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Investigating retail space performance through spatial configuration of consumer movement: A Comparison of York and Leeds

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ABSTRACT

Spatial layouts help to shape retail consumer movement, which in turn plays a role in determining the distribution of retailers and performance of retail space on city network. Spatial configuration can be understood through street segment analysis, computing to-movement (integration) and through-movement (choice) metrics within a given set of connecting street networks, making it possible to assign syntactic values to individual street segments (space). In this paper, such syntactic values for the cities of Leeds and York have been established to indicate a spatial accessibility index that can be used to understand potential human (consumer) movement on spatial layouts. Other studies have established relationships between computed syntactic values and ranges of socio-economic activities, including land uses and urban value distributions. However, little is known about how configured (movement) metric outputs relate to changes in retail space's rental values (as proxy for retail space performance) across different city network scales. In response, this study investigates the relationship between retail space performance and consumer movement patterns (CMP) within sampled spatial layouts. The CMP are defined as spatial configuration metric outputs of integration, choice and normalised angular choice (NACH) metrics, computed at macro (city) and meso (city centre) scales. Street segment analysis on spatial layouts at city (macro) and city-centre (meso) scales were computed using DepthMapX tool to obtain the CMP variables. The computed syntactic values of CMP variables were then exported as point features into QGIS for analysis with the retail space performance within the sampled spatial layouts. Rental value data for years 2010 and 2017 were obtained from the Valuation Office Agency VOA datasets for York and Leeds. The two datasets were linked through a common key variable (Unique Address Reference Number) to compute rental value changes using MS Access and MS Excel tools. The rental value change table was also exported as point features into QGIS for geospatial analysis with the computed syntactic values of CMP variables. To achieve this, the study utilises vector grid (developed at 500m X 500m at city scale, and 200m X 200m at city centre scale for both cities) to a create uniform platform for all variables per grid. The relationship outputs between variables were investigated at macro city scale and meso city-centre scale for the two cities. The study reveals that there are variations in relationships between retail space performance and computed movement syntax across different scales of spatial layouts. The variables exhibit significant positive relationships at mesoscale (city centre), while variables exhibit weak correlation at the macroscale (city) for both cities. It further reveals that the integration (to-movement) metric has the most significant impact on retail space performance, with the through-movement metric having the least impact across all spatial layouts. On this basis, the study conclude that integration metric has the capability of signalling future of retail space (rental value) performance at city mesoscale layouts.

KEYWORDS

Retail space, consumer movement, rental-values

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1. INTRODUCTION

Spatial configuration of spatial layouts can calculate accessibility index of city space by estimating syntactic values of choice (through-movement) and integration (to-movement) through street segment analysis. Preceding studies by Chiaradia, et. al. (2009), Law et. al. (2013), Muldoon Smith et. al. (2015) and Giannopoulou et. al. (2016) using spatial configuration techniques have investigated and corroborated the relationships between spatial accessibility (computed through spatial configuration technique) and distribution of rental values of various real properties across different cities. However, it is unclear how the configured accessibility metrics (i.e. integration and choice) relate and contribute to changes in urban rental value. This study argues that a clear understanding of this will be useful in estimating future performance of urban land value.

Of all urban land uses, retail is the one that most relies on accessibility to prosper and survive. Locational performance of retail space can help understand the future trends of city retail spaces. Cities, through connected streets, serve as the permissible link that enable physical transactions between retailers and their consumers. The pattern of spatial layouts helps to shape retail consumer movement, which in turn plays a role in determining performance of city space (Adebayo et al., 2017). Accessibility index of a city retail space contributes to the understanding of retail market performance because it signals potential flow of consumer movements and footfall (Huff, 1962; Curtis and Sheurer, 2007). Ordinarily, performance of retail market on city space are measurable through computation of changes in retail market variables (such as, rental value, floor area, retail clusters, retail diversity etc.) within a given location. The direction of changes in property market indicators over time would indicate trends in retail market performance in that location. Meanwhile, accessibility index of city space (unlike retail market variables) are measurable through street segment analysis (Peponis et. al., 2008). This study utilises changes in retail market variable (namely, rental value) and spatial accessibility index computed through spatial configuration to investigate retail space performance across sample spatial layouts. It focuses on investigating the influence of consumer movement pattern (CMP) variables (computed through street segment analysis) on locational changes of retail rental values over two dates, when changes in rental value are expected.

