		
		Avg Female Income	1.36671		-9.09E-07		
		P_rented	18.3671		0.375262		
28	P_Transit			0.0495322		326.579	0.6838
		Population Density	11.774		9.15E-06		
		Avg Individual Income	1.5872		-4.56E-07		
		P_singdet	0.122618		-0.00931717		
		P_semidet+row	2.21043		0.178103		
		P_low rise ap+duplex	3.36905		0.257578		
		P_high rise ap	2.04457		0.160611		
29	P_Transit Male			0.0243318		268.32	0.6399
		Population Density	12.6357		9.22E-06		
		Avg Male Income	0.324888		5.59E-08		
		P_singdet	0.171231		-0.012228		
		P_semidet+row	1.37676		0.104263		
		P_low rise ap+duplex	2.76597		0.198646		
		P_high rise ap	1.74962		0.129141		
30	P_Transit Female			0.121682		285.901	0.6544
		Population Density	8.98311		8.70E-06		
		Avg Female Income	3.89555		-2.56E-06		
		P_singdet	0.239798		-0.0227083		
		P_semidet+row	2.44563		0.246032		
		P_low rise ap+duplex	3.23012		0.30795		
		P_high rise ap	2.08906		0.20489		

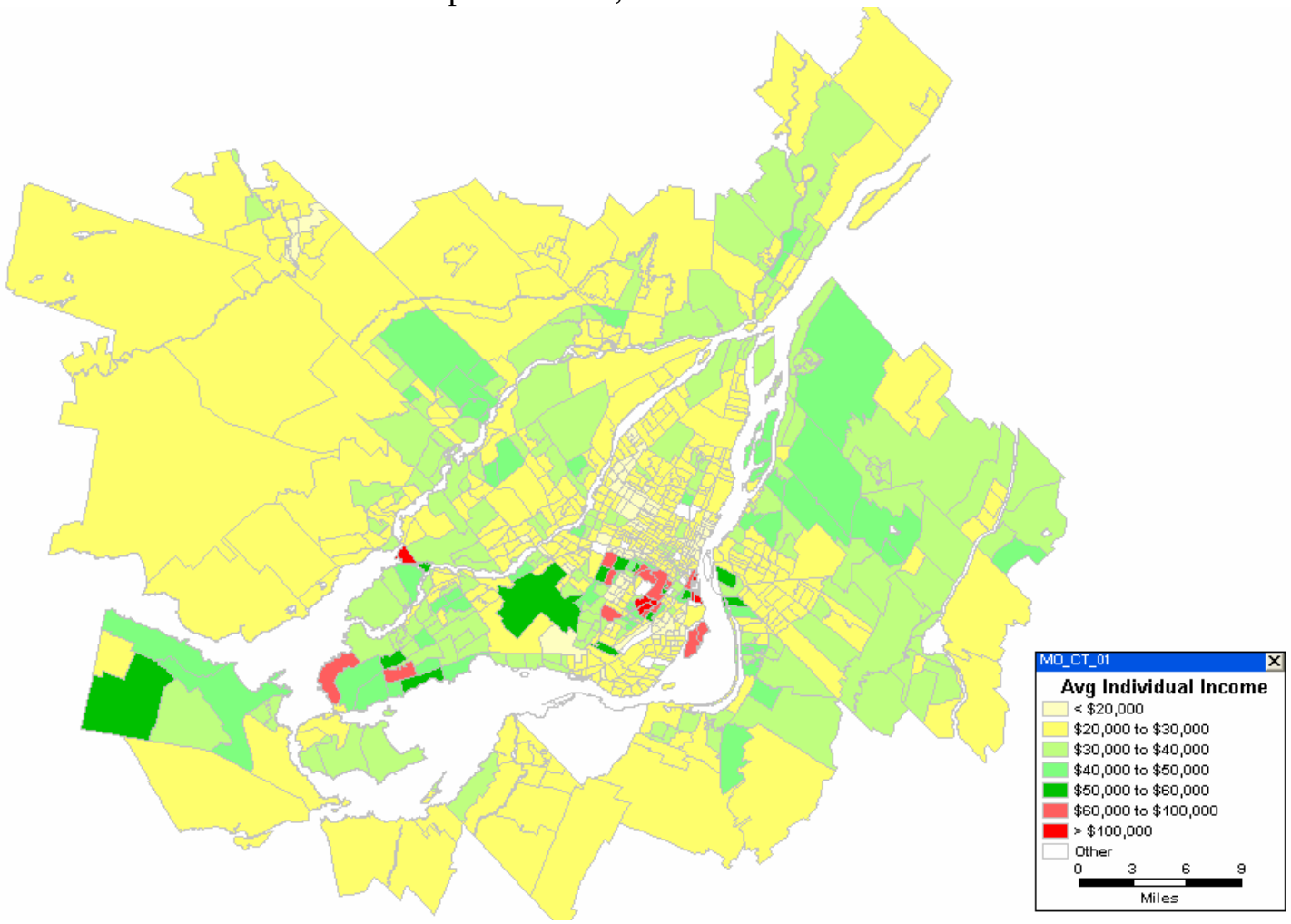
Map 1 – Population Density (persons per square Km)
Montreal Census Metropolitan Data, 2001



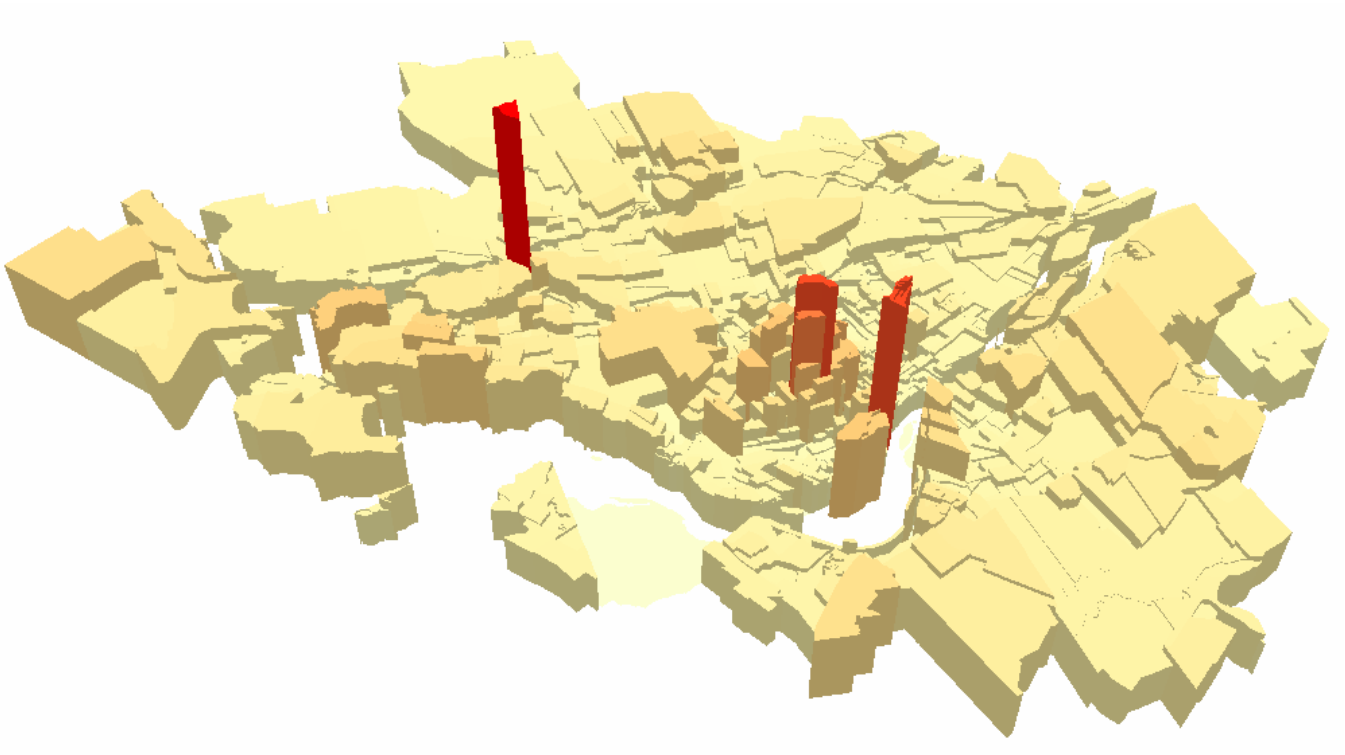
Map 2 – Population Density Prism Map
Montreal Census Metropolitan Data, 2001



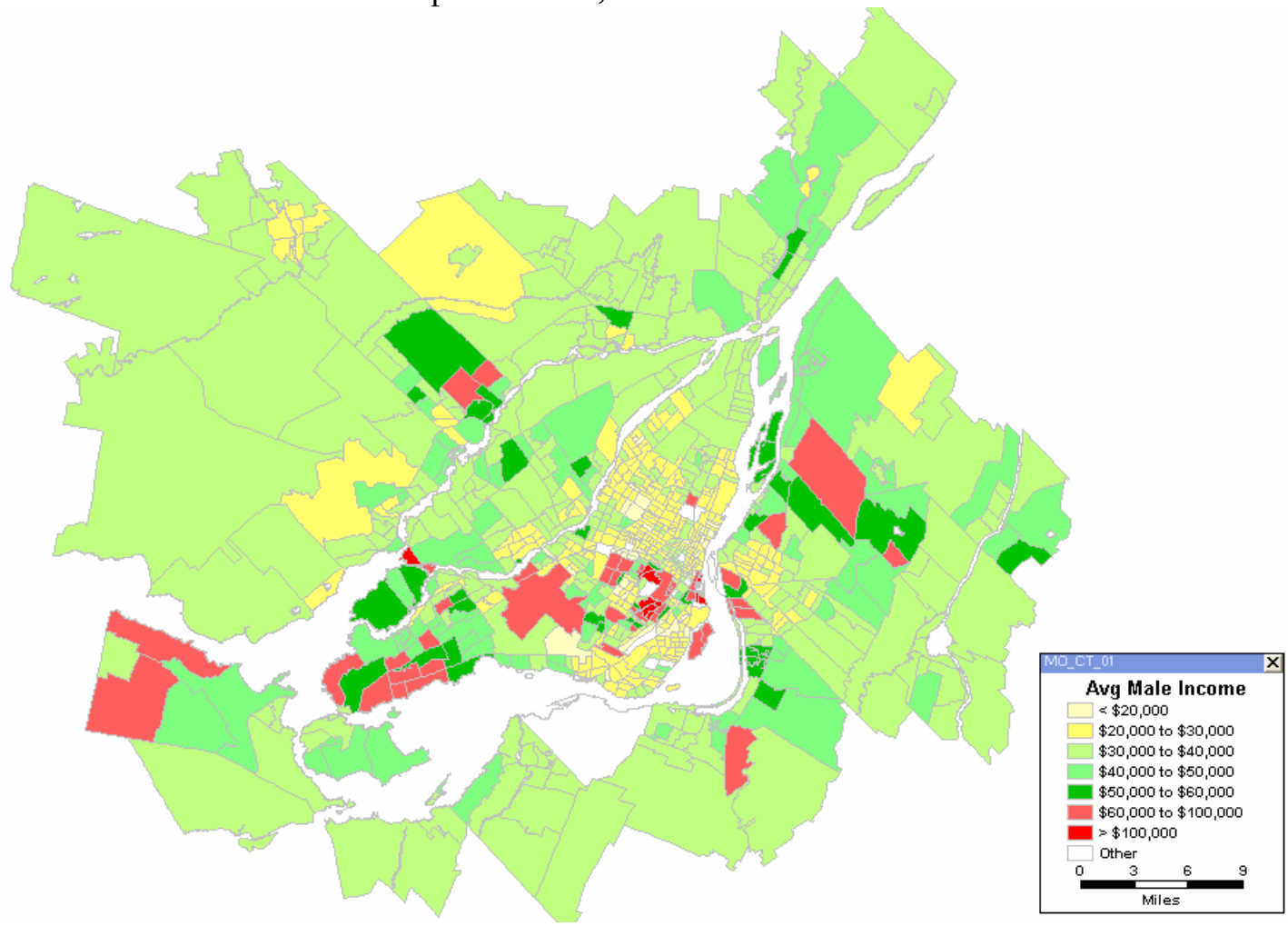
Map 3 – Average Individual Income ($)
Montreal Census Metropolitan Data, 2001



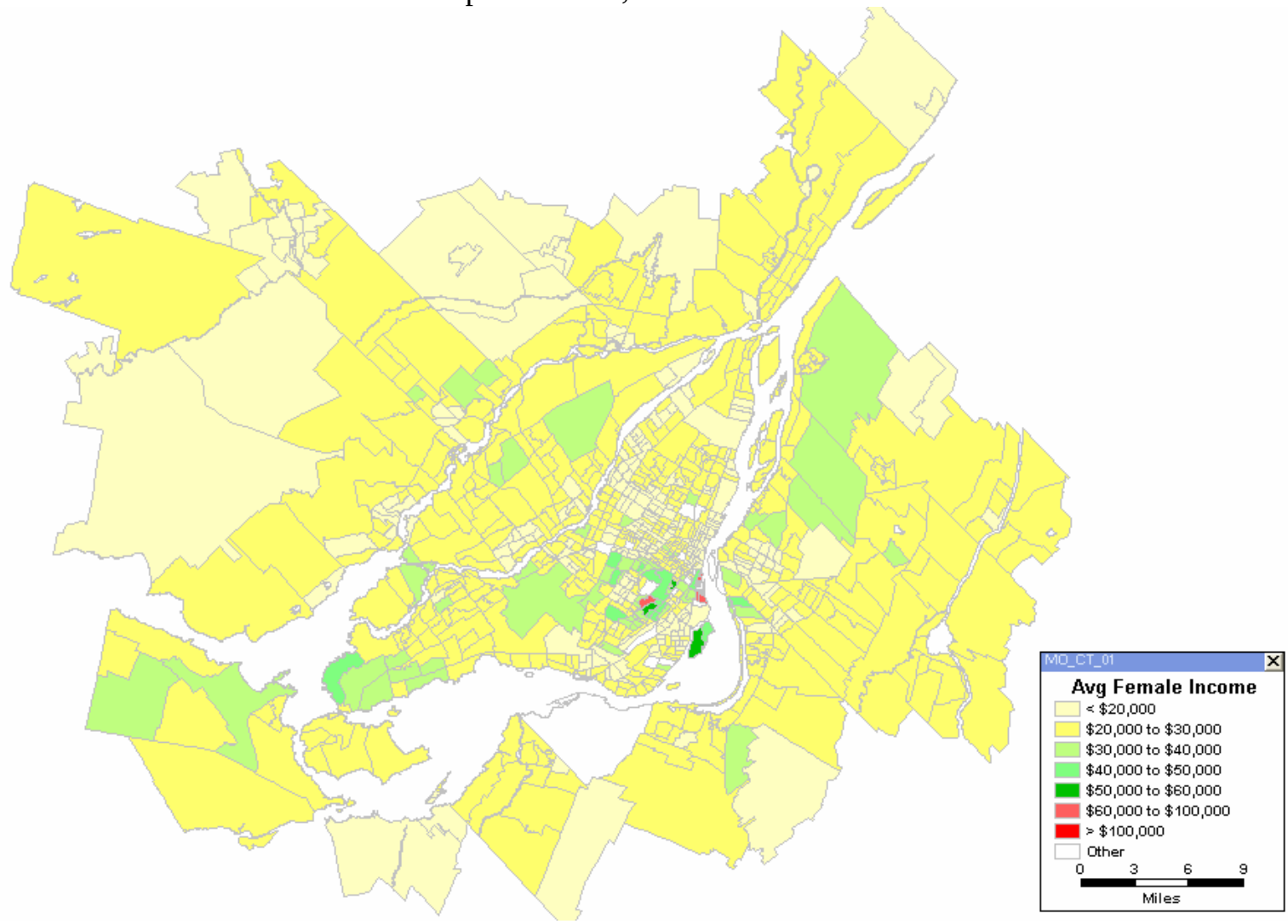
Map 4 – Average Individual Income Prism Map
Montreal Census Metropolitan Data, 2001



