Modelling the spatial pattern of housing-renovation employment in Melbourne, Australia: an application of geographically weighted regression

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Abstract: This paper discusses research aimed at identifying key factors influencing the distribution of residential housing renovation employment in metropolitan Melbourne. Using Geographically Weighted Regression (GWR), employment focused on residential housing renovation is modelled using six parameters representing urban space: *distance to the central business district*, *median household income*, *distance to highways, the number of nearby shopping centres*, *distance to public open space* and *accessibility to railway stations*. Of the six different explanatory variables, the estimated value of the Ordinary Least Square model for distance to CBD and open space were statistically significant. Mapping the values of local coefficient estimates of independent variables revealed their extent of influence and variation in residential housing renovation employment.

Keywords: Geographically weighted regression, ordinary least squares regression, and residential housing renovation employment.

1. Introduction

Housing renovation is an important component in the housing sector. It involves the rebuilding of an existing house or the remodelling of some parts of it (Dalton et al., 2013). It includes alterations and additions to buildings, but excludes routine repairs and maintenance (ABS, 2002). Old houses are renovated to improve the liveability of the dwelling or to expand it to fit changing family needs. People also renovate their house to boost the value of their property (McMillen & Thorsnes, 2006).

In general terms, residential buildings are renovated to meet basic living demands as they change over time. House renovation is a substantial contributor to the creation of better living conditions for residents and sustainable communities (Onque, 2007; Cattano, 2010).

However, there are a number of factors that impact on the levels of renovation that take place. First and foremost is matching the demand for skilled labour with the demands for renovation. Other factors include generating government policy relating to residential renovation, developing suitable educational opportunities for building and maintaining a skilled labour force and generating awareness around sustainable renovation methods (Cattano, 2010).

To date, studies of employment in the housing sector have mostly focused on new housing (Di Pasquale 1999). Therefore, allocating appropriate government resources and developing policies concerning the housing renovation market has been problematic. Examining the relationships between employment in house renovation and the key factors that underpin its spatial distribution will provide a valuable addition to urban housing research.

Ascertaining the location, magnitude and socio-spatial and economic drivers of housing renovation in cities will help urban planners to develop evidence based policy to tackle challenges associated with emerging housing markets. Urban structures are not only shaped by new built housing in newly created suburbs, or by the transportation footprint that follows this development, but also by housing renovation activities. House renovation expedites the process of gentrification and urban renewable initiatives. It also contributes to the social and demographic fabric of urban spaces, which in turn impact upon urban identity and character.

The research presented in this paper is aimed at identifying the key factors affecting the distribution of residential house-renovation employment across metropolitan Melbourne, Australia, using Geographically Weighted Regression (GWR). Six important and distinct factors identified are:

1. household income,
2. accessibility to a railway station,
3. distance to the Central Business District (CBD),
4. distance to a highway,
5. the number of nearby shopping centres, and,
6. public open space urban density.

The following section will examine the background literature in this area of study, and will outline the study area and datasets used here. A methodology section then outlines the techniques that are applied in the study; results are reported in the next section and these are followed by a discussion and conclusion. Underpinning the issues highlighted above, are the following research questions.

1. Is there spatial variability in house-renovation employment?
2. What are the factors that drive the sector's employment patterns?
3. How do we determine the model that best fits the data on house renovations?

2. Literature review

Having a well-established and vibrant housing market is beneficial not only for a nation's residents but also for the national economy (Tang, 2006). Housing satisfies a number of basic physiological and social needs for humans. These include providing a life-sustaining environment, privacy and an existential base, as well as an enabling mechanism for manifesting an individual's own taste, style, and needs (Hojer, 2011). Through renovation, these basic physiological and social needs can be fulfilled as the needs arise. Renovation is an essential housing development activity - old housing stock needs regular maintenance and repair.

Existing empirical research has identified factors such as changes in household composition (Baker & Kaul, 2002), interest rates and household income (Potepan, 1989), selling price of properties (Knight et al., 2000), and location and neighbourhood amenity (Boehm & Ihlanfeldt, 1986; Plaut & Plaut, 2010), as being responsible for driving housing renovation decisions. Plaut & Plaut (2010) found that 40 per cent of US households surveyed made some form of housing renovation during the last two years. Their study identified significant relationships between housing renovation and personal and household variables, housing location and neighbourhood characteristics.

Gyourko & Saiz (2004) have developed a theoretical model of the renovation decision process and they concluded that homes with market values below the value of construction are 50 per cent are less likely to be renovated. Despite several explanatory factors that determine housing renovation, budgetary constraints, as argued by Plaut & Plaut (2010), determines the type and level of renovation.

The costs associated with renovation are significant. In the US, home renovation accounted for US$280 billion in 2005. This was forecast to increase by 3.7% annually until 2015 (Bendimerad, 2007). The main components of housing renovation are the design, materials used and labour cost. Renovation is a cost effective option to improve or change housing to match the needs of a changing lifestyle.

However, the desire to renovate requires careful consideration to avoid the danger of overcapitalising (Baum & Hassan, 1999), and the costs associated with labour are substantial. The cost is often around one-third of the total renovation budget (Architecture Cost Guide, 2010). Apart from costs associated with labour in renovation, the availability of a skilled labour force in any particular area is itself another major problem compared to costs associated with the design and materials used (Dalton et al., 2013).

There is a clear mismatch between the demand and supply of a qualified building and construction labour force. The Australian Government regarded the supply problem as serious and it was highlighted in a budgetary overview statement that ‘housing supply has not kept pace with demand’ (Australian Government, 2008). In fact, Figure 1 shows the past and forecast divergence between the underlying demand for new housing and completion of new dwellings. The gap between the underlying demand and home completions have continuously increased since 2004.

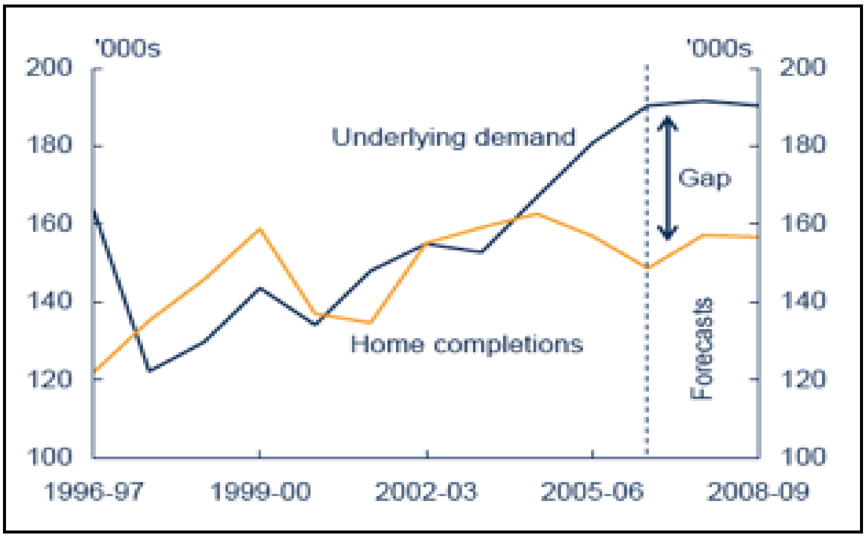


Figure 1 – Housing underlying demand and completions (Source: Australian Government, 2008)

The *National Housing Supply Council* has estimated the extent of this supply problem since 2004 (NHSC 2009; 2010), and in its most recent report (Australian Government 2010) it stated:

> *The gap between total underlying demand and total supply is estimated to have increased by approximately 78,800 dwellings in the year to June 2009 to a cumulative shortfall of 178,400 dwellings* (page 64).