The CMP of connecting streets are computable through spatial configuration of Road Centre Line (RCL) as input data using DepthMapX tool. In doing so, all individual street segments of the RCL are assigned syntactic values. The assigned syntactic values depend on the spatial characteristics of the RCL data that makes up the street segment network (Jiang and Claramunt, 2002; Jeong and Ban, 2011; Kolovou et. al., 2017). Consequently, changes in network size in turn changes the assigned syntactic values of the street segments in a consistent pattern (Figueiredo, 2015). In other words, the syntactic values of a street segment '*A'* computed at a city macroscale, is not the same for the same street segment '*A'* when computed at the city centre mesoscale. The syntactic values of a configured street segment network computed through DepthMapX include metric variables of connectivity, choice, integration, total depths and others. Studies by Chiaradia, et. al., (2009) and Law et. al. (2013) indicated that choice and integration metrics are spatial accessibility variables that are capable of signalling flow of human movement within a given street network. Hillier et. al. (2012) developed normalised angular choice (NACH) metric to regularise inconsistencies associated with variations in spatial characteristics of input (RCL) data. Despite the applicability of integration, choice and NACH metrics (herein, CMP variables) to retail consumer movement and accessibility index, there is vague understanding about how CMP variables influence retail space performance. Meaning the impact of CMP variables on changes in retail rental values on cities are relatively unknown. This study explores potential application of these variables on retail property markets to understand future performance of retail rental value across city spatial layouts. This is attained by investigating variables at mesoscale (city centre) and macroscale (city) boundaries for two UK cities, namely, York and Leeds.

2. DATASETS AND METHOD

The spatial layouts and retail market variables (2010 and 2017 rental value) of Leeds and York at macroscale and mesoscale boundaries form the basis of this investigation. The logic for investigating these cities at different boundary scales is to strengthen the confidence level of possible relationship between variables. The two variables investigated are CMP (i.e. spatial accessibility metrics) and changes in rental value of retail space (otherwise known as retail market variable RMV). The two variables were sourced, processed (differently), before geo-linking in GIS for spatial investigation.

The CMP herein, are defined as spatial configuration metric outputs of integration (to-movement), choice (through-movement) and normalised angular choice (NACH) metrics, computed at macroscale (city) and mesoscale (city centre) boundaries. The input data for CMP (that is, RCL) were sourced from Ordnance Survey OS - MasterMap ITN data. The data was converted in stages to drawing layer (dxf format), axial map and segment map before running angular segment map analysis in DepthMapX. On completion, an additional layer column was created for NACH metric. The NACH layer was then computed using:

'Log value (Choice) + 1/ Log value (Total depth) + 3' … (Hillier, et. al., 2012).

As such, all the required CMP variables (integration, choice and NACH metrics) were obtained from DepthMapX tool. These variables were then exported as point feature (CSV format) for geospatial analysis with retail market variable in GIS (QGIS).

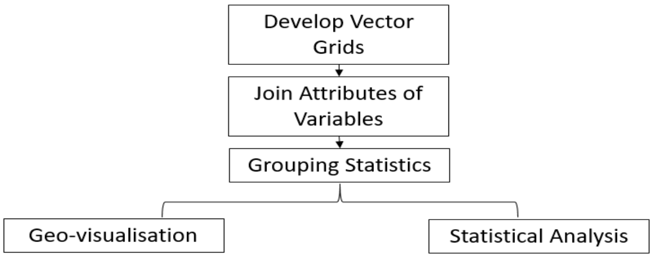
Meanwhile, the retail market variable across the sampled layouts were obtained from VOA's valuation summary list (henceforth, VOA data). The VOA data for 2010 and 2017 were processed in MS Access and MS Excel. The Doogal app was utilised in obtaining geographic (XY) coordinates of retail space addresses, while the Unique Address Reference Number (UARN) was used to link similar retail space before computing locational rental value changes between 2010 and 2017 using:

'2017 rental value – 2010 rental value = changes in rental value'

The resultant table comprises UARN, 2017 rental value, 2010 rental value, changes in rental value and XY coordinates (as the columns) and retail spaces (as the rows). The table was then exported as point features (CSV format) into QGIS for geospatial analysis.

Geospatial analysis of the two main variables (that is, CMP and RMV) were conducted on vector grids to understand locational performance of variables. In doing so, all the sampled spatial layouts were divided into vector grids before transposing values (CMP and RMV) into their respective grids. Performance index of spatial accessibility and changes in rental value are visualised and analysed by location. This technique should enhance application and understanding of space syntax (street segment analysis) in the field of real estate that understands property markets as a locational entity and not streets. Hence, three (3) basic steps were taken in GIS (QGIS) to analyse and visualise relationships between CMP and RMV performance on sampled cities. These three steps include, developing vector grids, joining attributes of variables to the grids and grouping statistics of variables per grid before conducting geo-visualisation and statistics analysis as shown in Figure 1 below.

Figure 1: Steps in geo-visualising and analysing relationships between CMP and performance of retail space variables.



Source: Authors' concept (2019)

2.1 Developing vector grids

One of the reasons for developing vector grids was to create a uniform location backdrop for all variables (CMP metrics and RMV) for geospatial analysis. As such, all the sampled spatial layouts are divided into vector grids. Each grid was assigned unique ID and spatial coordinates to represents retail location on the sampled city space. The total number of grids within spatial demarcations of macroscale boundaries for Leeds and York are 6,360 and 5,510 grids respectively, while the total number of mesoscale grids for Leeds and York are 2,240 and 665 respectively. This indicates that Leeds's spatial layout has a larger land area than York. Nevertheless, the total areas per grid at macroscale and mesoscale for the two sampled cities were equally defined at 115,000m^2 and 7,200m^2 respectively. Table 1 below shows attributes (including number and areas of grids) across spatial boundaries at mesoscale and macroscale of York and Leeds.

Table 1: Vector grid components of sampled spatial layouts

Attributes	York		Leeds	
	Mesoscale	Macroscale	Mesoscale	Macroscale
Area (m^2) per grid	7,200	115,000	7,200	115,000
Number of grids	665	5,510	2,240	6,360
CMP nodes*	4,177	81,558	15,869	209,639
RMV nodes*	1,173	2,189	2,459	8,058

*Nodes are the number of processed point features. It represents number of street segments and retail space units for CMP and RMV respectively

Source: Authors' own (2019)