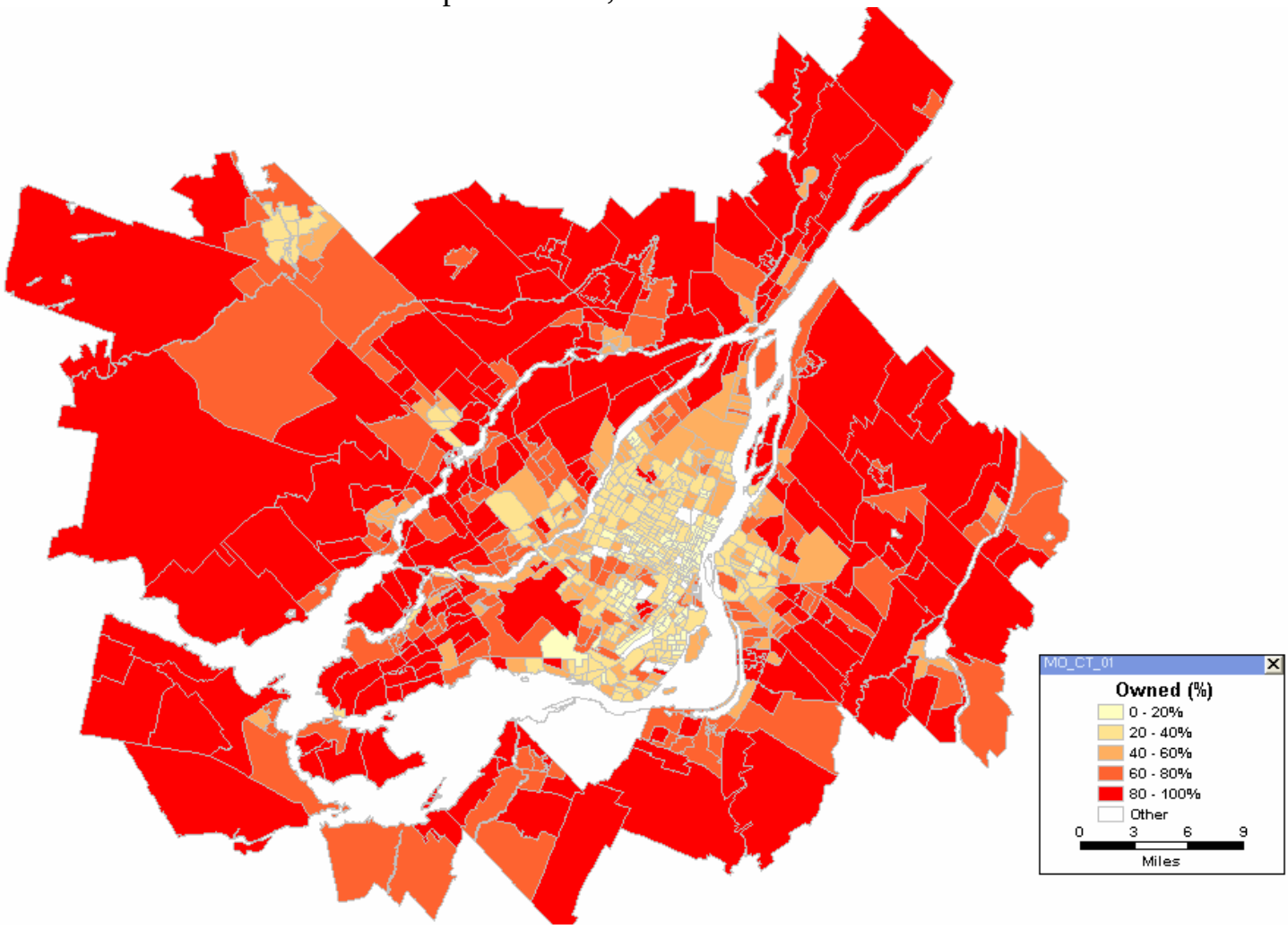
Map 5 – Average Male Income ($)
Montreal Census Metropolitan Data, 2001



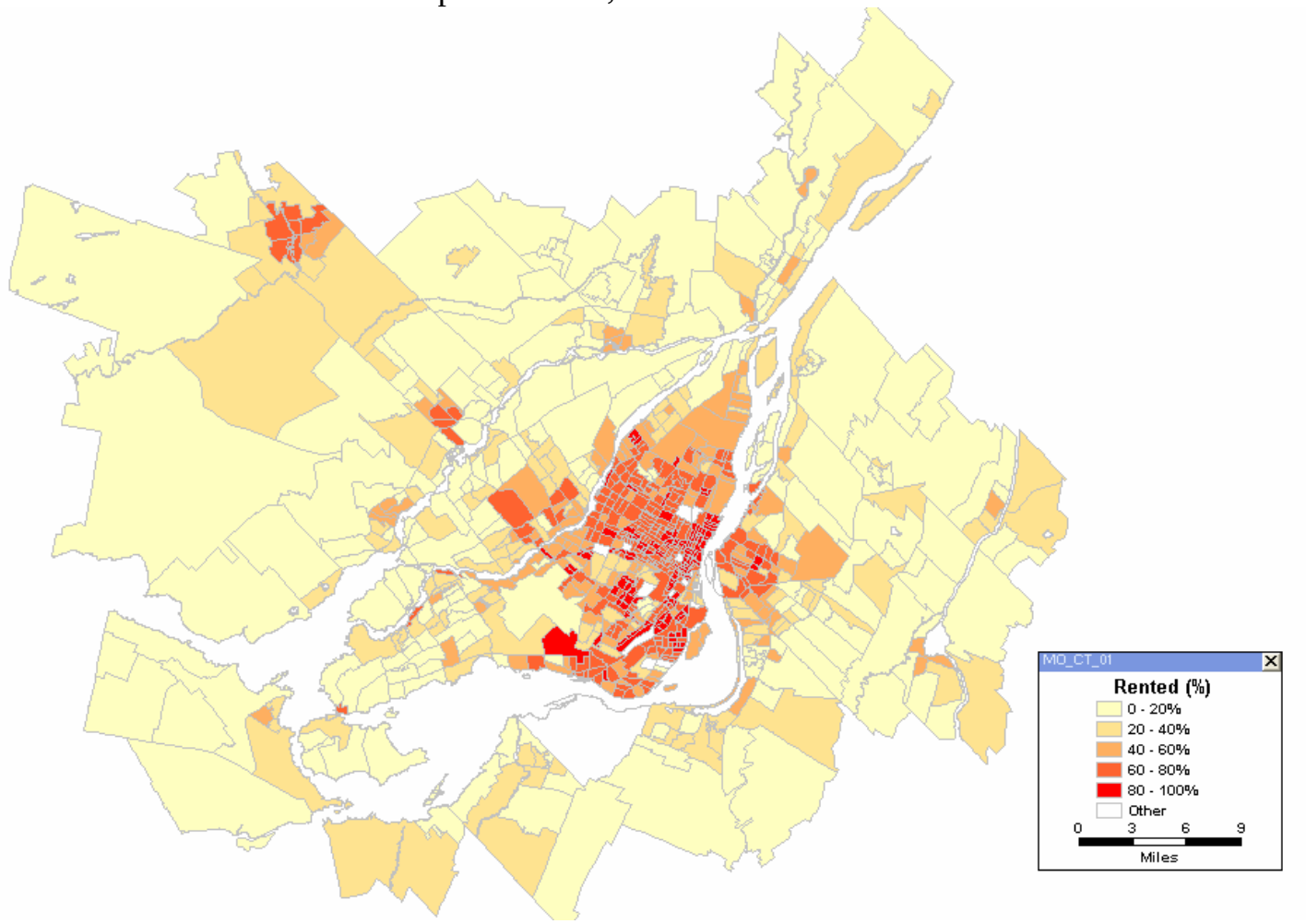
Map 6 – Average Female Income ($)
Montreal Census Metropolitan Data, 2001



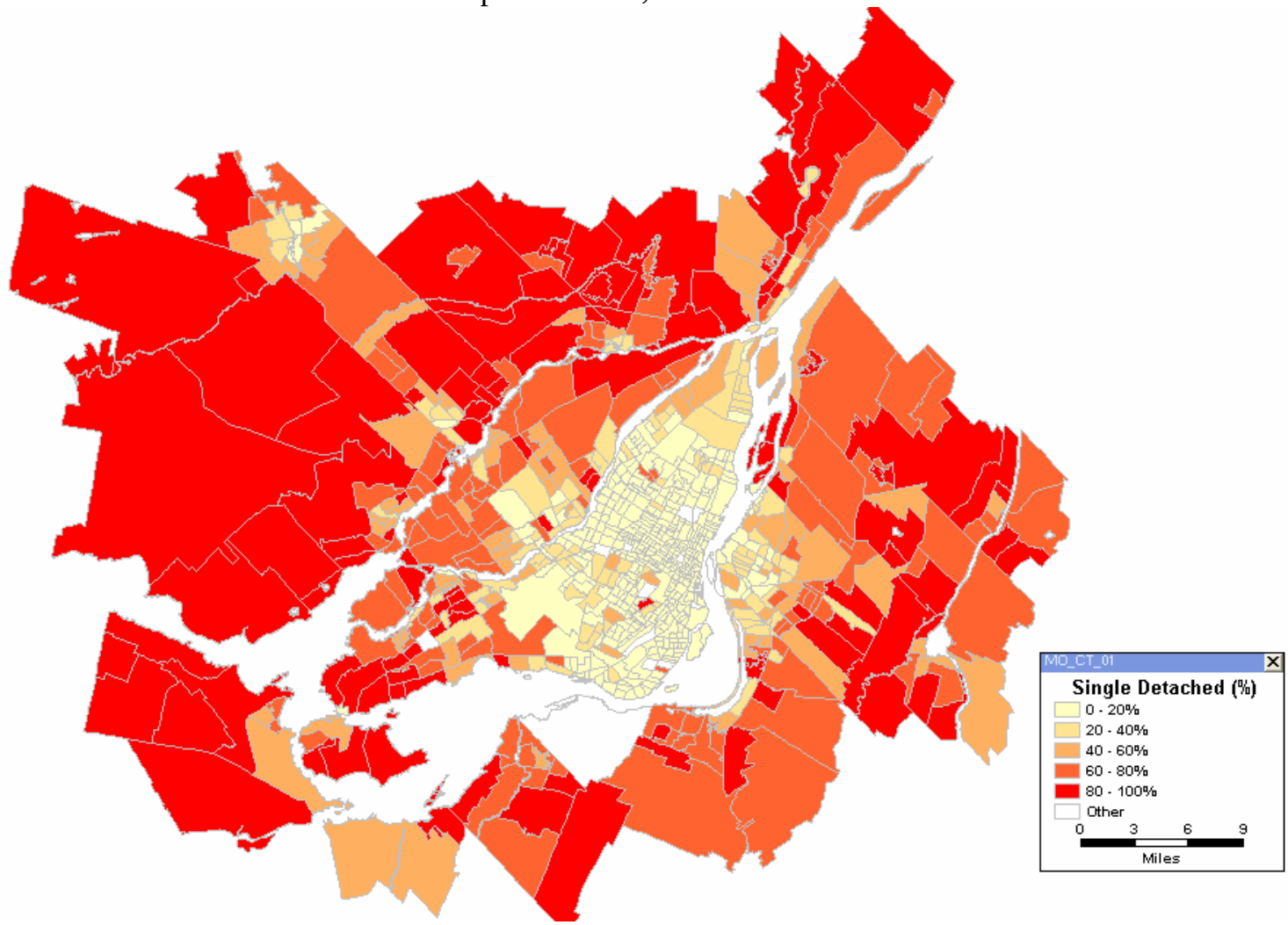
Map 7 – Owned Dwellings (%)
Montreal Census Metropolitan Data, 2001



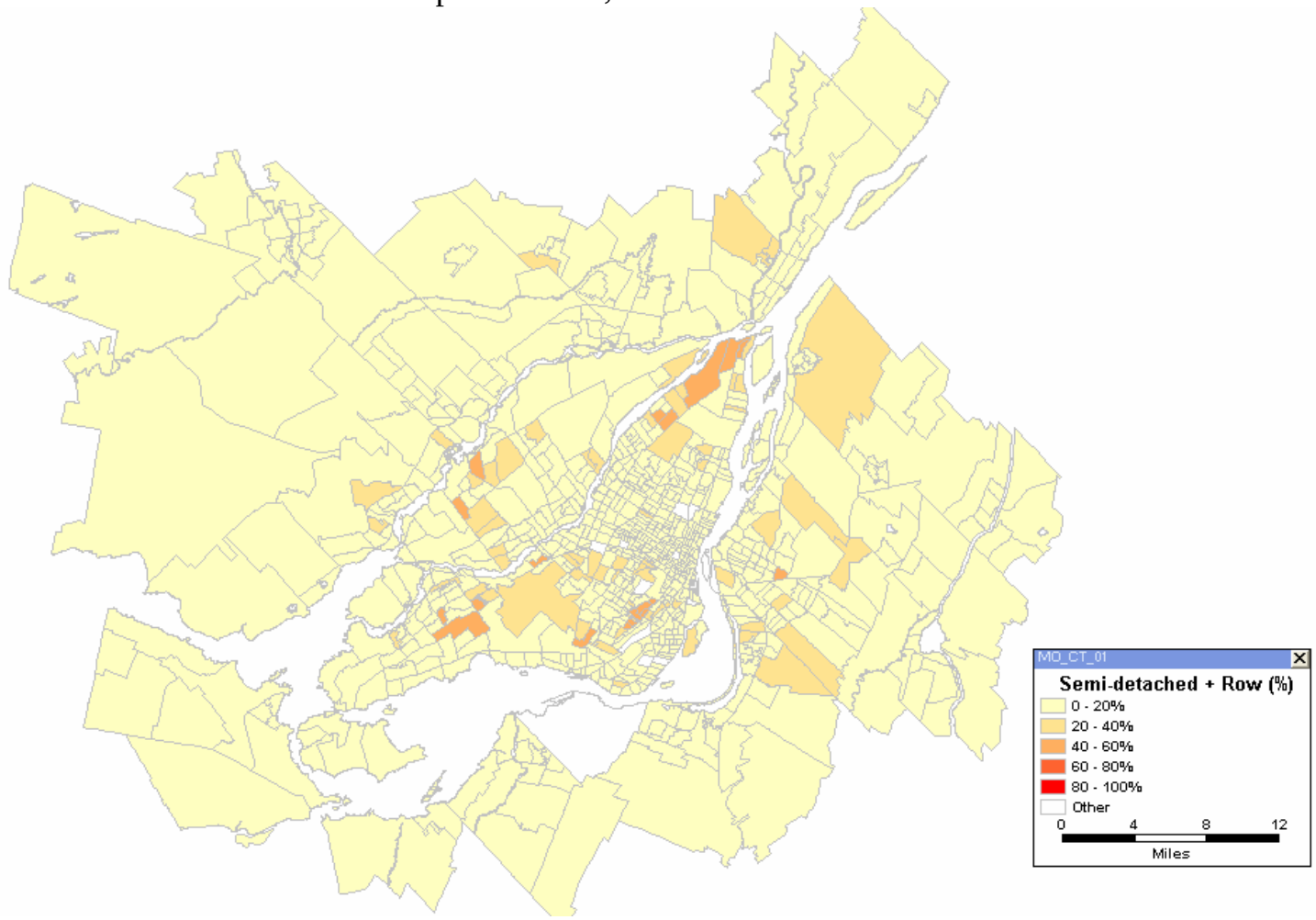
Map 8 – Rented Dwellings (%)
Montreal Census Metropolitan Data, 2001