Data presenting the 'value of residential work done' for both alterations/additions and new dwellings, is presented in Figure 2 for the period 1974 – 2010. It shows that the proportion of resources devoted to alterations and additions increased steadily until the early 1990s. Since then, it has largely remained in the range of 14 – 17 per cent of the total value of work done in the residential sector. Why this should be so is an important question.

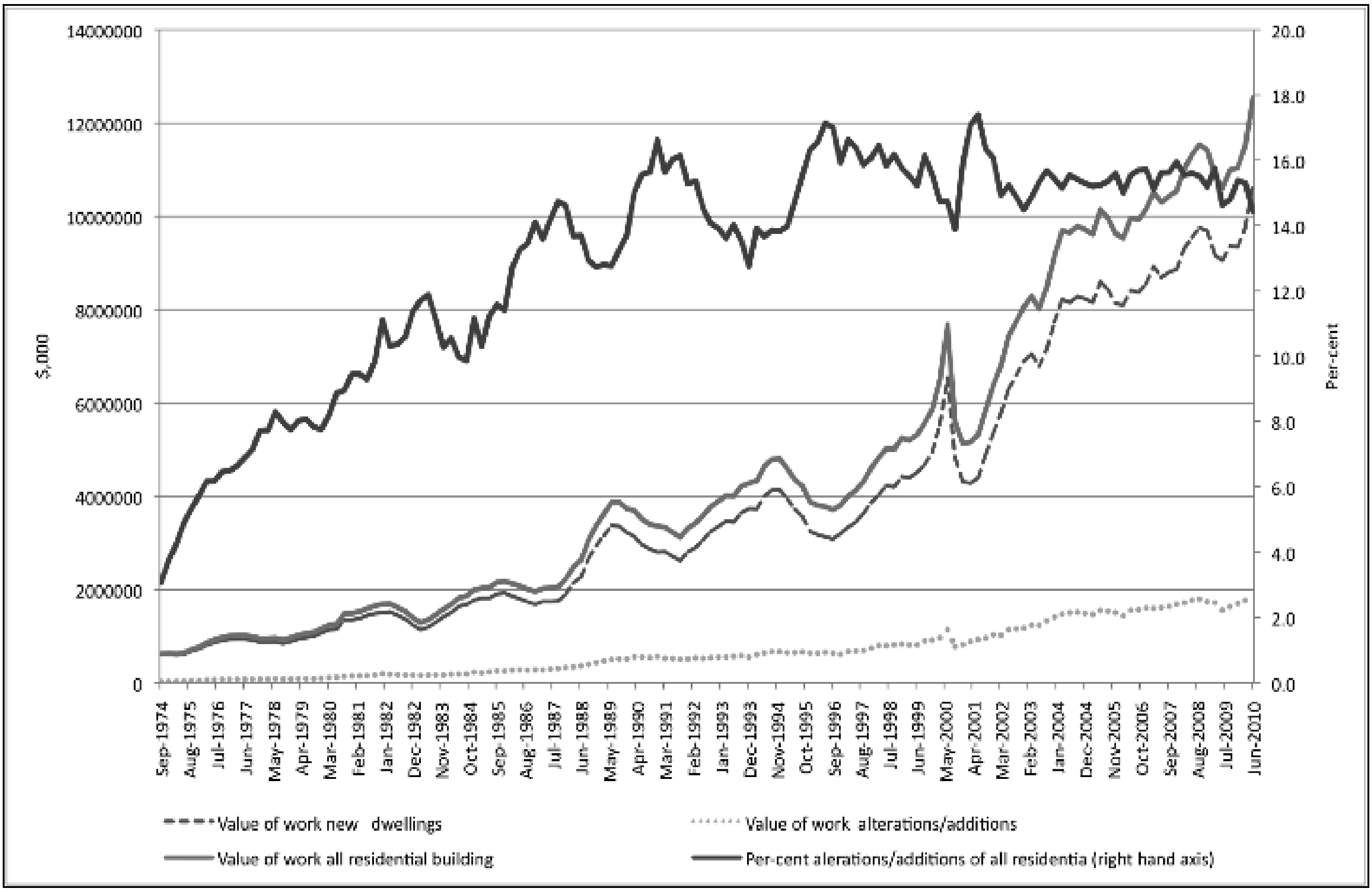


Figure 2 – Value of work on new dwellings, and alterations and additions (Source: ABS Cat 8752.0 Building Activity)

The major factor responsible for residential construction and renovation is increasing population, which evidently results in more expensive dwellings and a social upgrading of the inner city. As a result of renovation and higher rents, inner city-housing has become increasingly less accessible to lower-income people, and metropolitan Melbourne is no exception to this trend (Murdie & Borgegard, 1998). Housing renovation programs can, therefore, be a cost-effective way of providing a broad opportunity for individual flexibility and expression of local preferences and customs. We need programs to renovate and rehabilitate sound, existing low-rise multi story structures in a manner that makes the final product reflective of the local culture, and at a reasonable cost (Firmin, 2001). Renovation has significant positive impacts in terms of increasing overall housing stock, increasing access to housing amenities like safe drinking water, good sanitation, and electricity. Impact on employment is beneficial since renovation projects result in the creation of jobs that help sustain low unemployment levels in local and regional economies (Eglin, 2005).

Moreover, the demand for labour associated with projects would most likely be filled from the pool of locally available workers, thus negating the potential in-migration of workers (and their family members) from outside the region. In the absence of such an influx of new residents, negligible change would be expected in regional population or demand for additional housing as a result of projects (Eglin, 2005). Apart from this, housing renovation is influenced by the neighbourhood effects in the form of endogenous “spill over” or “feedback”. Renovation activities influence neighbourhood quality and vice versa. Hence, household investment decisions are spatially interdependent (Helms, 2011).

Gentrification is one of the key drivers of housing renovation (Melchert & Naroff, 1987). The resettlement of middle and upper income groups in the inner city neighbourhood generates housing renovation activities and investments in new developments. For example, Helms (2003) used detailed parcel-level data that hold information about all residential renovation activities in Chicago between 1995 and 2000. This study established that there is a significant relationship between residential building renovation and neighbourhood and demographic characteristics. Helms (2003) concluded that neighbourhoods consisting of parks and water bodies, greater proximity to the CBD, accessibility to mass transit, distance from the highways and demographic characteristics such as age distribution and population of blacks and other minorities are all likely to stimulate greater demand for housing renovation.

However, it is not always the relocated middle- or high-income people in these neighbourhoods that influence renovation. Building characteristics, such as building age, size, and owner occupied units that are structurally sound influence renovation (Mayer, 1981; Melchert & Naroff, 1987). Of the building characteristics, most empirical studies have identified building age as the most significant attribute to decide to renovate (Chinloy, 1980; Montgomery, 1992).

In similar research, Jacob (2007) found that deciding whether to renovate or not, is more likely to be affected by the requirement for building extension and motivation, rather than by socio-economic variables such as income, education or age. However, these socio-demographic variables may influence the decision on whether to renovate or not.