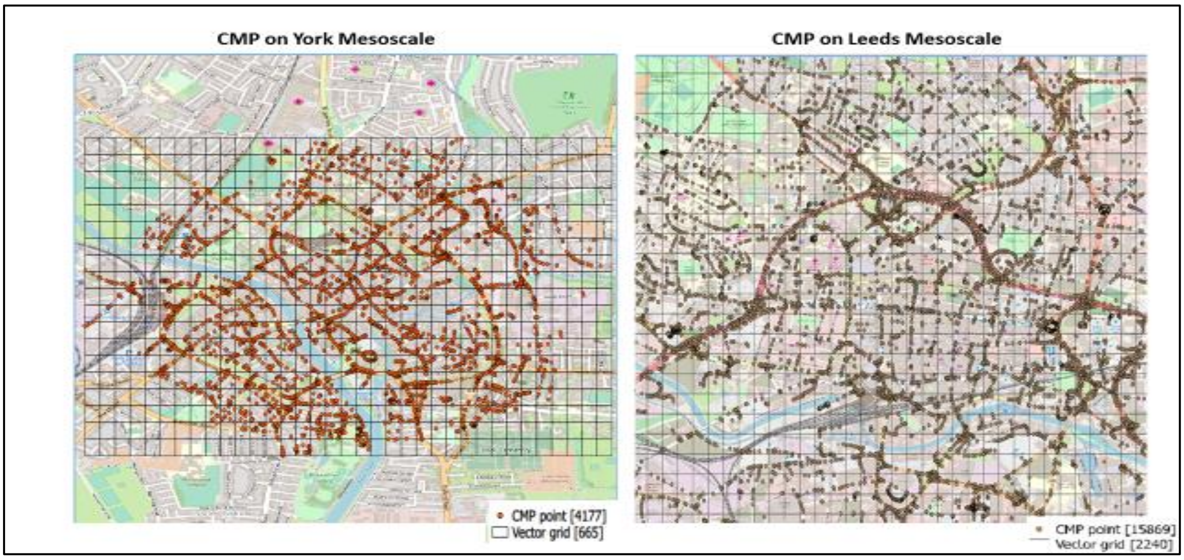
Table 1 reveals that both cities are different in terms of retail space and street segment compositions. Consequently, numbers of the processed point features of CMP (street segments) and RMV variables for Leeds at mesoscale and macroscale are more than that of York's spatial demarcations. The point features of both variables were then transposed onto the developed vector grids for further analysis.

2.2. Joining attributes of variables:

Having established vector grids for all the sampled spatial layouts, all variables were joined to the vector grids as point feature. This was done by using the *join-attribute-by-location* tool of QGIS. The ID of the points variables (CMP and RMV) were discretely joined with the developed grid ID as join vector layers. As such, geographical locations of all variables in points were established. The distribution of CMP nodes depict the street segment network on each sampled layouts while the RMV points reveal the concentration pattern of retail space across all spatial layouts. The defined mesoscale boundary for York has been defined based on the existing historical city centre wall structure (having about 2km radius from the centre), while the Leeds mesoscale was defined by 2km radius away from a chosen[4] city centre point. The macroscale boundaries for both York and Leeds have been defined by 10km radii measure from the chosen city centre points.

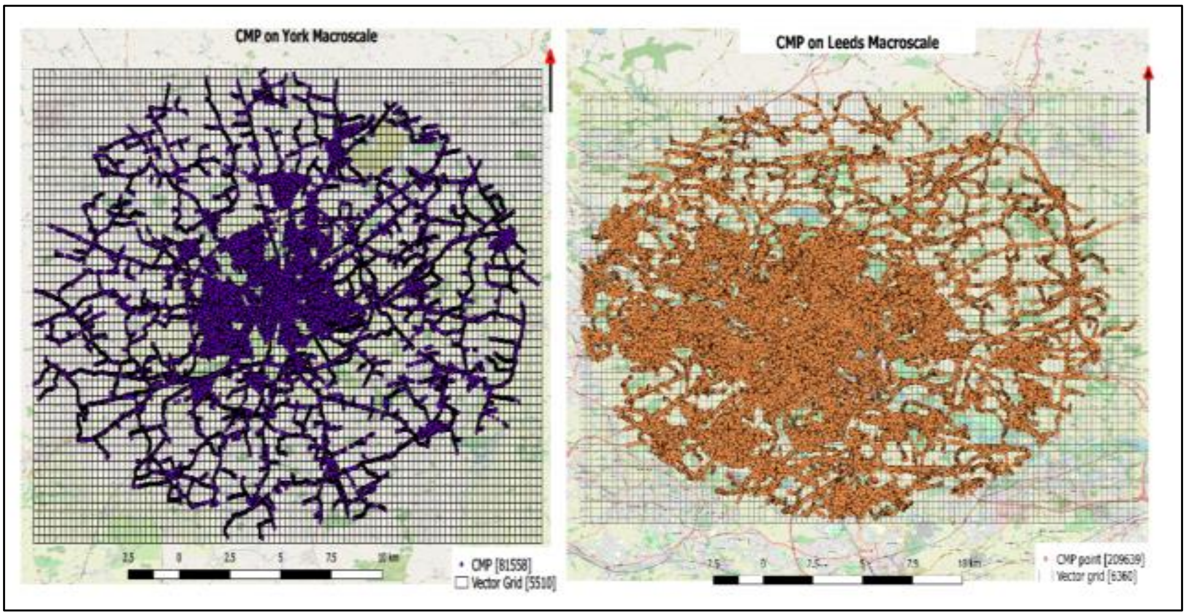
Figures 2 and 3 present comparisons of CMP points features distributions at mesoscale and macroscale boundaries as defined in this study for Leeds and York respectively. Each of these points holds corresponding syntactic values for CMP variables that is required for further geospatial investigation of relationships between variables.