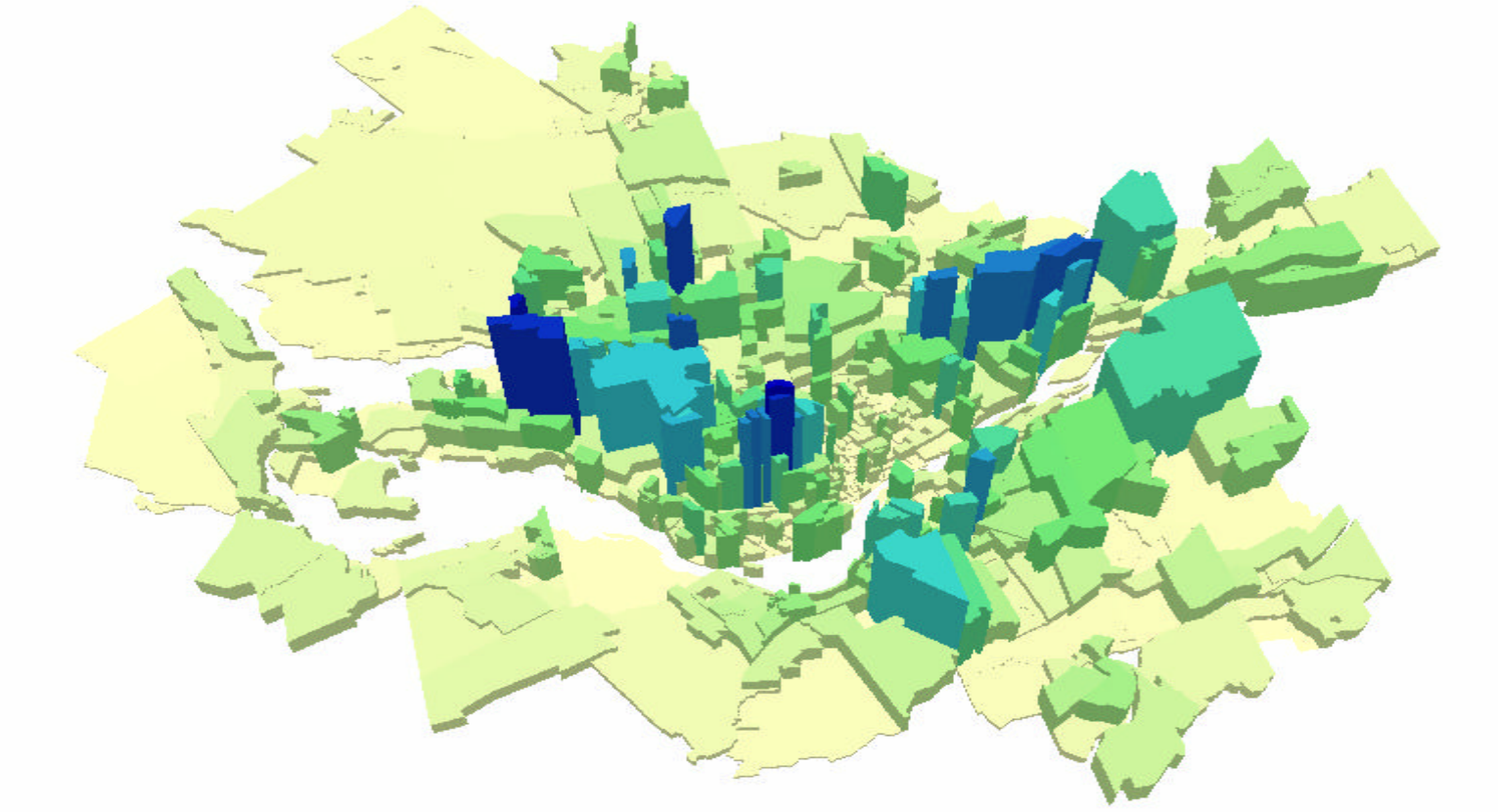
Map 9 – Single Detached (%)
Montreal Census Metropolitan Data, 2001



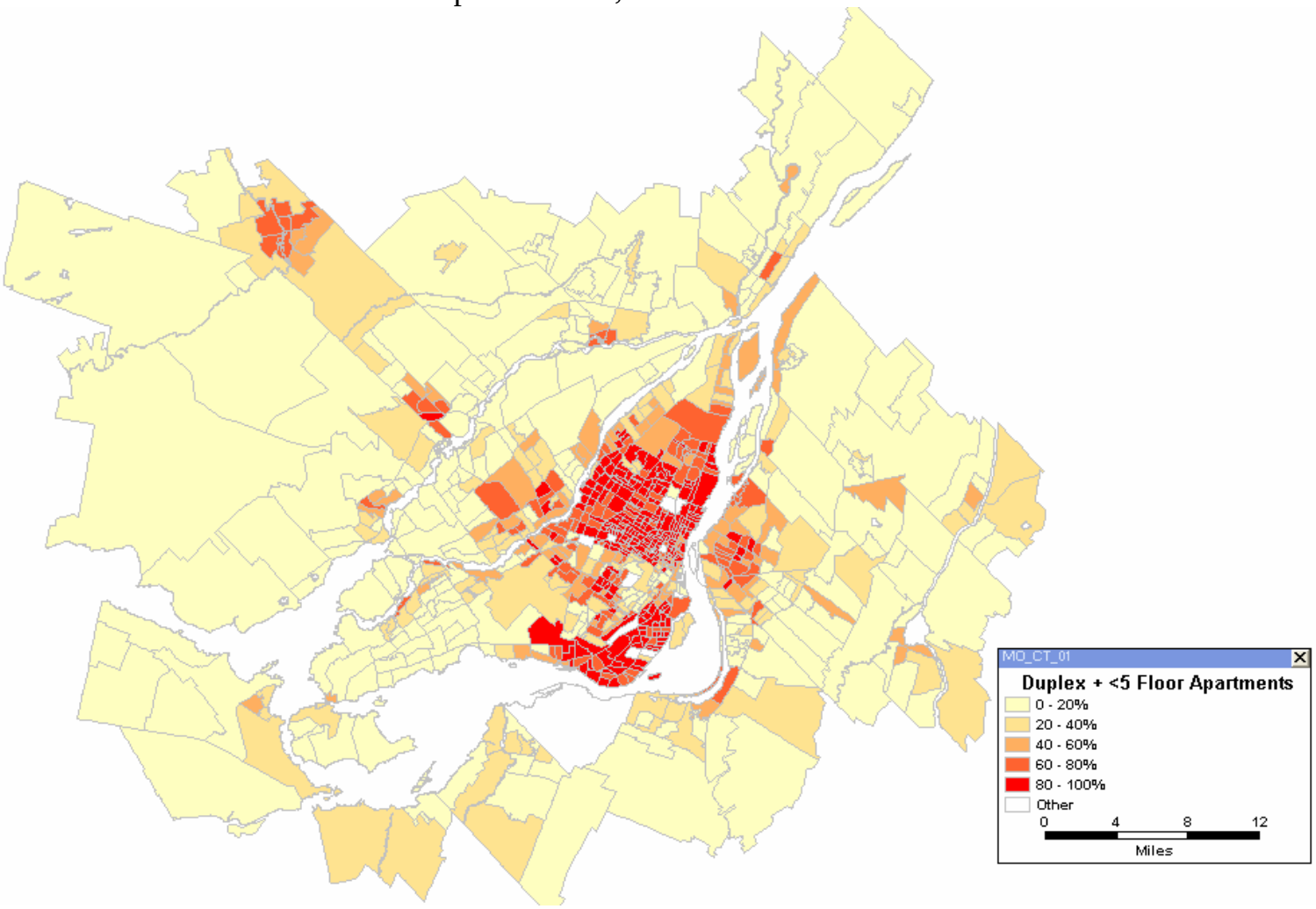
Map 10 – Semi-Detached + Row Housing (%)
Montreal Census Metropolitan Data, 2001



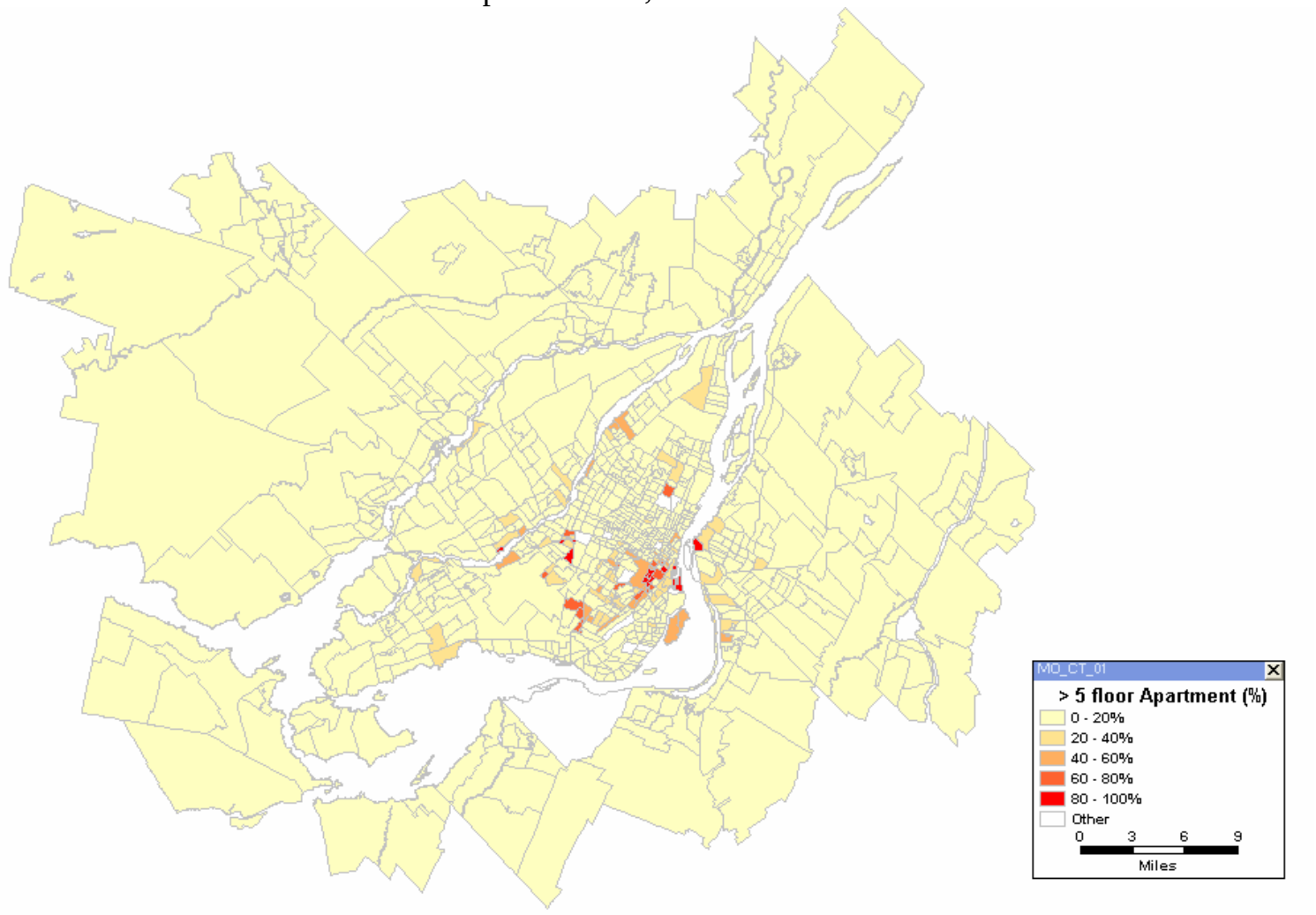
Map 11 – Semi-Detached + Row Housing Prism Map
Montreal Census Metropolitan Data, 2001



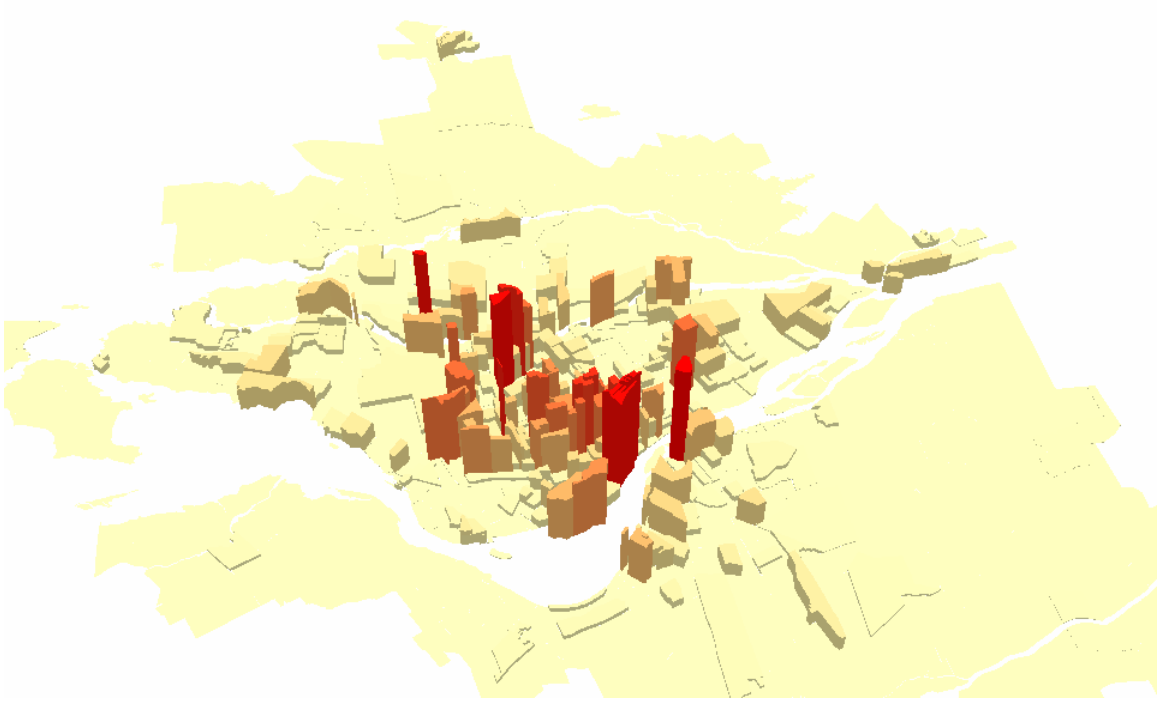
Map 12 – Duplex + <5 floor apartments (%)
Montreal Census Metropolitan Data, 2001