Literature surrounding renovation decision making are growing with recent studies particularly focused on building econometric models (Plaut & Plaut, 2010). Cirman et al., (2013) also linked housing renovation with social capital, and they argue that the social networks within a locality impact upon the decision to renovate.

More than thirty years ago Wright (1983) stated “the real changes in housing during the coming decade will involve new ways to use, buy and sell the kinds of housing that already exist” (p. 279). Above all, previous studies on renovation decision and their determinants have highlighted that housing renovation activities are likely to escalate with greater accessibility to neighbourhood amenities for example, recreational areas, shopping centres and proximity to transportation facilities and due to certain building and population characteristics.

Social and demographic characteristics of people living in urban areas have been rapidly changing (Chhetri et al., 2008). Therefore, the spatial pattern of housing renovation across metropolitan Melbourne could provide insights into the spatial dynamics of labour force movements to help ascertain a balance in demand and supply of labour force in housing renovation.

In summary, housing renovations are one of the important sub-sectors of the housing industry and they have gained importance as a source of housing supply. Due to gentrification or urban renewal, development of older industrial and residential areas has resulted in a tightening of the city structure. Through urban renewal, the demands of a changing housing market can be met.

But such changes reinforce the spatial polarisation of urban space and help strengthening spatial fragmentation of economic space, creating greater differences between rich and poor areas. This necessitates a rigorous analysis of the location, size, scope and drivers of housing renovation, which will help determine the planning implications of housing renovation in producing 'new' local sub-housing markets within a city. The application of GWR can examine the impact of local variability in socio-urban fabric on housing renovation activities. For instance, does accessibility to amenities differently impact in different parts within the same city? New evidence to demonstrate the transformation of inner and middle city suburbs is required to improve urban planning decisions. This paper aims to fulfil this purpose.

This research focuses on metropolitan Melbourne so that the main factors affecting the distribution of residential, house-renovation employment can be determined. Metropolitan Melbourne is one of the fastest growing regions in Australia (McGuirke & Argent, 2011) and it displays a spatially mixed housing stock. The Australian Bureau of Statistics (ABS), and the Australian and New Zealand Standard Industrial Classification (ANZSIC) data have been used to identify numbers of people working in the housing renovation sector.

Employment in housing renovation was estimated using the 4-digit ANZSIC industrial classification. Housing related industries were first extracted, which were then split up between "new build and alteration and additions". The ratio of "New Builds" was calculated on the basis of the building approval values (i.e. values of new houses plus new other residential buildings divided by the value of total residential building). The data contains the estimated number of workers operating in the housing renovation sub-sector (for more detail on methodology see Dalton et al., 2010). In addition, other datasets such as distance to the CBD, income generation, accessibility to a train station, distance to a freeway/highway, number of open spaces and shopping centres were acquired and processed using a geographical information system (GIS).

3. Geographically weighted regression

Geographically Weighted Regression (GWR) has been shown to be a useful approach for studying spatial relationships at the local level (Brunsdon et al., 2007). The advantages of this technique are that it is based on the traditional regression framework but also incorporates local spatial relationships in an intuitive and explicit manner (Fotheringham, et al., 2002). GWR techniques are now increasingly used in geography and other disciplines.

Simple linear regression involves calculating the least squares estimator of a linear regression model using a single explanatory variable. Suppose there are "n" data points $\{y_i, x_i\}$, where I = 1, 2, …, n. The equation for a straight line provides the simplest model to use, where the line of best fit minimises the squares of the residuals for each of the data points from that line (Stapel, 2012). Therefore the global regression model can be written as:

$$Y = \beta_0 + \sum k \, \beta_k \, x_k + \varepsilon$$

where:

Y is the dependent variable,

β_0 and β_k are regression coefficients,

x_k is the independent variable, and

ε is the standard error.

GWR extends this traditional regression framework by allowing local rather than global parameters to be estimated. That is, the model is rewritten as:

$$Y_i = \beta_0 (u_i, v_i) + \sum k\ \beta_k (u_i, v_i)\ x_{ik} + \varepsilon_i$$

where:

(u_i, v_i) are coordinates of the i^{th} point in space, and

β_k (u_i, vi) is a realisation of the continuous function β_k (u, v) at point i.

Therefore a continuous surface of parameter values can be determined, and measurements from this surface are taken at certain points to denote the spatial variability across the surface. GWR is a powerful tool for exploring spatial heterogeneity which exists whenever the structure of the process being modelled varies across the study area (Charlton & Fotheringham, 2007).

Increasingly, GWR models are being used for spatial prediction (Harris et al., 2010). GWR analysis is a nonparametric modelling method where the numbers of parameters used in the input can vary and the predictions of the model are determined by the values of the data provided. These models also provide readily interpretable relationships and can be used to measure sources of local variation and reduce variable co-linearity (Kimsey et al., 2008).

Nevertheless a comparison between GWR and OLS is presented in this paper. Two measures have been used to do this - the akaike information criterion (AIC) value and adjusted R-squared value. Table 1 provides a list of the variables used- variables that may influence the pattern of housing renovation using the Statistical Local Area (SLA) as the basis for geographic regionalisation.

Variable	**How it is measured**
Distance to CBD	Network distance in kilometres measured from the centroid of a SLA to the centroid of the Melbourne CBD
Household Income	The median household income.
Accessibility to train station	Network distance in kilometres measured from the centroid of a SLA to the nearest train station.
Freeway Highway Distance	Network distance in kilometres measured from the centroid of a SLA to the nearest freeway/highway.
Shopping Centre	Weighted number of shopping centres adjusted for sizes
Open space	Open space areas per square kilometres.

Table 1 – Variables and their descriptions

4. Results and analysis

This section discusses the spatial variability in employment in the housing renovation sector throughout metropolitan Melbourne. The top ten SLA's in terms of house-renovation employment percentage in metropolitan Melbourne are presented in Table 2. It is clear that the area surrounding the CBD, “Melbourne (C) – Remainder” holds the highest percentage of employment in housing renovation compared to other SLA's. Moreover, the higher amounts of house-renovation activity are found in most of the inner suburbs of metropolitan Melbourne. Of the top ten SLA’s, Moonee Valley (C) – Essendon, Port Phillip (C) – West and Yarra (C) – North are the top five SLA’s neighbouring the Melbourne CBD.

	SLA Name	Count	Percentage
1	Melbourne (C) - Remainder	597	6.26
2	Moonee Valley (C) – Essendon	346	3.63
3	Port Phillip (C) - West	339	3.55
4	Stonington (C) - Malvern	328	3.44
5	Yarra (C) – North	315	3.30
6	Kingston (C) - North	309	3.24
7	Melbourne (C) - Inner	270	2.83
8	Nillumbik (S) - South	239	2.50
9	Maroondah (C) - Croydon	210	2.20
10	Darebin (C) - Northcote	206	2.16

Table 2 – Top ten housing-renovation Statistical Local Areas in metropolitan Melbourne, 2006

The spatial pattern across metropolitan Melbourne can be seen in Figure 3 which maps areas of low, medium, high and very high house-renovation employment based on labour market activity for 2001 and 2006. Most renovation tends to occur throughout metropolitan Melbourne but with particular focus on inner and middle suburbs - areas where housing stock is older. The supply of labour force is high in the CBD and the surrounding suburbs, whereas it is low in the outer suburbs, particularly in Melton, Sunbury and Werribee South to the west and Healesville, Yarra Junction and Yarra Glen to the east. Although there is an increasing trend in the supply of labour in the east including the Yarra Ranges, particularly Dandenong, Lilydale and Seville, there is still a shortage of labour in the outer suburbs.