Figure 2: Comparing of CMP points distribution on mesoscales of York and Leeds.



Source: Authors' own (2019)

Figure 3: Comparing of CMP points distribution at macroscale of York and Leeds



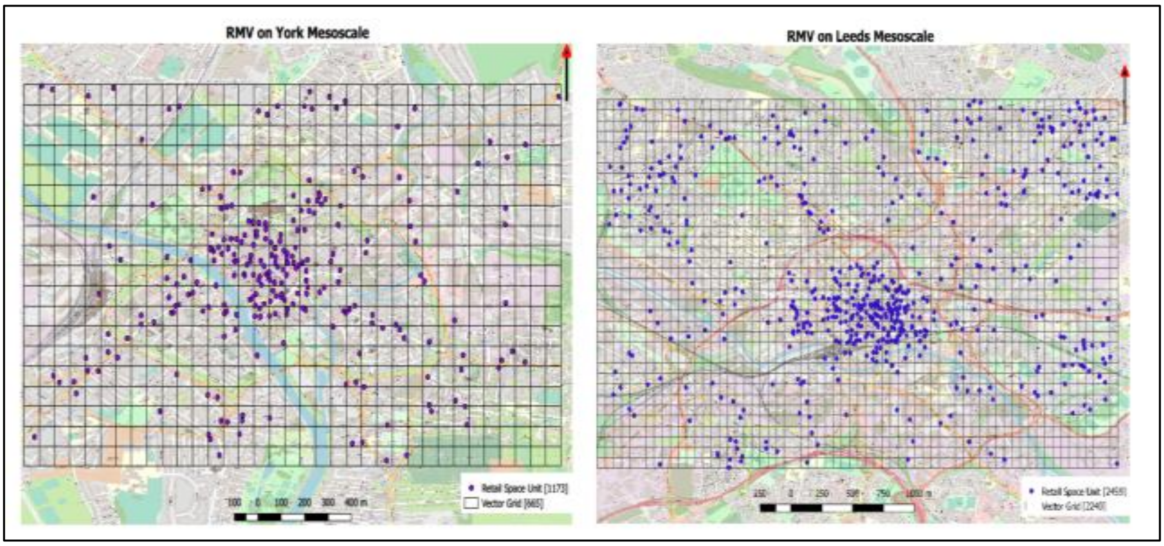
[4] The chosen centre point for Leeds is the ancient city museum

Source: Authors' own (2019)

The figures (2 and 3) above represent initial stage of computing the corresponding syntactic values within the CMP layers into the vector grids for geo-visualization and statistical relationship analysis with RMV. Similar procedures were taken in joining attributes of RMV across all the defined spatial boundaries after establishing changes in rental value per retail space using a common key (that is, UARN). While a point in CMP variables represents a street segment, a point for RMV represents a retail space unit. Herein, a retail space unit is defined as all retail space within a defined VOA address. As such, performance of RMV have been established based on the location that the retail space unit exist within the vector grids.