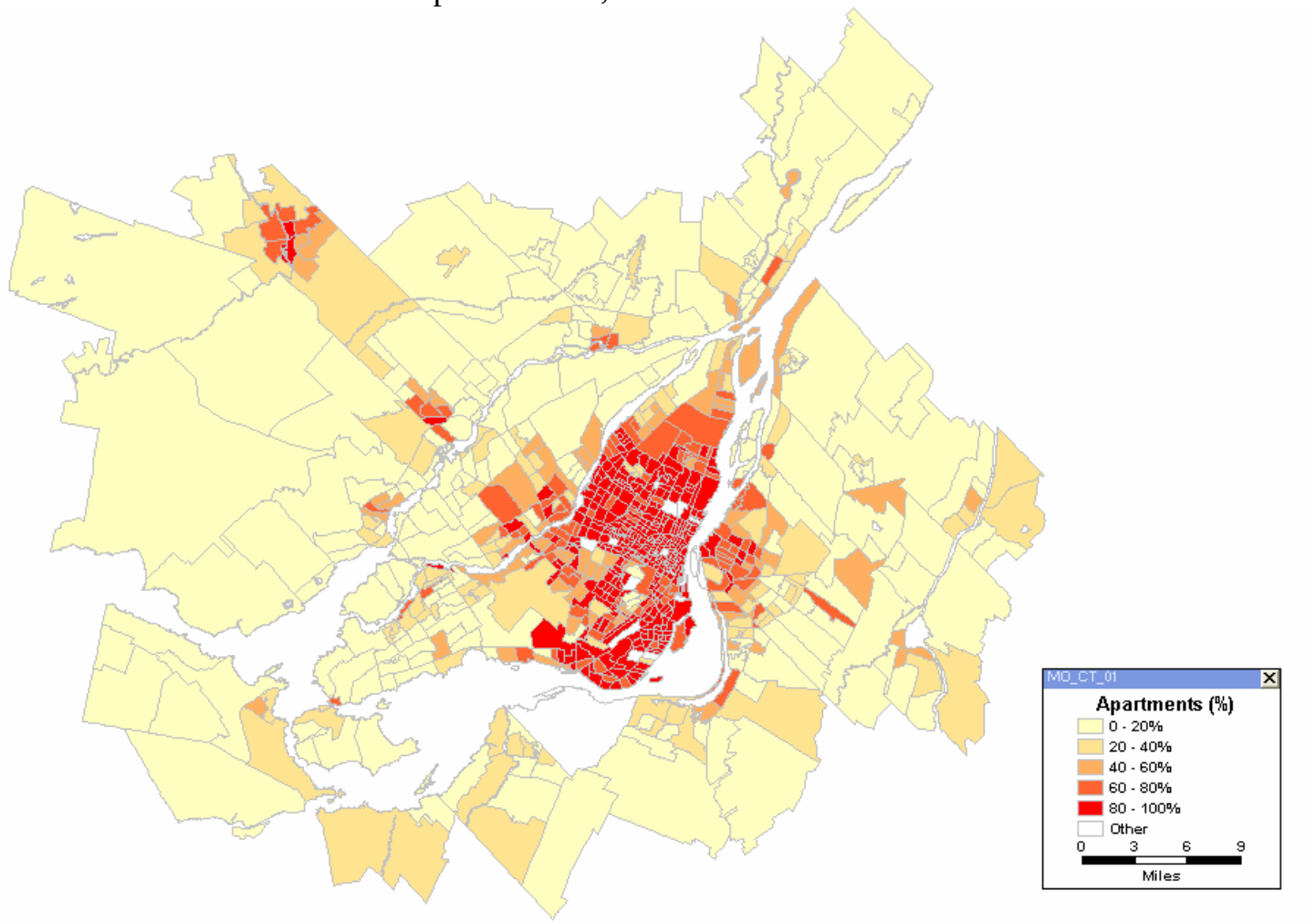
Map 13 – >5 floor apartments (%)
Montreal Census Metropolitan Data, 2001



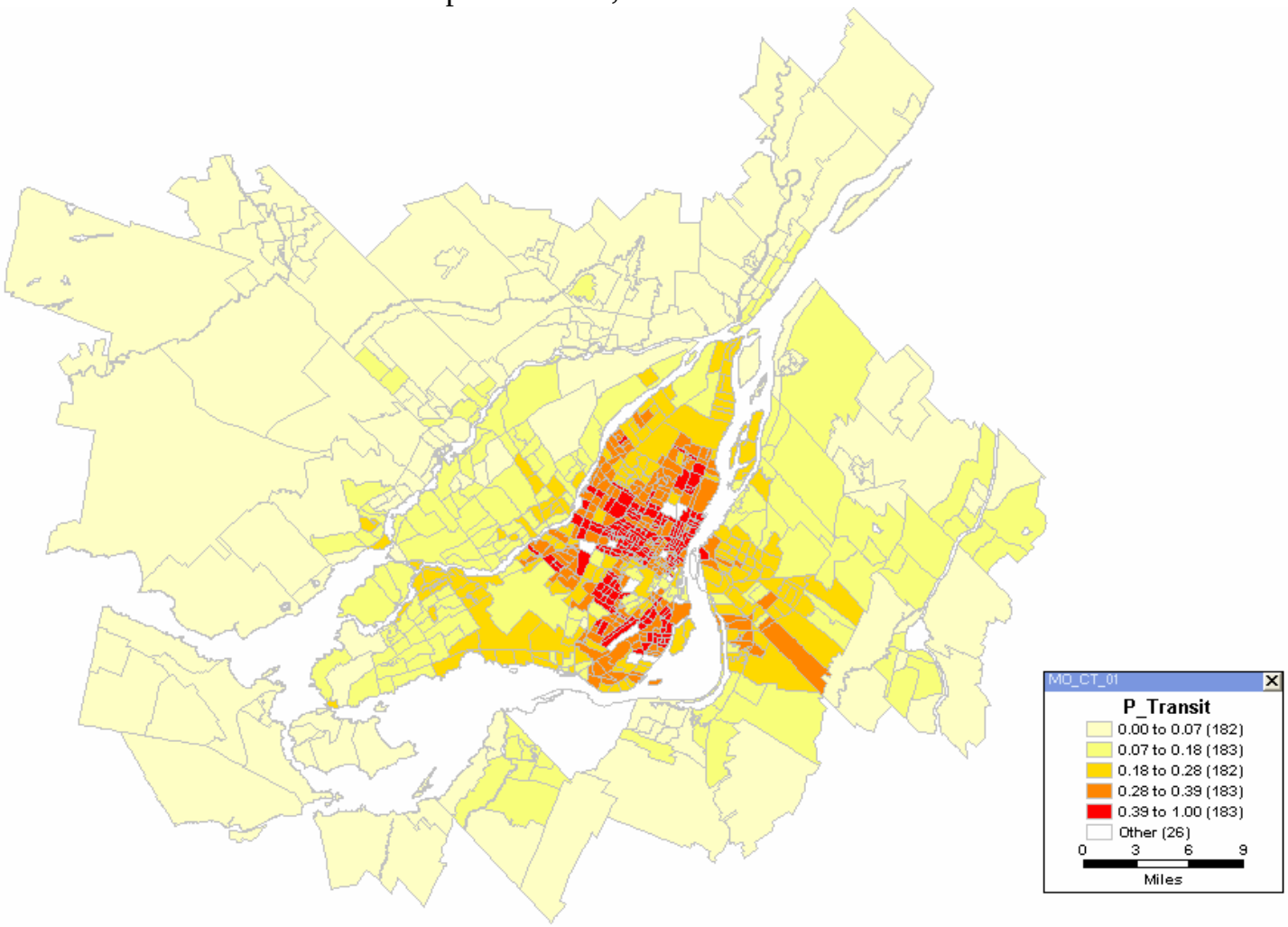
Map 14 – >5 floor apartments Prism Map (%)
Montreal Census Metropolitan Data, 2001



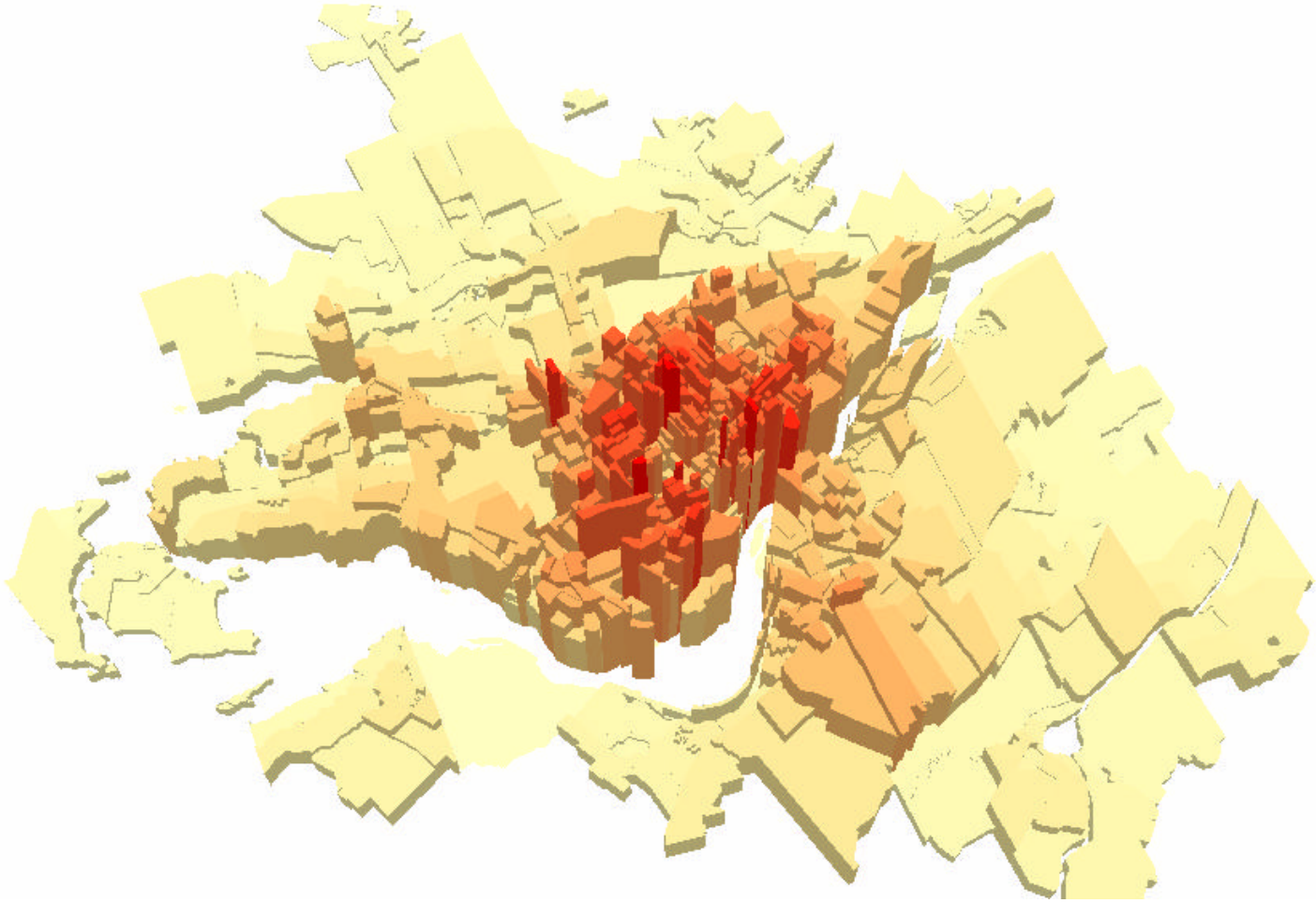
Map 15 – Apartments (all types) (%)
Montreal Census Metropolitan Data, 2001



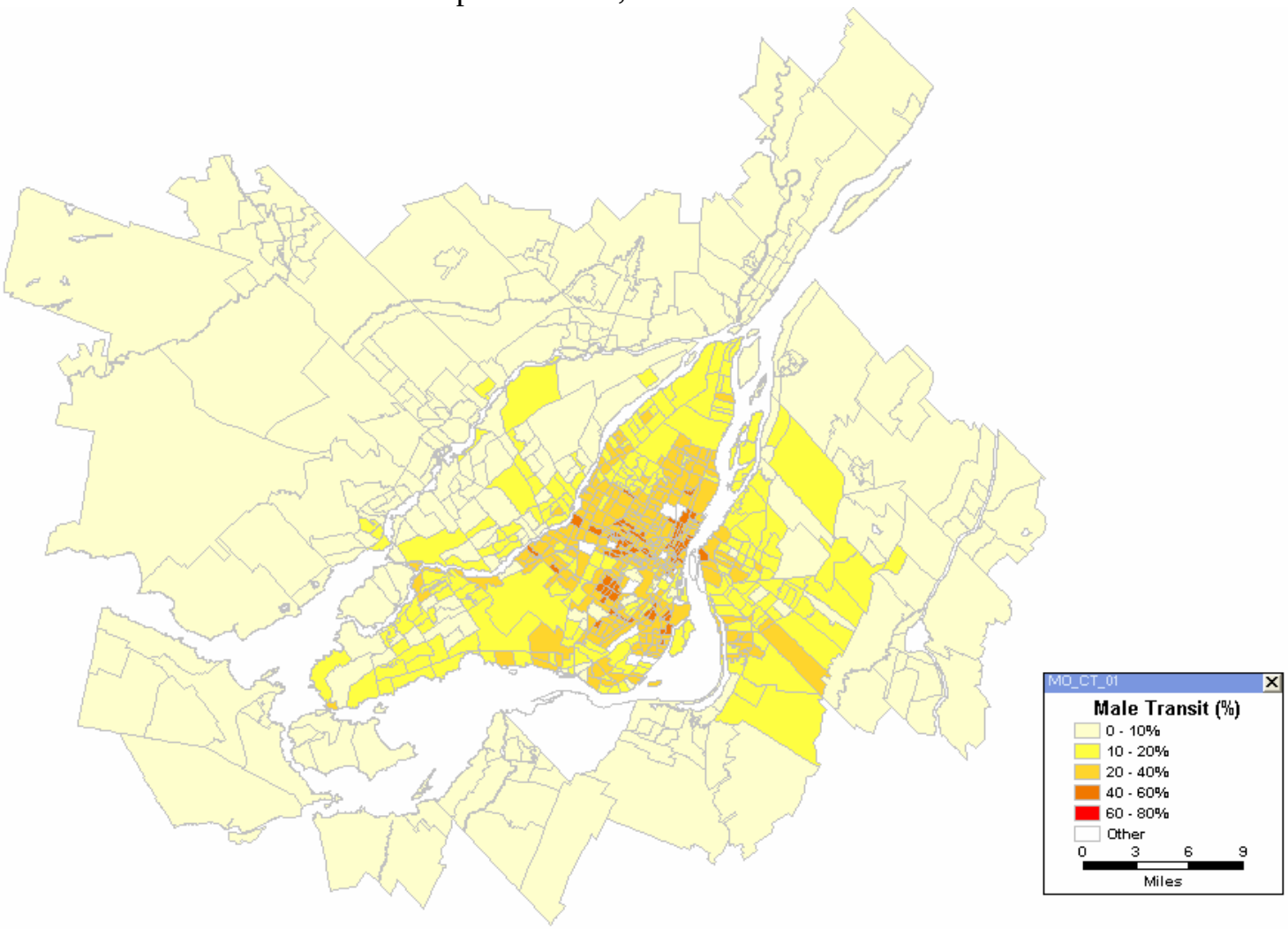
Map 16 – Transit Trips (%)
Montreal Census Metropolitan Data, 2001