In Melbourne, areas around the inner suburbs along Port Phillip Bay, and Whittlesea South have experienced renovation activity in 2001 with reduced levels in 2006. More activity can be seen in inner and middle city areas such as Melbourne Inner, Mooney Valley, Essendon, Moreland and Brunswick as well as outer areas classified as Melbourne Remainder, Port Phillip West, Knox North, Knox South, Yarra Ranges South and Frankston (C) - West. There are many reasons behind these changes from the year 2001 to 2006. Although this paper does not focus on this aspect, it could be an interesting area of research for future studies

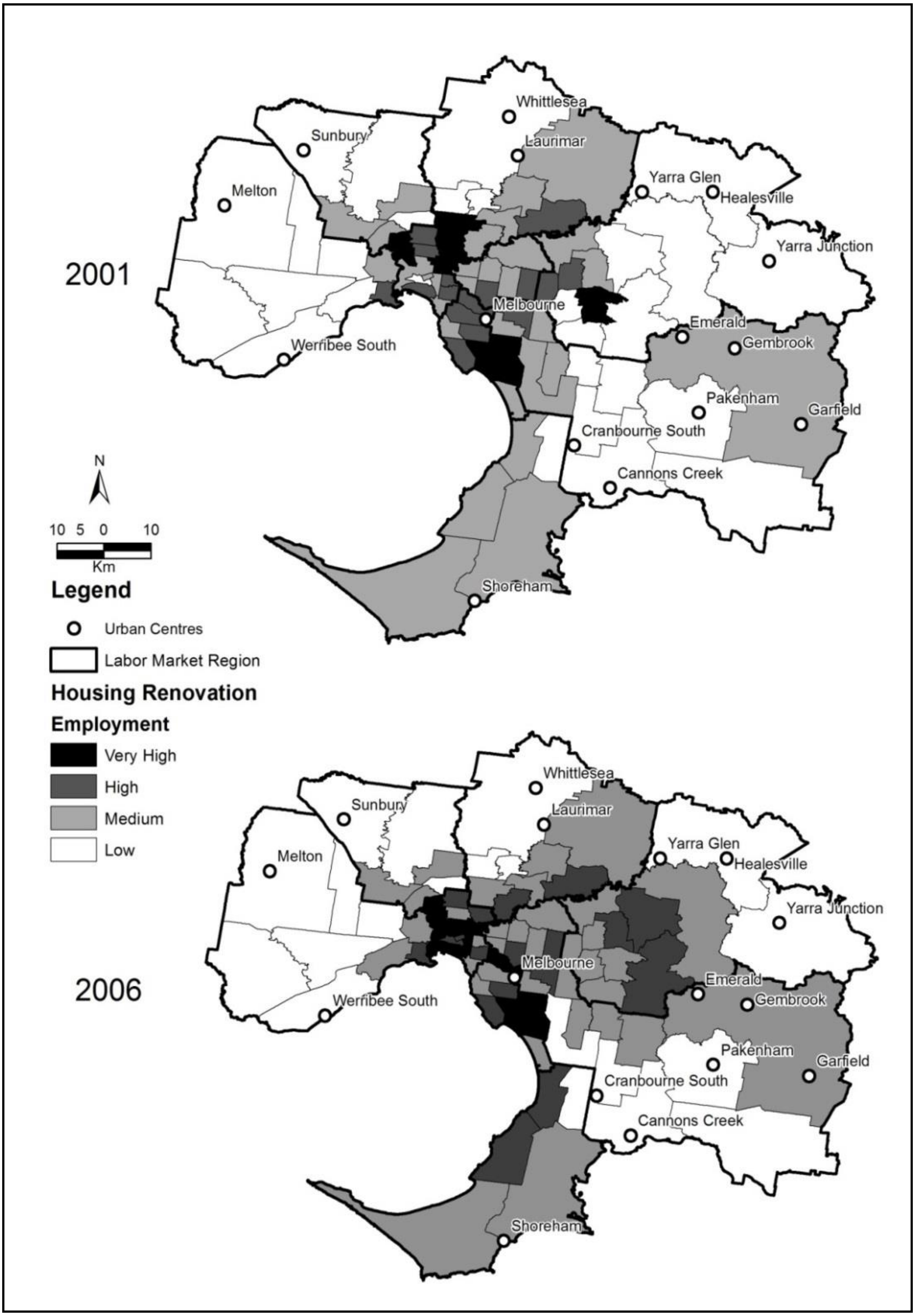


Figure 3 – Housing-renovation employment distribution by labour market region, 2001 and 2006

4.1. Modelling results

This section discusses the statistical results of the OLS and GWR models and explains the spatial variation of the key predictors in employment in the residential housing renovation sector in metropolitan Melbourne. While there are different goodness-of-fit measures, the adjusted R^2 and the akaike information criterion (AIC) values are the two main measures used in this paper to determine model performance - which model best fitted the data.

Using OLS the assessment of model performance is measured with both multiple R^2 and adjusted R^2 values. Values range from 0 to 1, where those closer to 1 indicate better predictive performance. The R^2 value is calculated to find out the proportion of variation in the dependent variable, in this case employment in housing renovation, which is determined by the variation in independent variables within the model. However, the adjusted R^2 is a preferable measure since it reflects the model complexity, i.e. the number of variables in the model (Charlton & Fotheringham, 2007).

The OLS diagnostic report, shown in Table 3, revealed that with the R^2 value is 0.29 whilst the adjusted R^2 is 0.24. An adjusted R^2 value of 0.24 indicates that this model (i.e. the explanatory variables modelled using linear regression) accounts for approximately 24 per cent of the variation in the dependent variable. The results indicate that either some variables are omitted from this model or the model is not good as it is failing to account for approximately 76 per cent of the variation in residential housing renovation employment. In other words, this model tells approximately 24 per cent of the residential housing-renovation employment story.

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_ SE	Robust_ t	Robust_ Pr [b]	VIF [c]
Intercept	95.524676	68.075178	1.403223	0.164853	65.5136	1.4580	0.14917	-------
DIST_CBD	-2.473633	0.824092	-3.001647	0.003690*	0.7232	-3.4202	0.00103	1.75
HH_INCOME	0.049895	0.047824	1.043291	0.300300	0.0489	1.0202	0.31100	1.38
RAIL_DIST	-1.069714	3.786156	-0.282533	0.778349	3.7048	-0.2887	0.77362	1.99
FWY_HWY_DI	-1.472829	5.201272	-0.283167	0.777865	3.9445	-0.3733	0.70996	1.42
SHOP_CENTR	18.656192	16.195528	1.151935	0.253157	14.1245	1.3208	0.19074	1.26
OPEN_SPACE	5.870640	2.603928	2.254533	0.027202*	3.6063	1.6278	0.10793	1.16

Input Features:	Renovation Employment Variables	Dependent Variable:	REN_2006
Number of Observations:	79	Akaike's Information Criterion (AICc) [d]:	943.632442
Multiple R-Squared [d]:	0.299852	Adjusted R-Squared [d]:	0.241506
Joint F-Statistic [e]:	5.139231	Prob(>F), (6,72) degrees of freedom:	0.000192*
Joint Wald Statistic [e]:	30.582048	Prob(>chi-squared), (6) degrees of freedom:	0.000030*
Koenker (BP) Statistic [f]:	12.150098	Prob(>chi-squared), (6) degrees of freedom:	0.058703
Jarque-Bera Statistic [g]:	51.479429	Prob(>chi-squared), (2) degrees of freedom:	0.000000*

Table 3 – OLS diagnostic report

Another key measure of the goodness-of-fit of the OLS model is given by the akaike information criterion (AIC). The AIC is not an absolute measure. It is the measure of the relative distance between the model that has been fitted and the unknown true model. It is a relative measure of performance used to compare models. Smaller values of the AIC are preferable than higher values. However, the difference in the AIC value less than 3 or 4 is not significant in determining the best fitted model. The AIC value given by this OLS model is 943.63. This value can also be compared against the AIC value calculated later for the GWR model.