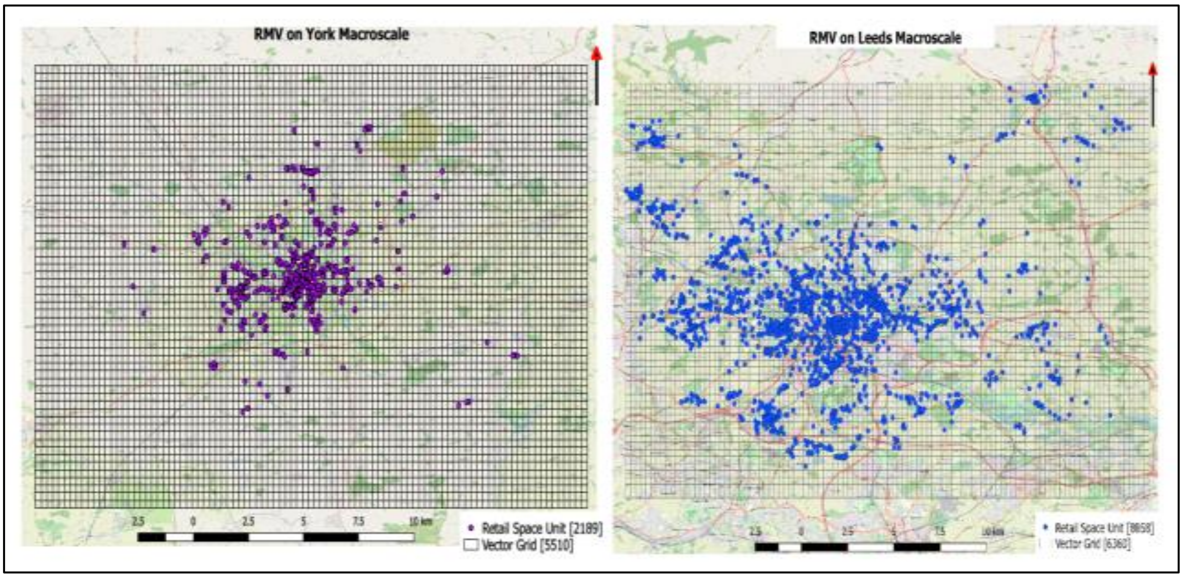
The Figures 4 and 5 respectively shows the comparisons between distribution of RMV points for York and Leeds at mesoscale and macroscale boundaries. Each of these points holds corresponding values for RMV that is required for geospatial investigation of relationships between variables.

Figure 4: Comparing of RMV points distribution at mesoscale of York and Leeds



Source: Authors' own (2019)