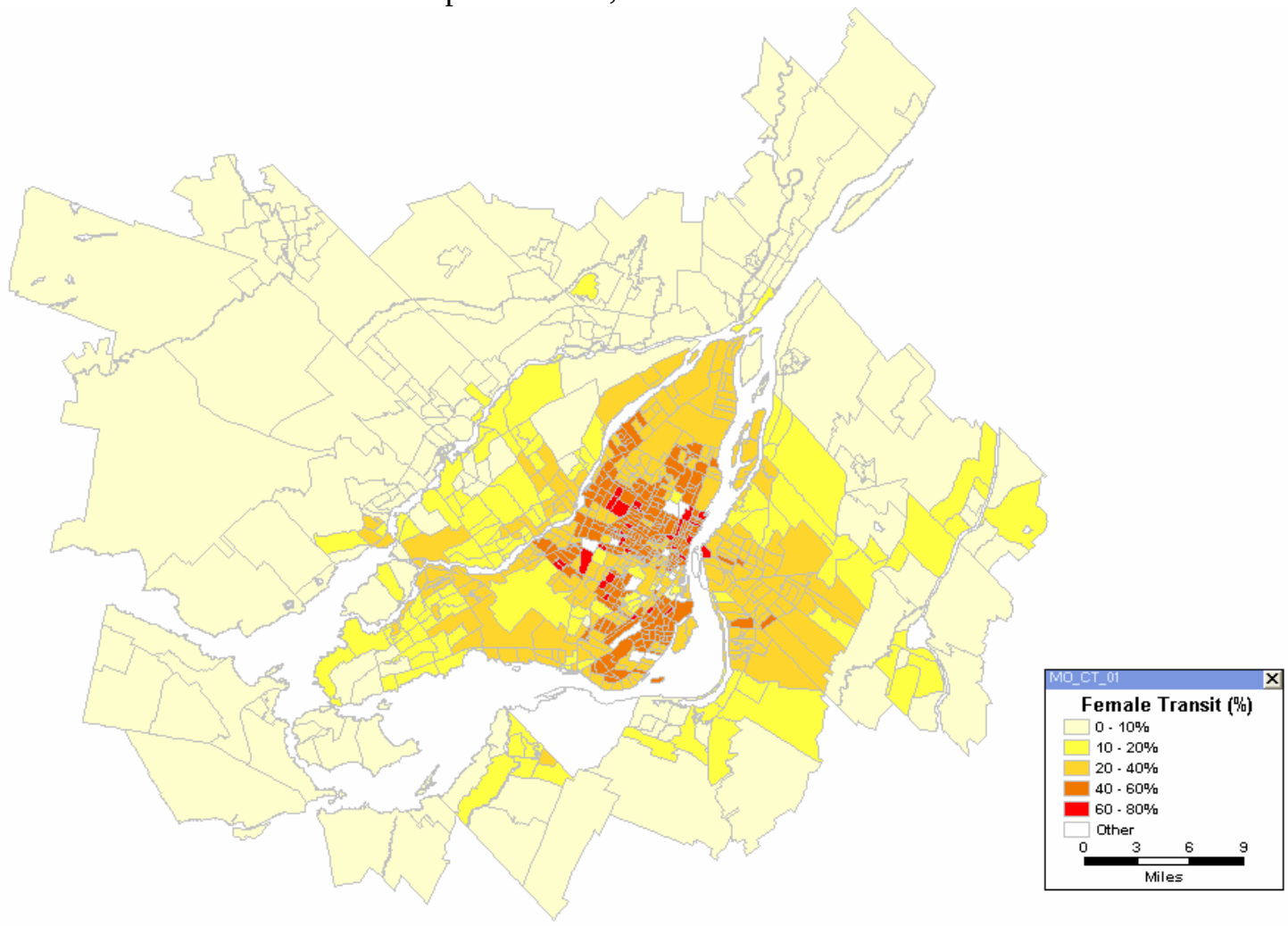
Map 17 – Transit Use Prism Map
Montreal Census Metropolitan Data, 2001



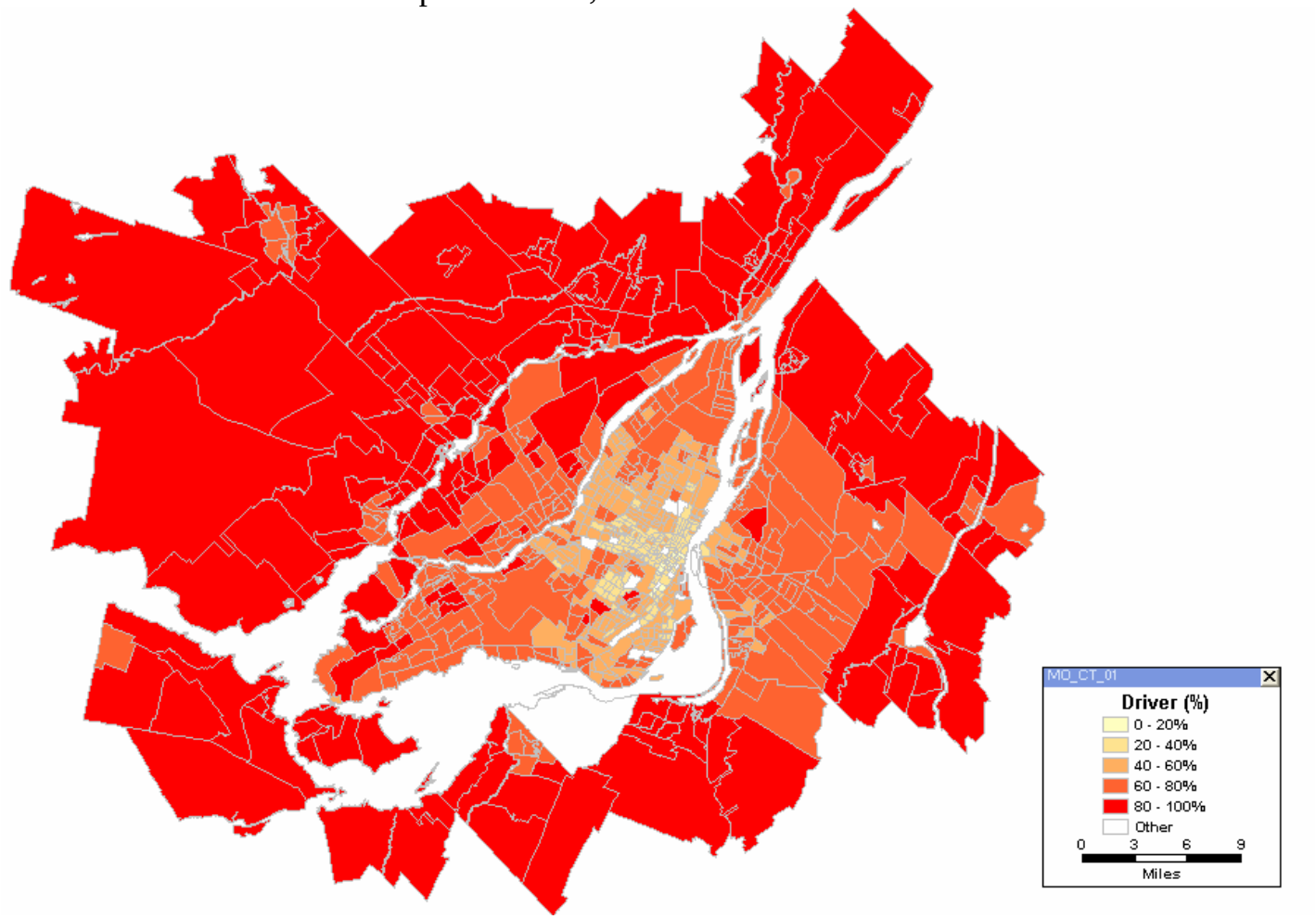
Map 18 – Male Transit Trips (%)
Montreal Census Metropolitan Data, 2001



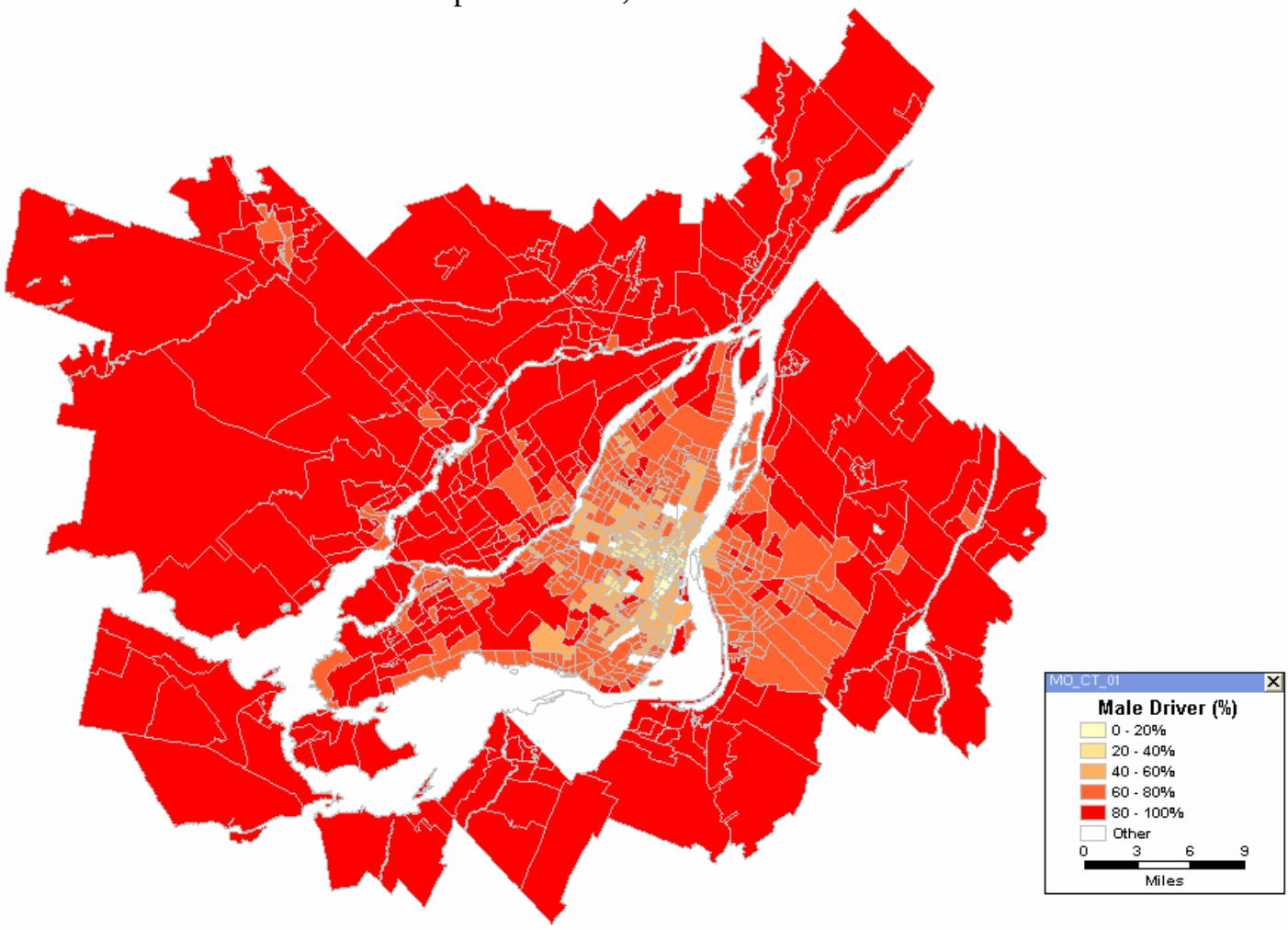
Map 19 – Female Transit Trips (%)
Montreal Census Metropolitan Data, 2001