The explanatory variables for the OLS model are also assessed using coefficient estimates, t-statistics, probability or robust probability and the variance inflation factor (VIF) values, as shown in Table 3. The coefficient estimate of each independent variable reflects the strength and type of relationship with the dependent variable. The results from the OLS model revealed that the signs are as expected. However, the strengths of each of the relationships are different.

The t-statistics test is used to assess the statistical significance of the explanatory variable, meaning that a coefficient value equal to zero has no significance in the model. Although the Koenker's studentized Bruesch-Pagan (BP) statistic is not significant, the probability values (p-value) indicates that only two variables "distance to CBD" and "open space" are statistically significant. These two variables are most important to the regression model as they support the underlying theory used in the model.

Note that the coefficient estimate for "household income" is close to zero meaning this variable does not strongly affect predicting employment in the housing renovation sector. This contradicts the findings from many of the previous studies (Potepan, 1989; Plaut & Plaut, 2010). The variance inflation factors are all smaller than 7.5. This means there is strong evidence that there is no redundancy in the selection of explanatory variables and that each variable adds something to the model.

As the OLS model is fitted to spatial data, it is quite possible that there will be some spatial structure to the residuals. Given the p-value of the Koenker (BP) statistic, the Joint F-Statistics is used to assess the model significance. The Joint F-Statistic test indicates that this model is statistically significant.

However, the Jarque-Bera statistic (p-value) shows that the residuals are not normally distributed. This indicates that the model is biased. To determine whether spatial autocorrelation exists in the residuals, Moran's Index *(Moran's I)* can be used to test to measure the significance of spatial dependence (Chhetri et al., 2014). The Moran's Index value for the OLS model is 0.06, and given the p-value of 0.008 (Z = 2.63) there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Table 4 shows the outputs from the Moran's *I* analysis. It shows that autocorrelation is not present in the residuals and also indicates that there is a presence of a systematic pattern throughout the spatial distribution in the data values (Can, 1998). Although the OLS model performs relatively well, improvements may be achieved through applying the GWR model using same dependent and independent variables. As well as examining the adjusted R^2 and AIC values, those observations where the standardised residuals exceed 2.5 (where the model has under-predicted) or standardised residuals less than -2.5 (where the model has over-predicted) will be of interest.

Moran's Index	0.061355
Expected Index	-0.012821
Variance	0.000796
z-score	2.628756
p-value	0.008570

Table 4 – Diagnostics for spatial dependency (Moran's *I)* for OLS residuals

Table 5 presents the output statistics from the GWR model. The bandwidth or neighbours value relates to the number of neighbours used for determining parameter values for each local area. The value of 69 is considered relatively high considering the number of observations in the dataset (79). This means that that 87 per cent of values are used in each "kernel" or geographic area selected to determine local estimates for each of the independent parameters.

The complexity of GWR model also depends on the bandwidth (Fotheringham et al., 2002). A spatial kernel is used to provide the geographic weighting in the model (Charlton & Fotheringham, 2007). Because the observations were expected to be clustered i.e. the density of observations would vary across the study area, an adaptive kernel type was used to provide the geographic weighing in the GWR model. For an adaptive kernel type, the bandwidth distance will change according to the spatial density of features in the input feature class. The bandwidth value given by this model indicates a very high reliability of model predictions. Like the OLS model the corrected akaike information criterion (AIC) was also determined to compare the goodness-of-fit between the OLS and GWR models as both of these models were using the same input variables.

Bandwidth or Neighbours Value	69
Residual Squares	364582.270153
Effective Number	19.743225
Sigma	78.438407
AICc	934.728693
R2	0.549623
R2Adjusted	0.407166

Table 5 – GWR diagnostic report

Comparing the results from the OLS and GWR models, the R^2 and adjusted R^2 given by GWR model is 0.55 and 0.41 respectively. This is significantly better than the R^2 value of 0.29 and adjusted R^2 of 0.24 given by the OLS model. The adjusted R^2 value indicate that the GWR model performance is significantly better and, therefore, the explanatory variables modelled are better at explaining the variation in the dependent variable. The GWR model, therefore, accounts for 41 per cent of the variation in location of employment in the residential housing sector.

The AIC value given by GWR model is 934.73 and as predicted the AIC value is better than that of OLS model of 943.63. The difference of 8.9 is a strong evidence of an improvement in the fit of the model to the data. The findings from this research have revealed that GWR model performs better and it is more reliable when compared to OLS model.

Table 6 shows the diagnostics for spatial dependencies (Moran's *I*) for the GWR standard residuals. The residuals obtained from the GWR model are the difference between the observed values of the dependent variable and the fitted values. Given the p-value of 0.83 (Z = 0.21), Moran's *I,* which was close to 0, calculated from the GWR residuals showed the absence of autocorrelation in the residuals within the dataset. The spatial autocorrelation results indicate a high level or reliability for the GWR model predictions.

Moran's Index	-0.000688
Expected Index	-0.012821
Variance:	0.003094
z-score:	0.218133
p-value:	0.827325

Table 6 – Diagnostics for spatial dependency (Moran's *I*) for GWR residuals

The standardised values of the residual values have a mean of zero and standard deviation of 1. Mapping the values of the standard residuals revealed that employment in housing renovation is spatially dependent i.e. high values are surrounded by high values and low values are surrounded by low values. The values of standardised residuals are used to determine whether the model predicts well, under-predicts or over-predicts values.

Points of interest are the statistically significant clusters of very high values greater than 2.5 times the standard deviation and very low values less than 2.5 times the standard deviation. These values indicate where certain explanatory variables are missing from the model. As shown in Figure 5, with the exception of Frankston (C) - West and Melbourne (C) Remainder where values were under predicted and Hobsons Bay (C) - Altona where values were over predicted, the standard residuals obtained from the GWR model are within the 2.5 standard deviations of the mean.

More research is required for a closer inspection to discover possible reasons for under-prediction and over-prediction in those SLA's that were over and under predicted. This research has revealed that most renovation works are likely to occur around metropolitan Melbourne with particular focus in inner and middle suburbs.

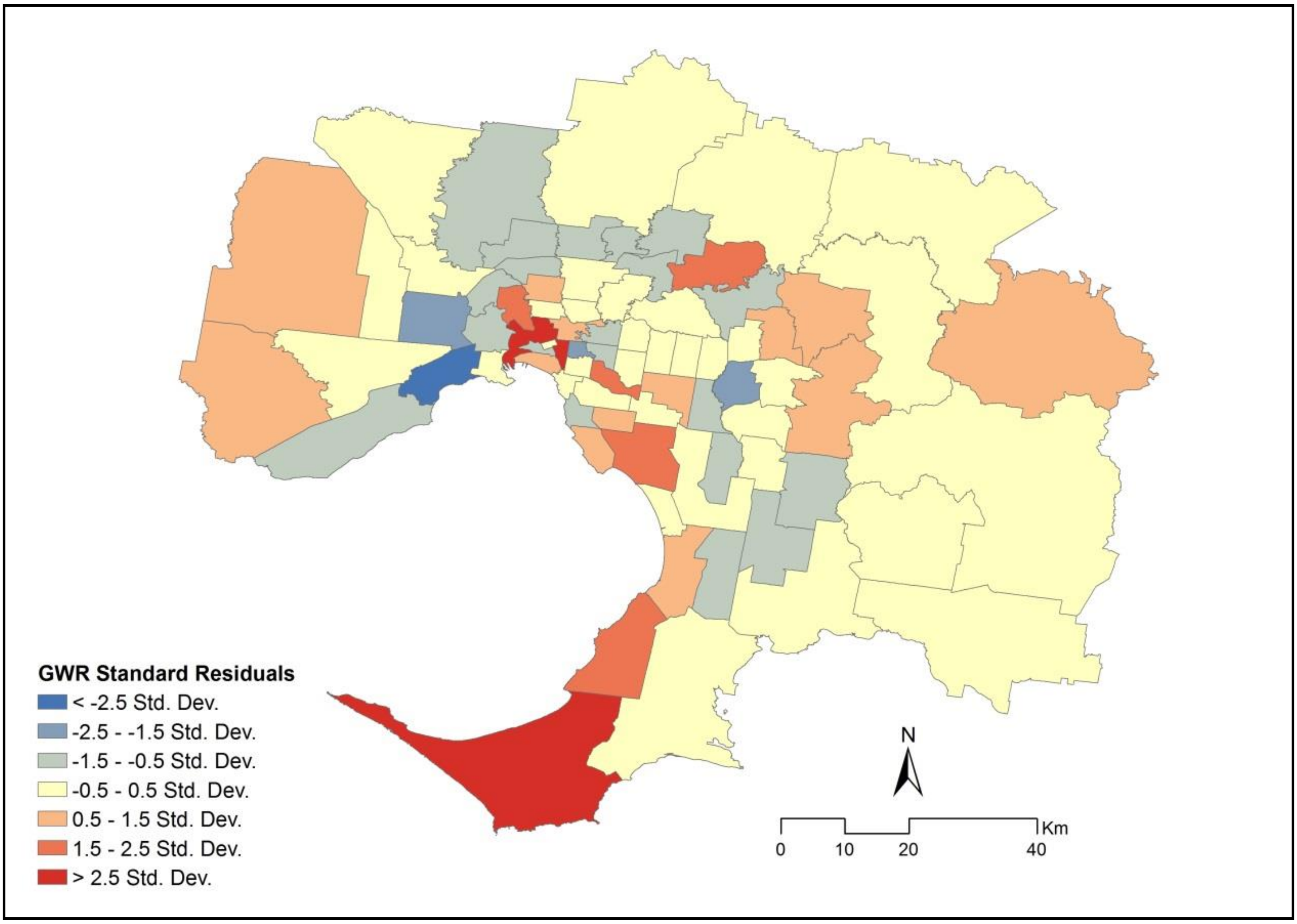
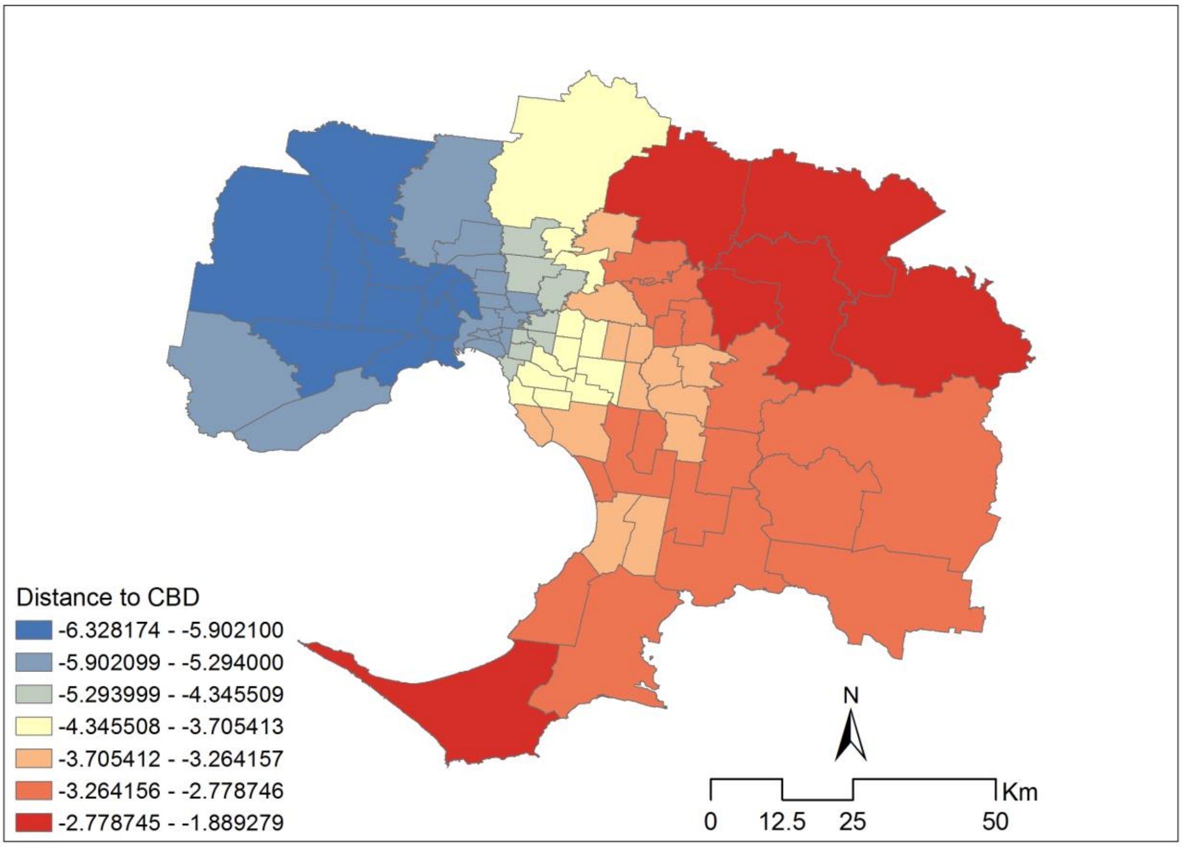


Figure 5 – GWR standard residuals

Mapping the local co-efficient estimates from the GWR model, for each of the variables (Figure 6–8), shows the relative influence for each variable on renovation industry employment. Of the six explanatory variables, estimated values for the OLS (global) model for distance to CBD and open space were statistically significant.