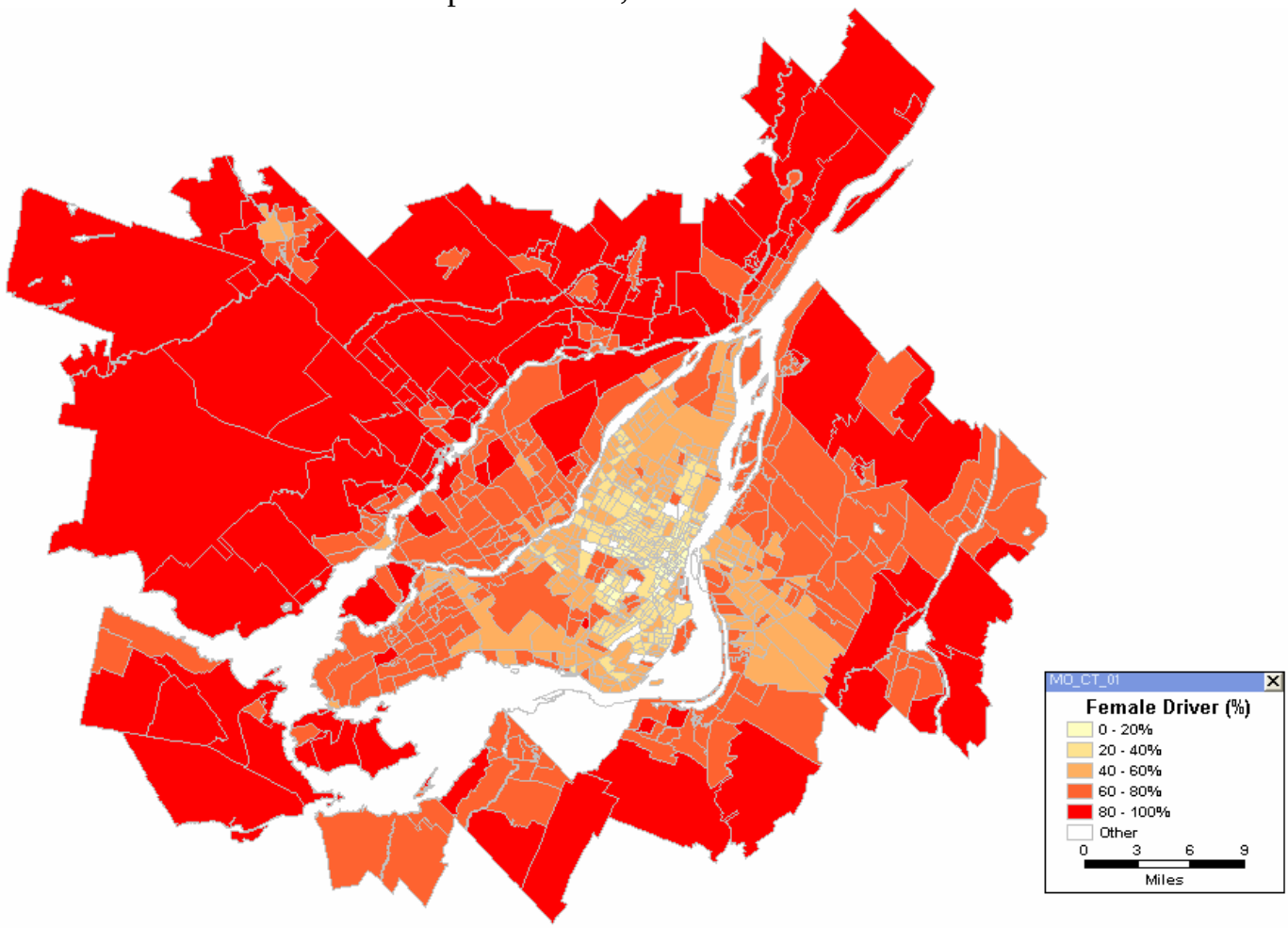
Map 20 – Driver Trips (%)
Montreal Census Metropolitan Data, 2001



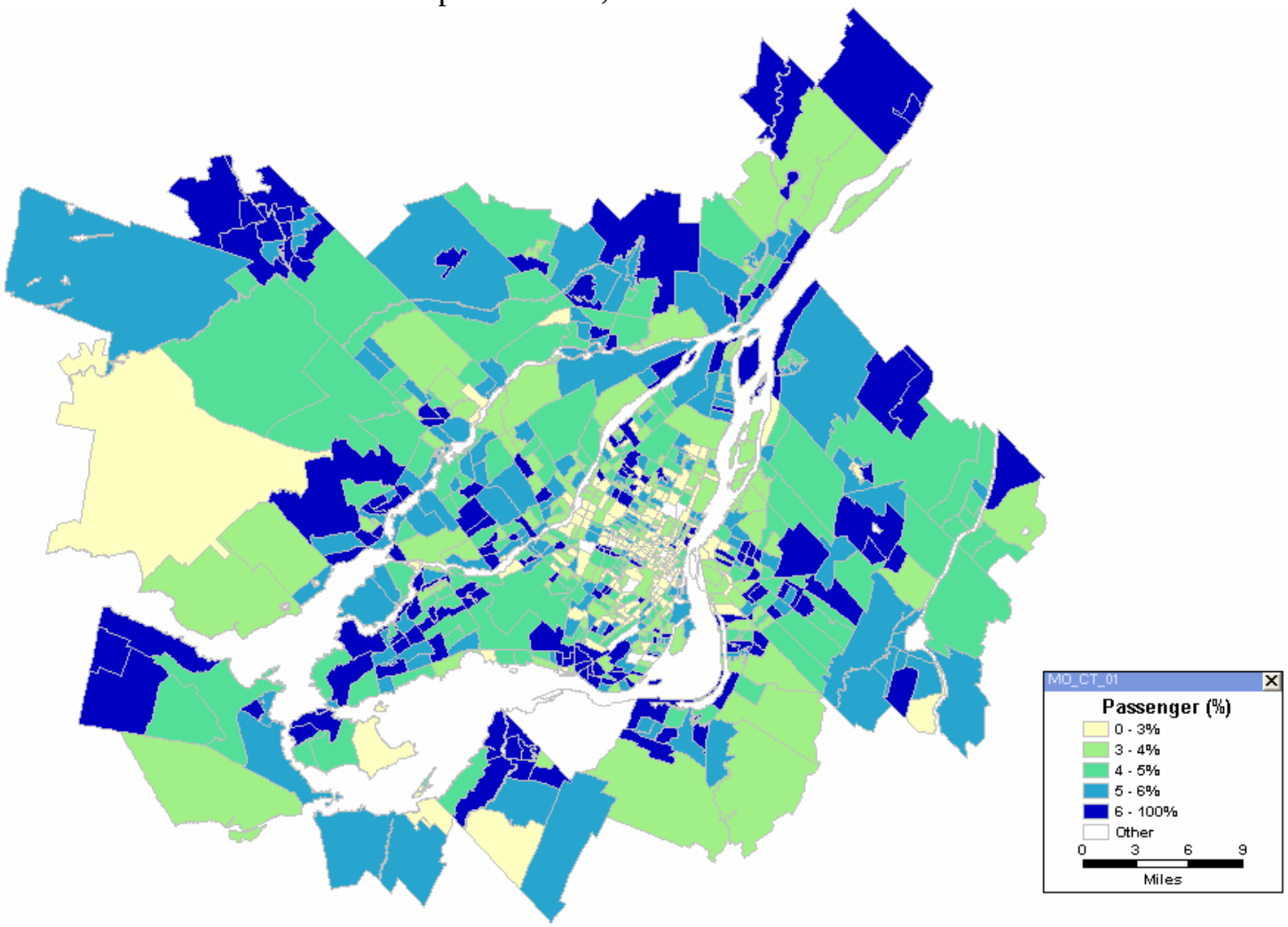
Map 21 – Male Driver Trips (%)
Montreal Census Metropolitan Data, 2001



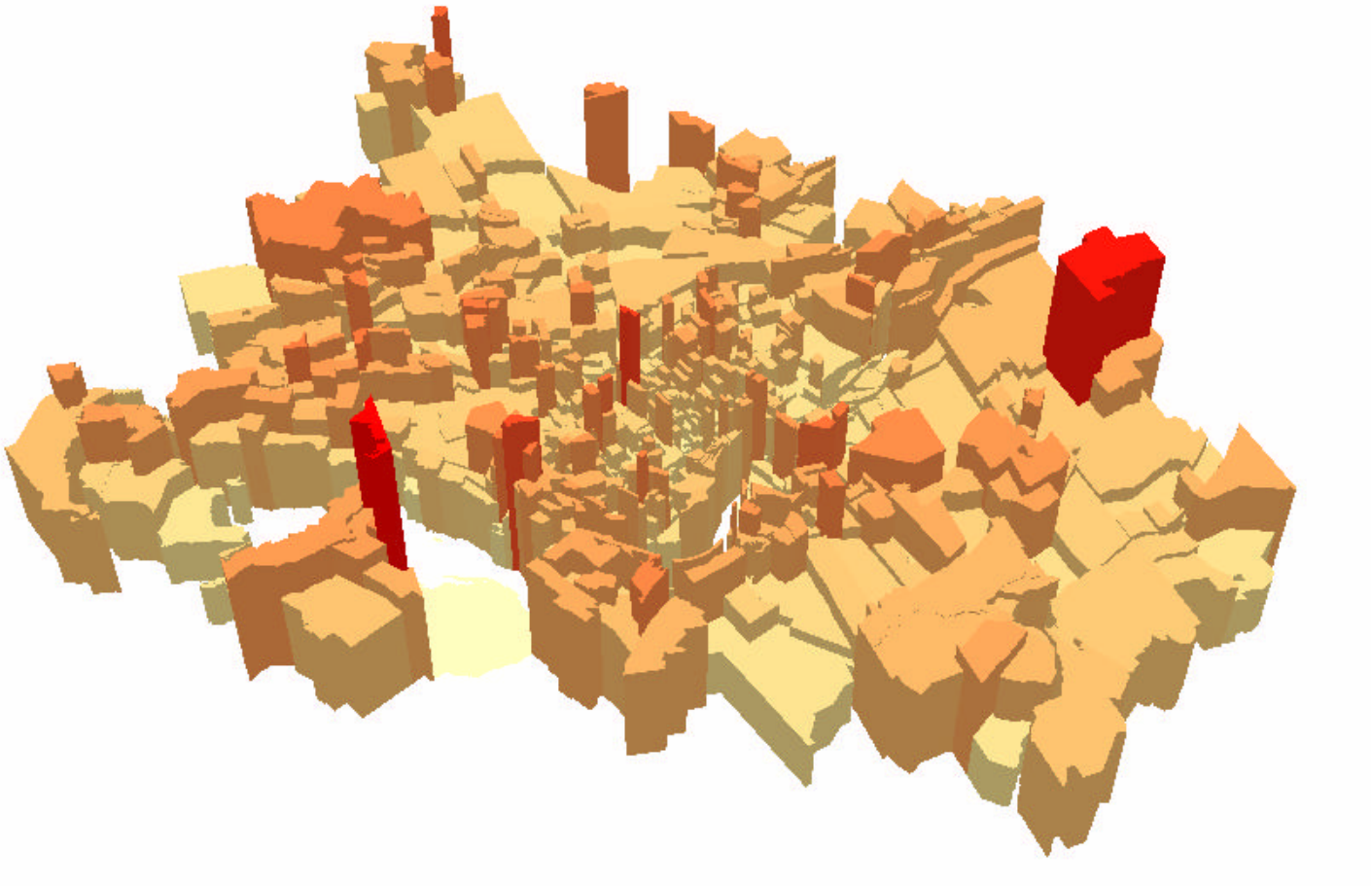
Map 22 – Female Driver Trips (%)
Montreal Census Metropolitan Data, 2001



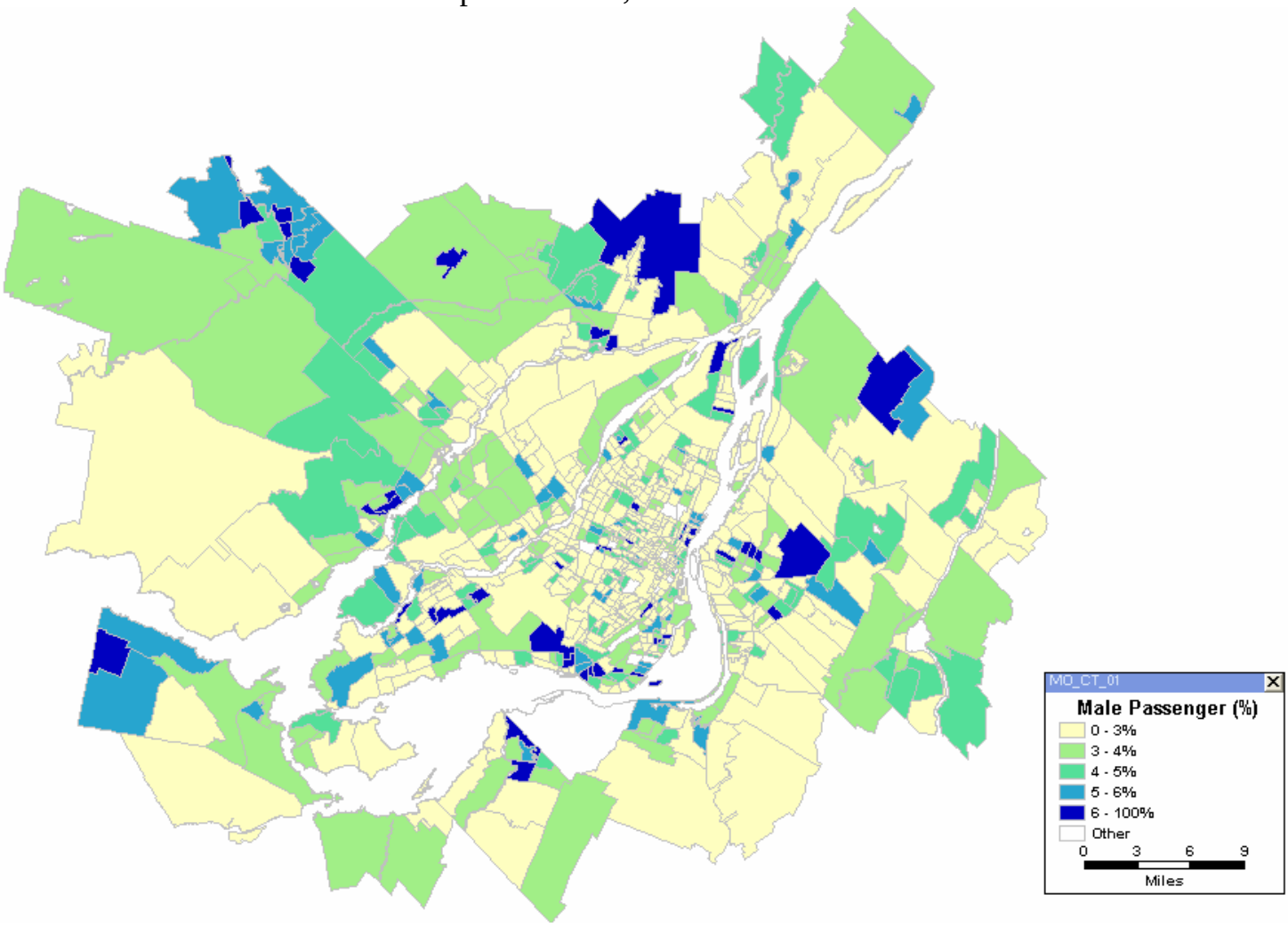
Map 23 – Passenger Trips (%)
Montreal Census Metropolitan Data, 2001