There is agreement between the two models on the direction of influence for these two variables. While distance to the CBD is a negative indicator, the open space variable is positive. When distance increases from the CBD or when there is less open space in the area, housing renovation activities decline.



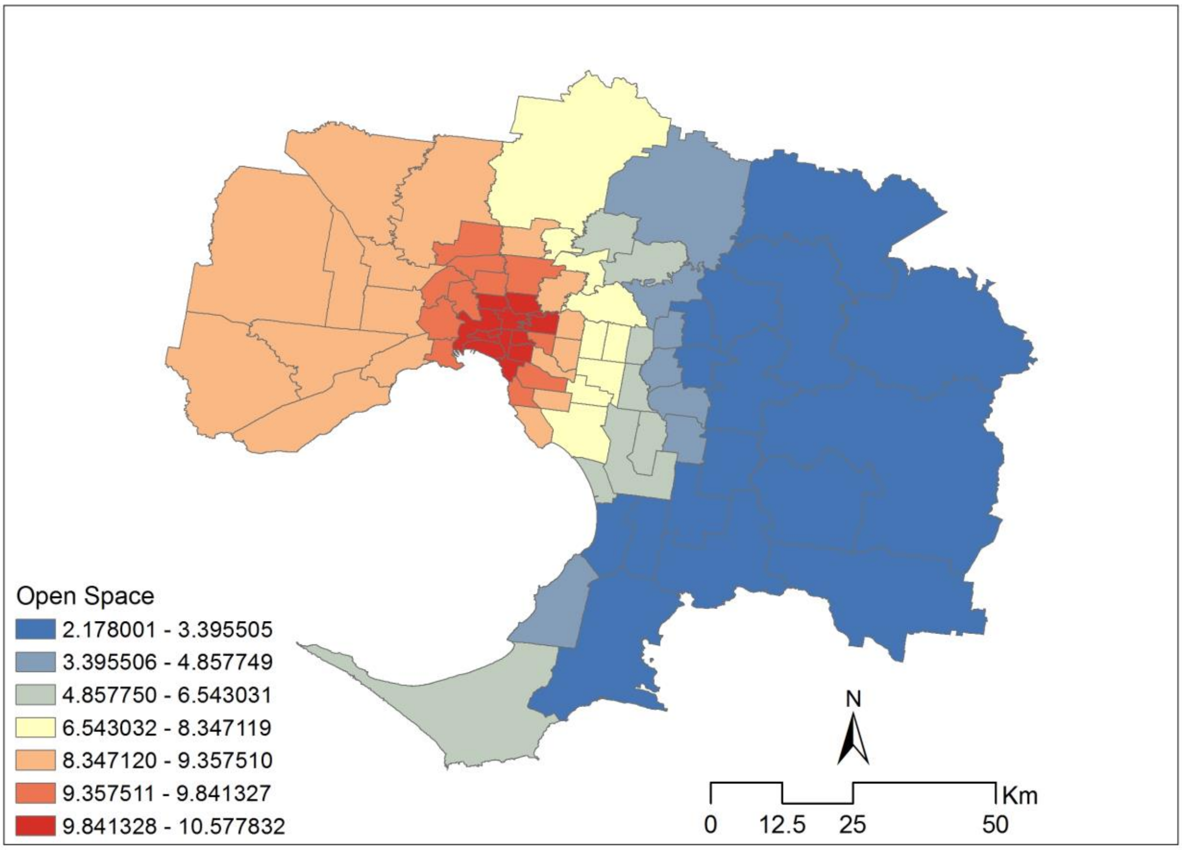


Figure 6 – GWR local coefficients of distance to CBD & open space variables

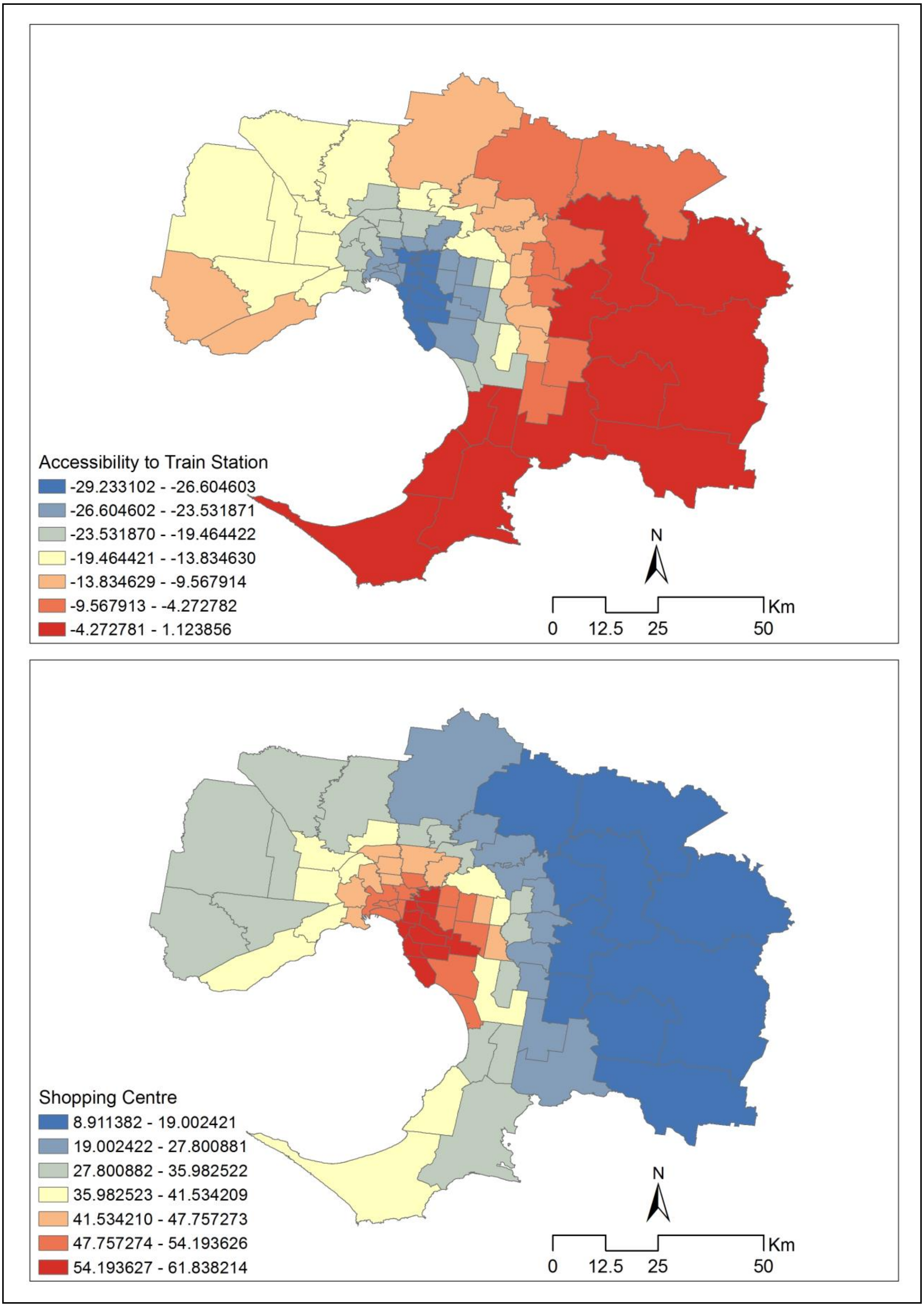


Figure 7 – GWR local coefficients of accessibility to train station & shopping centre variables