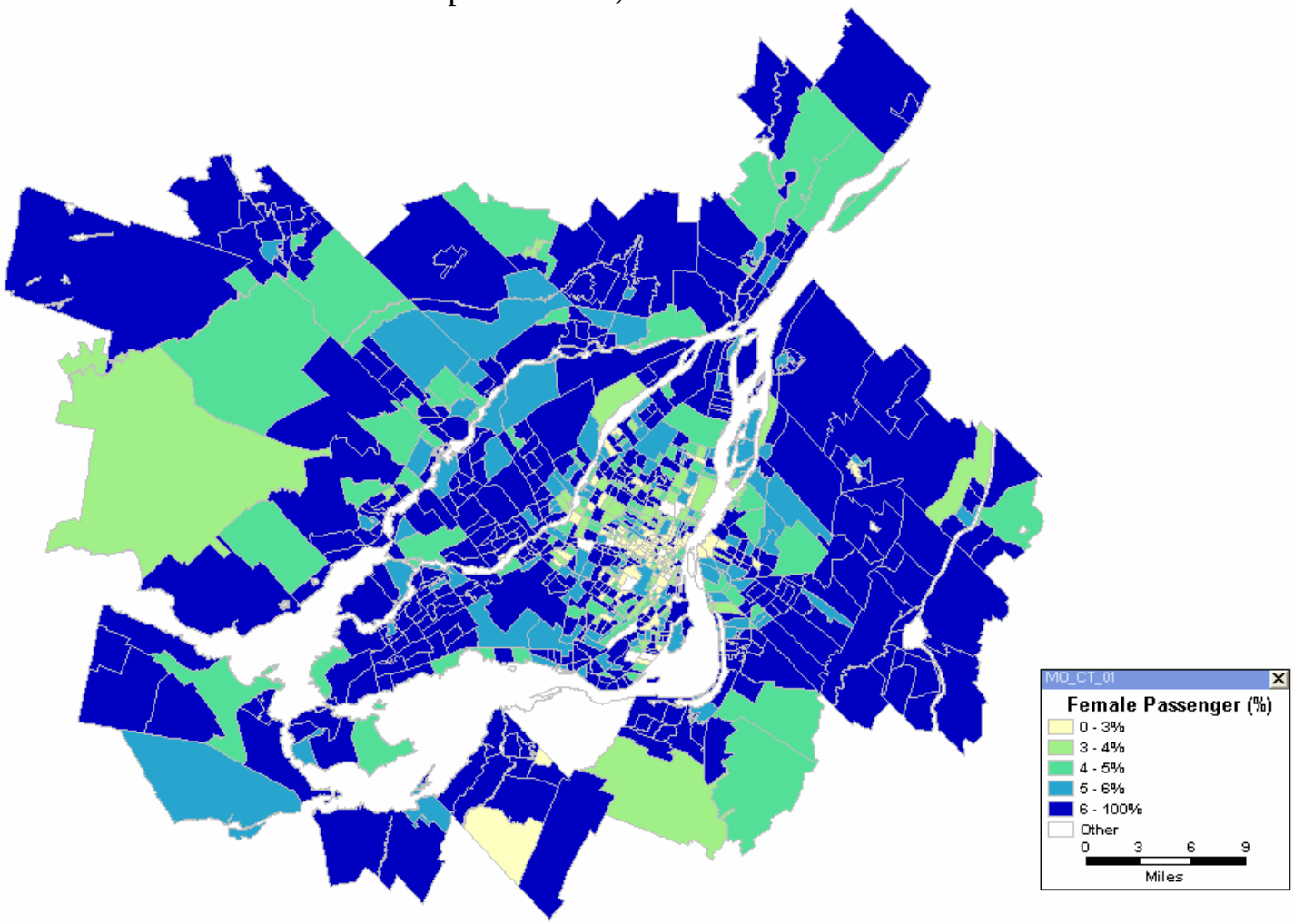
Map 24 – Passenger (%) Prism Map
Montreal Census Metropolitan Data, 2001



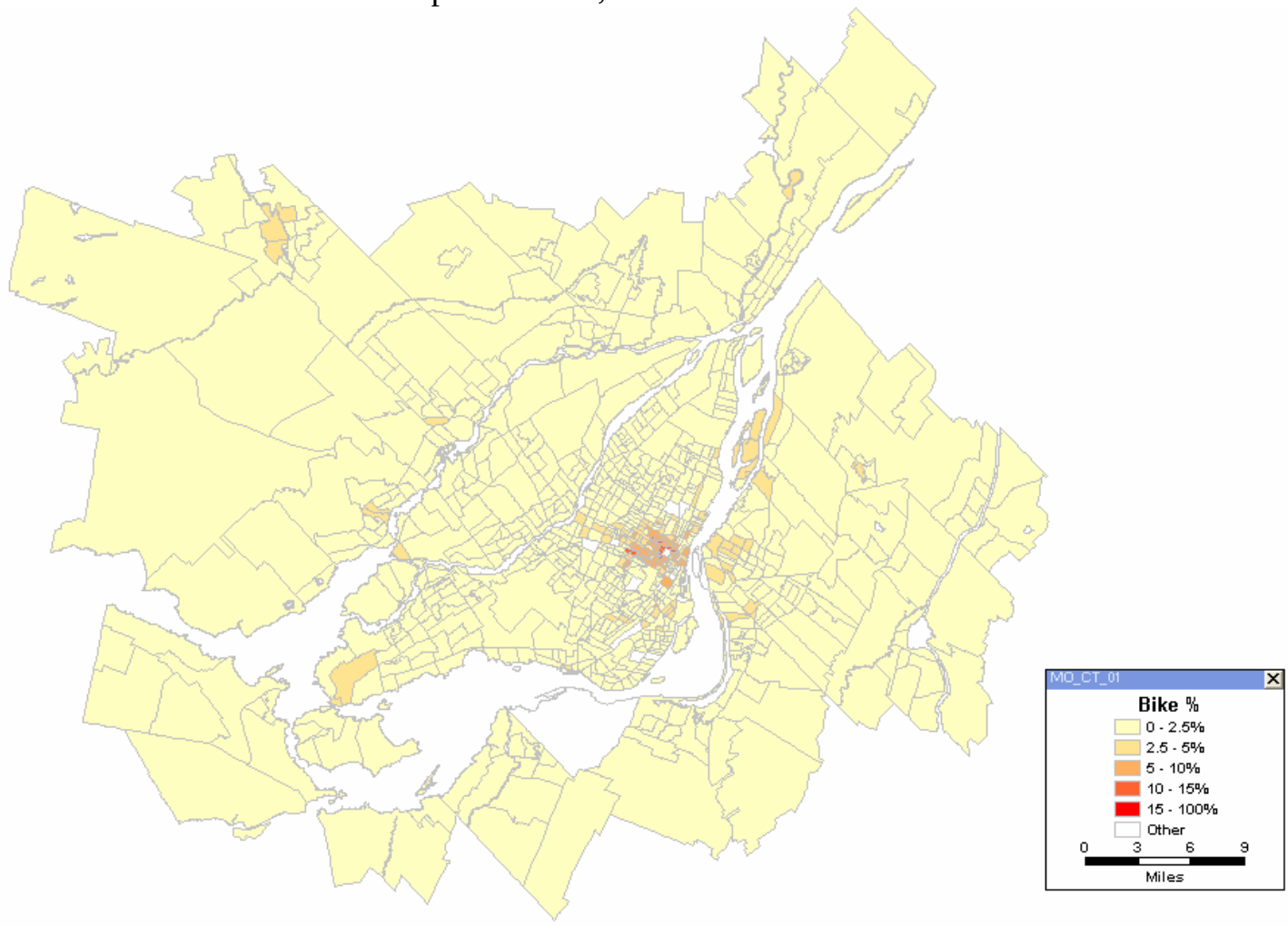
Map 25 – Male Passenger Trips (%)
Montreal Census Metropolitan Data, 2001



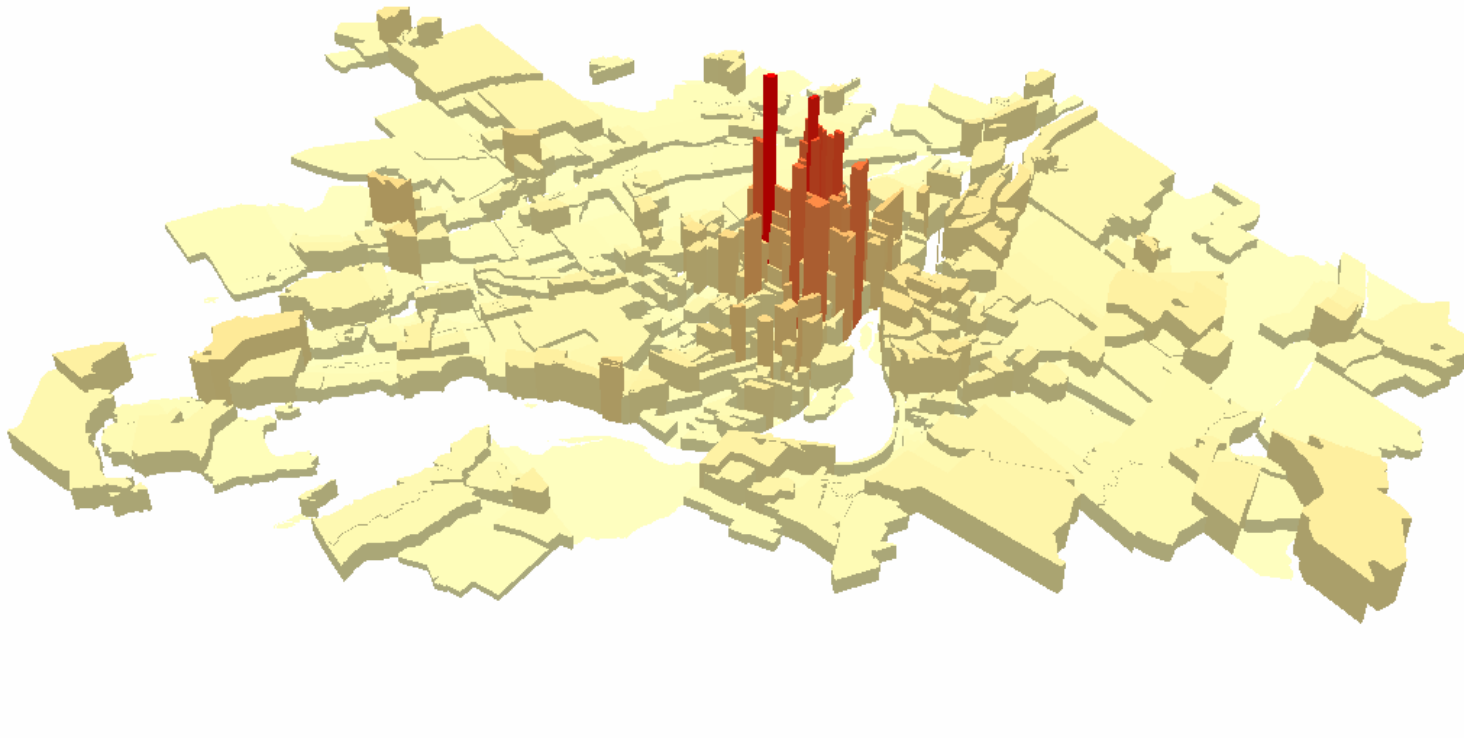
Map 26 – Female Passenger Trips (%)
Montreal Census Metropolitan Data, 2001



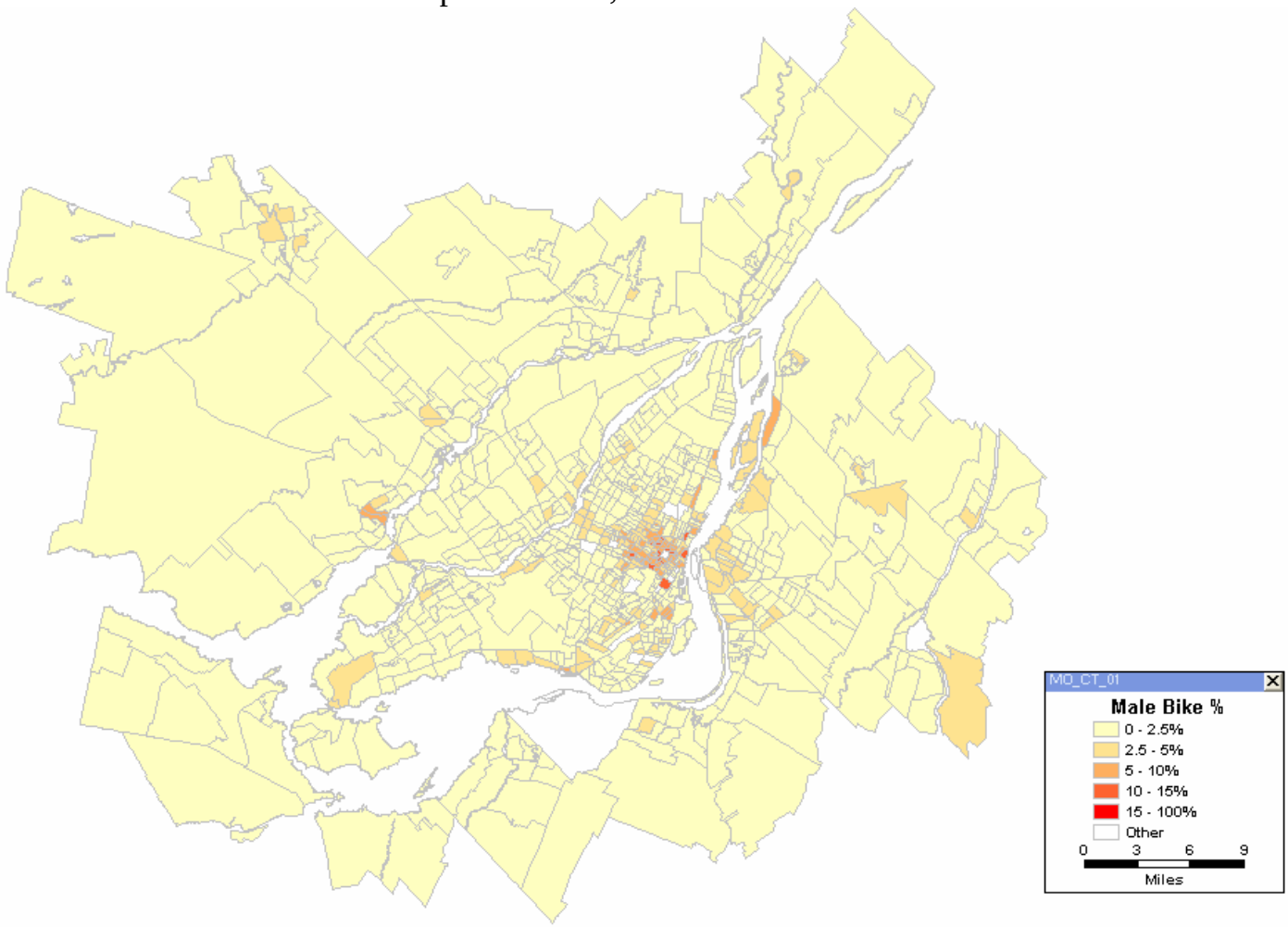
Map 27 – Bike Trips (%)
Montreal Census Metropolitan Data, 2001



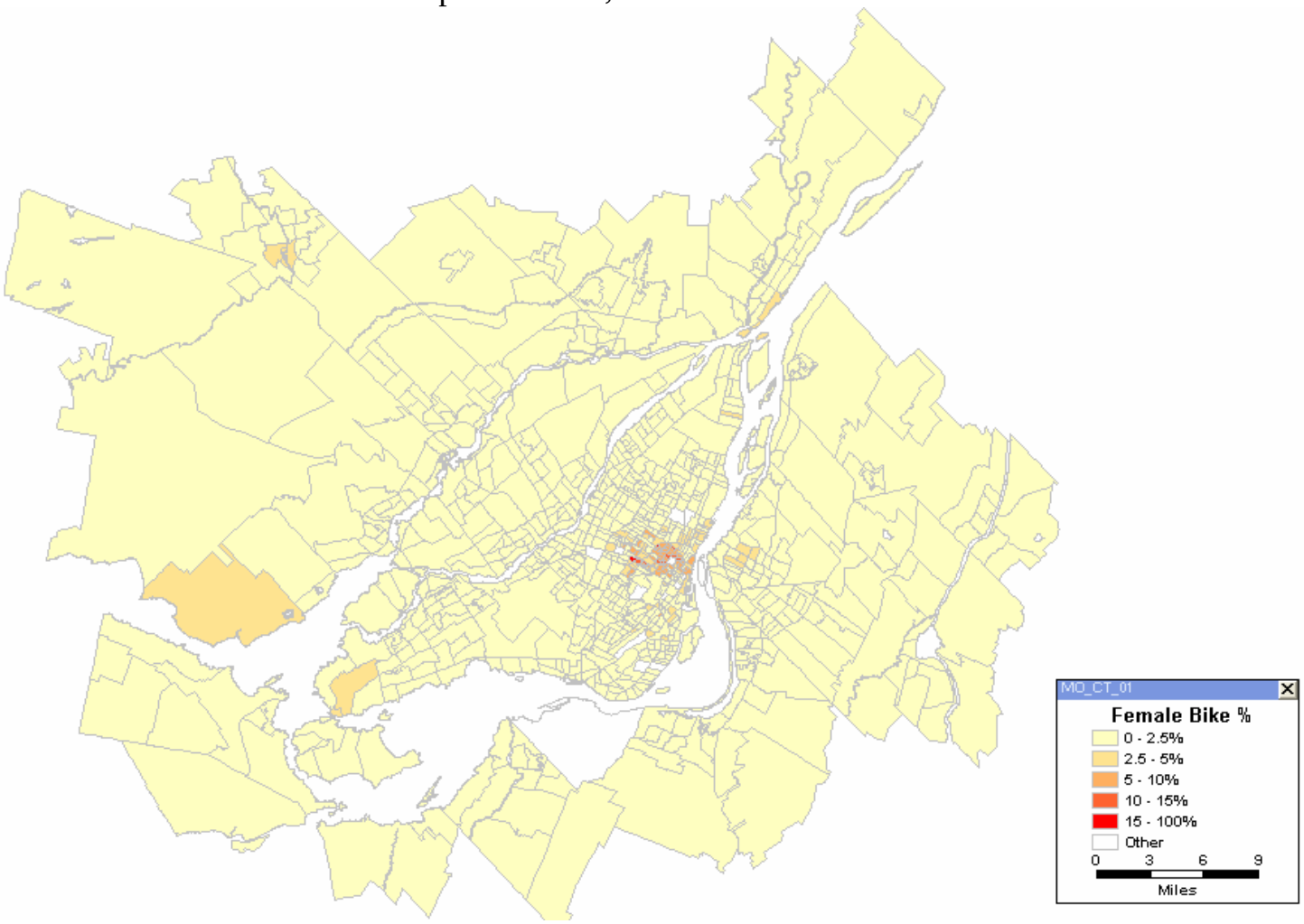
Map 28 – Bike Prism Map
Montreal Census Metropolitan Data, 2001



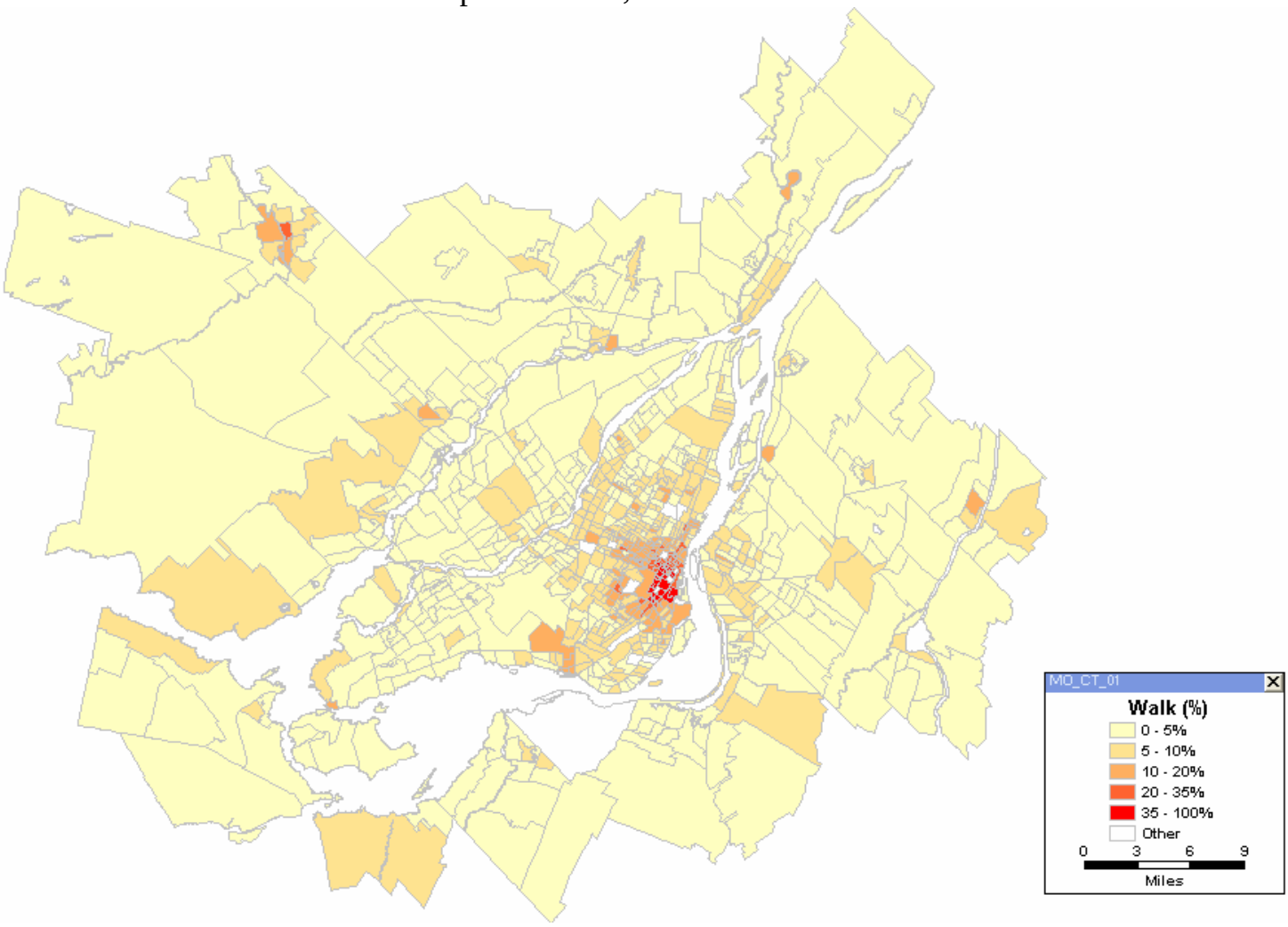
Map 29 – Male Bike Trips (%)
Montreal Census Metropolitan Data, 2001



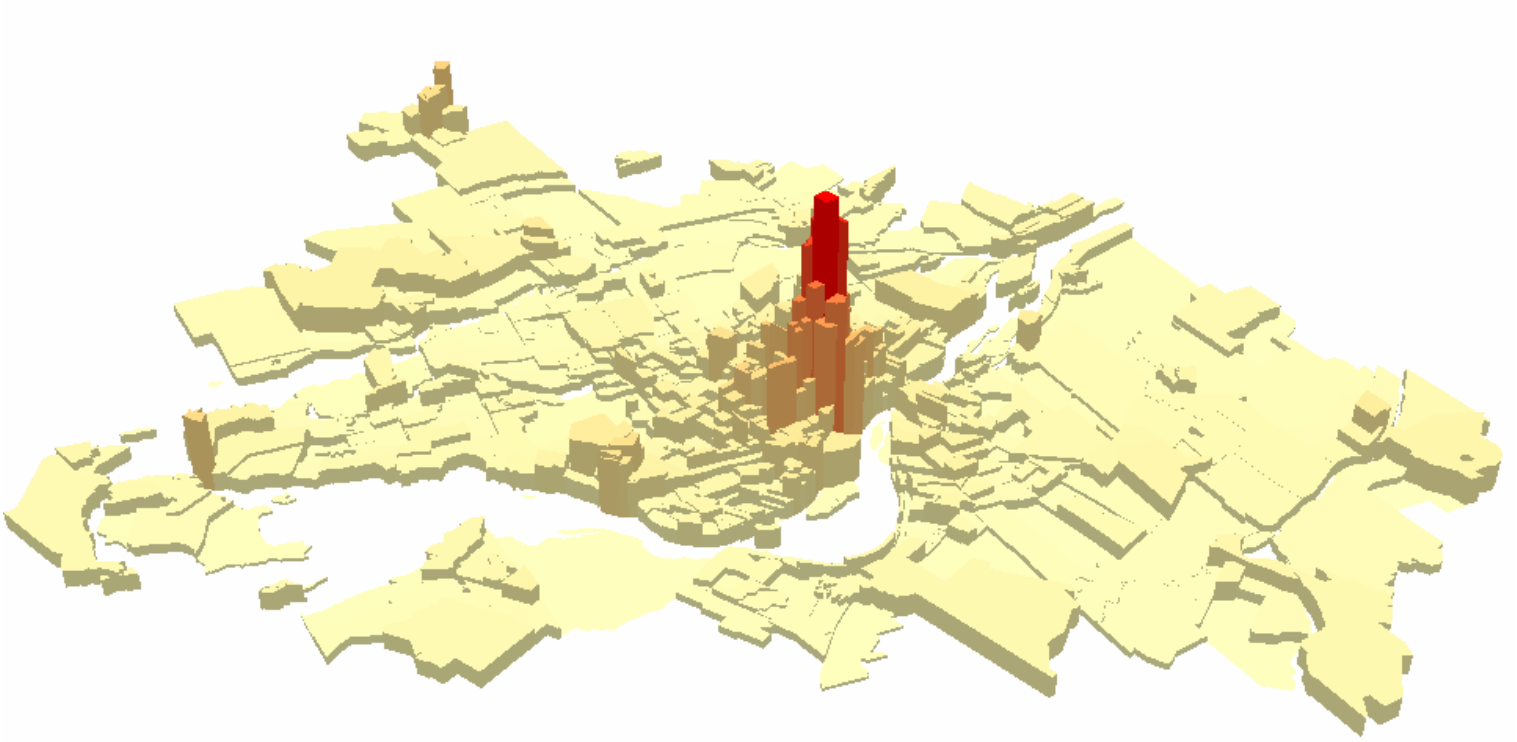
Map 30 – Female Bike Trips (%)
Montreal Census Metropolitan Data, 2001



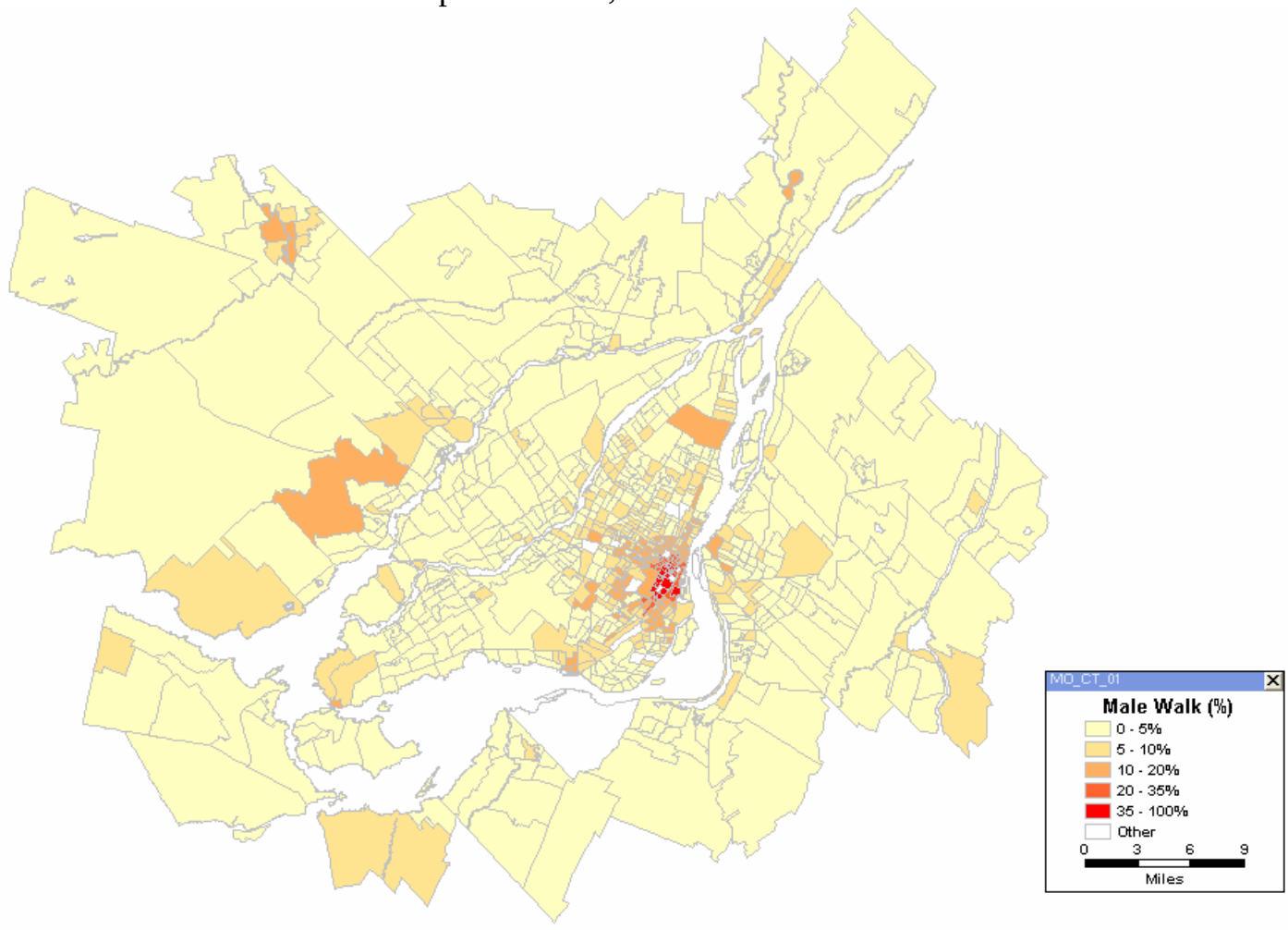
Map 31 – Walk Trips (%)
Montreal Census Metropolitan Data, 2001



Map 32 – Walk Prism Map
Montreal Census Metropolitan Data, 2001



Map 33 – Male Walk Trips (%)
Montreal Census Metropolitan Data, 2001



Map 34 – Female Walk Trips (%)
Montreal Census Metropolitan Data, 2001