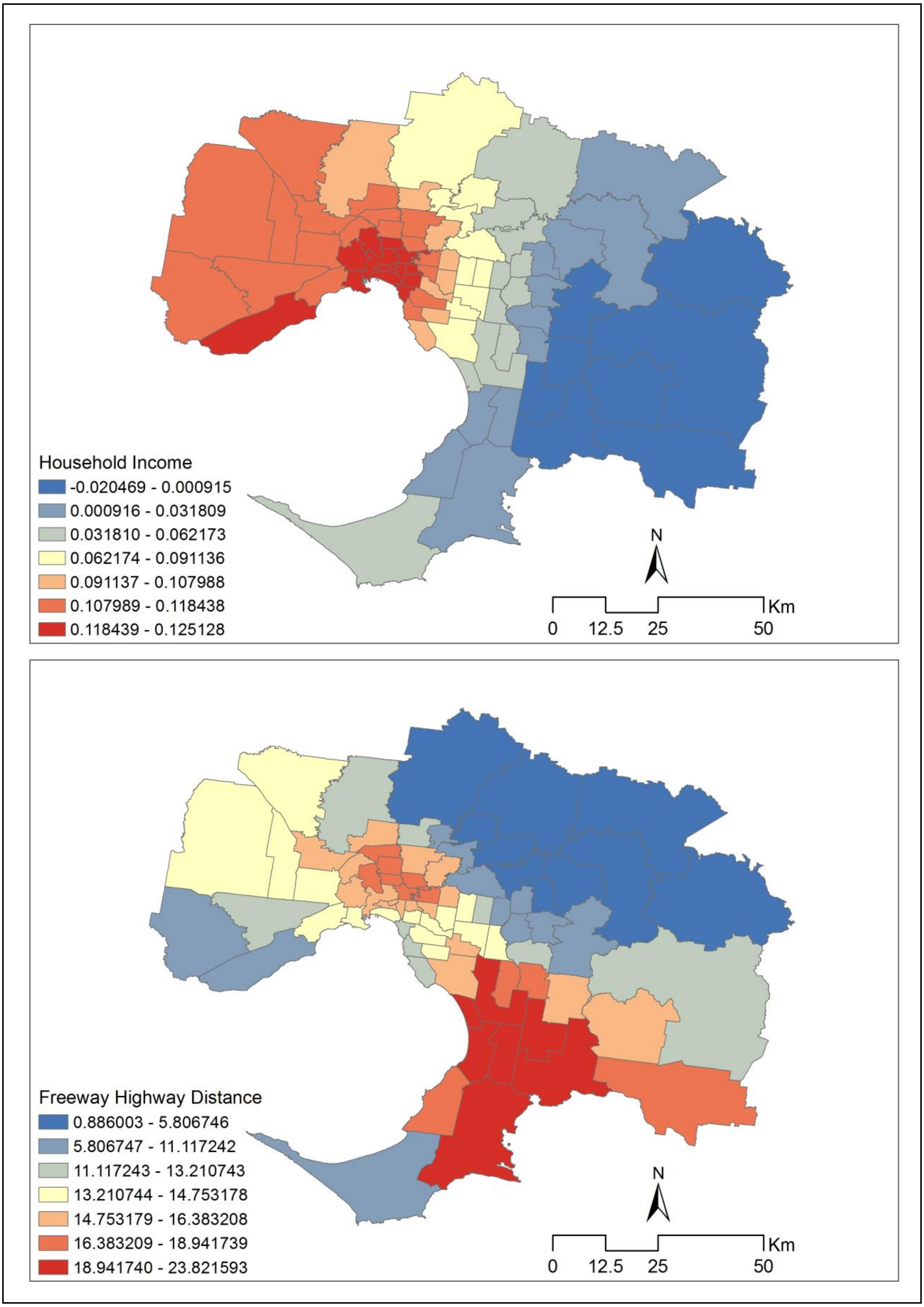


Figure 8 – GWR local coefficients of household income & freeway highway distance variables

Figure 6 shows that the distance to the CBD has a strong influence in an east-west direction whereas the influence of open space is strong from the CBD towards the west. The results reveal that these two variables are strong predictors of employment in the housing renovation sector in metropolitan Melbourne, which supports findings from previous studies.

As shown in Figure 7, accessibility to train stations and shopping centres are negative and positive indicators respectively. While the estimated values of these variables from the OLS (global) model were statistically insignificant, the range of the local coefficient values is very high in the GWR model. This indicates evidence of heterogeneity in the GWR model structure throughout metropolitan Melbourne. The direction of influence for accessibility to train stations is more significant to the north-east of the CBD, whereas the influence of shopping centres is more important in the western suburbs.

Figure 8 shows that the coefficient estimates for the household-income variable have both negative and positive values. When these values are close to zero, these variables do not influence local variation in the model -as mostly seen in the western parts of metropolitan Melbourne including Garfield and Cannons Creek. The range of the local coefficients for income varies less in metropolitan Melbourne. Although the influence of this variable is less across the study area, there is some positive influence around suburbs neighbouring the CBD.

The question of interest for future studies is why does this variable have a negative influence in some areas and a positive influence in other areas? Overall, employment in housing renovation reduces as we move away from the CBD and it increases if there are more neighbourhood amenities, such as open space and shopping centres. This research revealed that the GWR model improves model estimations over that derived by OLS.

5. Conclusions

This paper has discussed a project that has demonstrated that housing renovation is spatially dependent - SLAs with a high level of residential house-renovation employment are surrounded by other SLAs with high levels, and most renovation activities tend to occur in inner and middle suburbs. In particular, Melbourne (C) Remainder has the highest percentage of housing-renovation employment. The lower AIC value and higher adjusted R^2 value given by the GWR model revealed that the GWR model predicted the pattern of residential, house-renovation employment across metropolitan Melbourne, better than OLS.

Morans I was used to show that there was no autocorrelation present in the GWR residuals and, therefore, the outputs could be relied upon. In addition, residuals from the model across most SLAs in the study area were predicting within 2.5 standard deviations from the mean. The only exceptions were the Frankston (C) - West and Melbourne (C) Remainder area, both of which were over-predicted, and, Hobsons Bay (C) – Altona area, which was under-predicted. Further research into why this is the case is required.

All six driving factors were found to influence the pattern of residential, house-renovation employment. Of the six explanatory variables, distance to CBD and access to open space variables were identified to be statistically significant predictors. As distance to the CBD increases, the need for housing renovation labour declines. Conversely as distance decreases towards a railway station and freeway/highway, the need for housing renovation labour increases.

Moreover, renovation activities are more prevalent with the increase in neighbourhood amenities such as shopping centres and open spaces. Housing renovation is generally associated with affluence or more specifically with land value. Nevertheless, unlike the findings from previous studies, the impact of household income was statistically not significant in determining residential housing-renovation employment across metropolitan Melbourne.

In summary, it can be concluded that the requirement for employment in the housing renovation sector is more prevalent under certain conditions, such as in a particular area if the distance from the CBD and train station are closer and if there are more neighbourhood amenities such as open space and shopping centres. Studies such as this are useful for generating appropriate policies and plans for better managing house-renovation employment.

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