Figure 5: Comparing of RMV points distribution at macroscale of York and Leeds



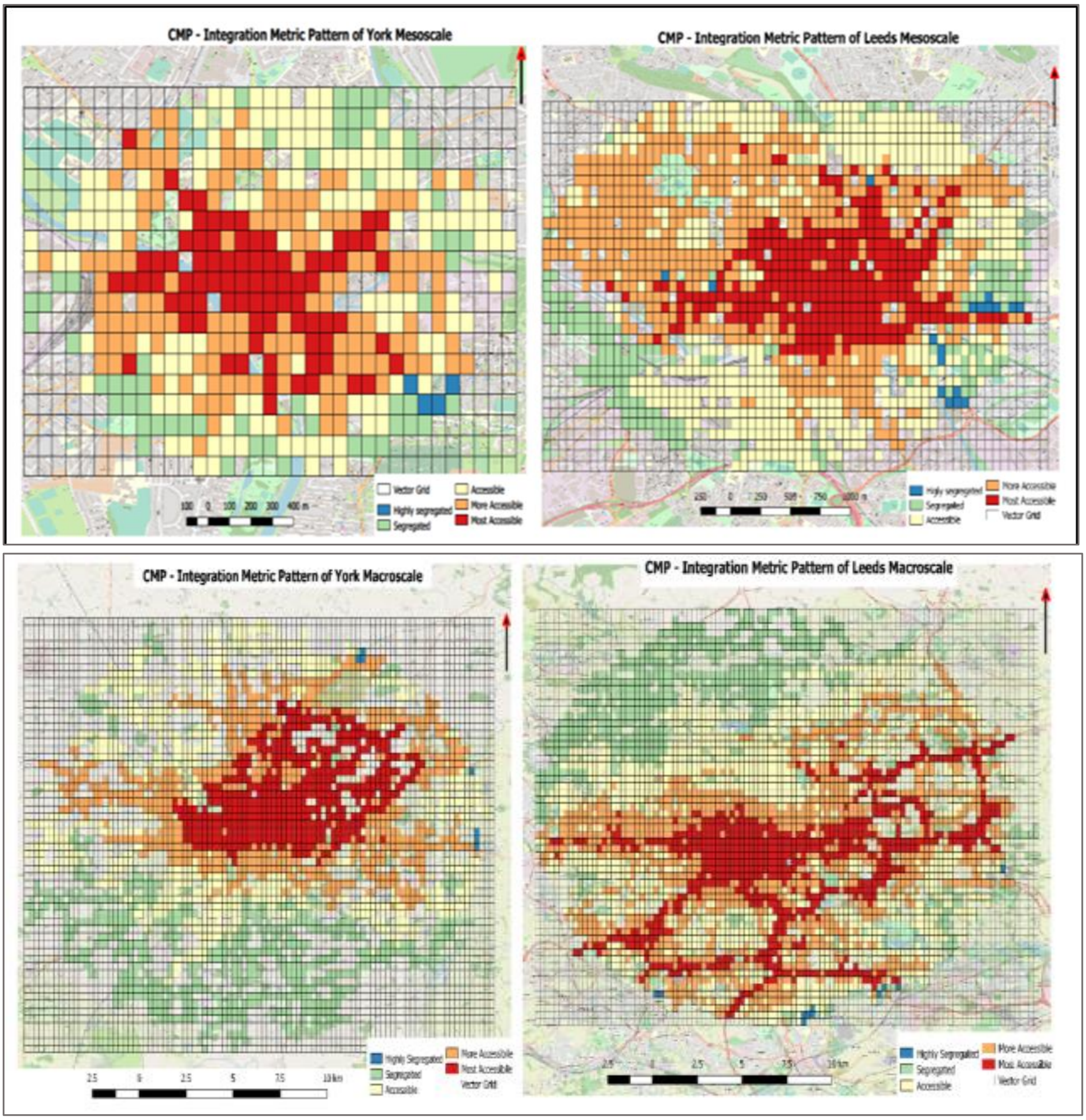
Source: Authors' own (2019)

These figures have shown that retail space distributions across the two cities at both mesoscale and macroscale are uneven just as the CMP points (street segment). Similarly, the unit (point) distribution of CMP is more than the point distribution of RMV across all sampled layouts. Meaning that estimating relationship between these different variables at any given layouts will require locational evaluation of variables rather than considering all variables within the sampled network. This study therefore took additional steps in computing index statistics of variables per grid for further analysis.

2.3 Grouping Statistics

A group-stat tool in QGIS was utilised to compute sum and average variables per grid. The CMP variables (integration, choice and NACH) have been computed by averaging total syntactic values of street segment (points) per grid, while the RMV per grid were summed-up. The logic behind averaging CMP variables and summing RMV is to obtain the average accessible index per grid and the total retail rental value changes per grid. The group stat values of CMP and changes in rental value are visualised by styling all variables in suitable colour formats. An inverted spectral colour format was adopted in styling CMP variables to maintain uniform colour standard with the traditional street segments analysis output in DepthMapX. Where red and orange street segments indicate most integrated (that is, most accessible) and blue and green indicating segregated (least accessible) locations. Figure 6 shows an example of a CMP grid pattern comparing of accessibility index (using integration metrics) between York and Leeds at mesoscale and macroscale.

Figure 6: Comparing accessibility index of York and Leeds at mesoscale in QGIS

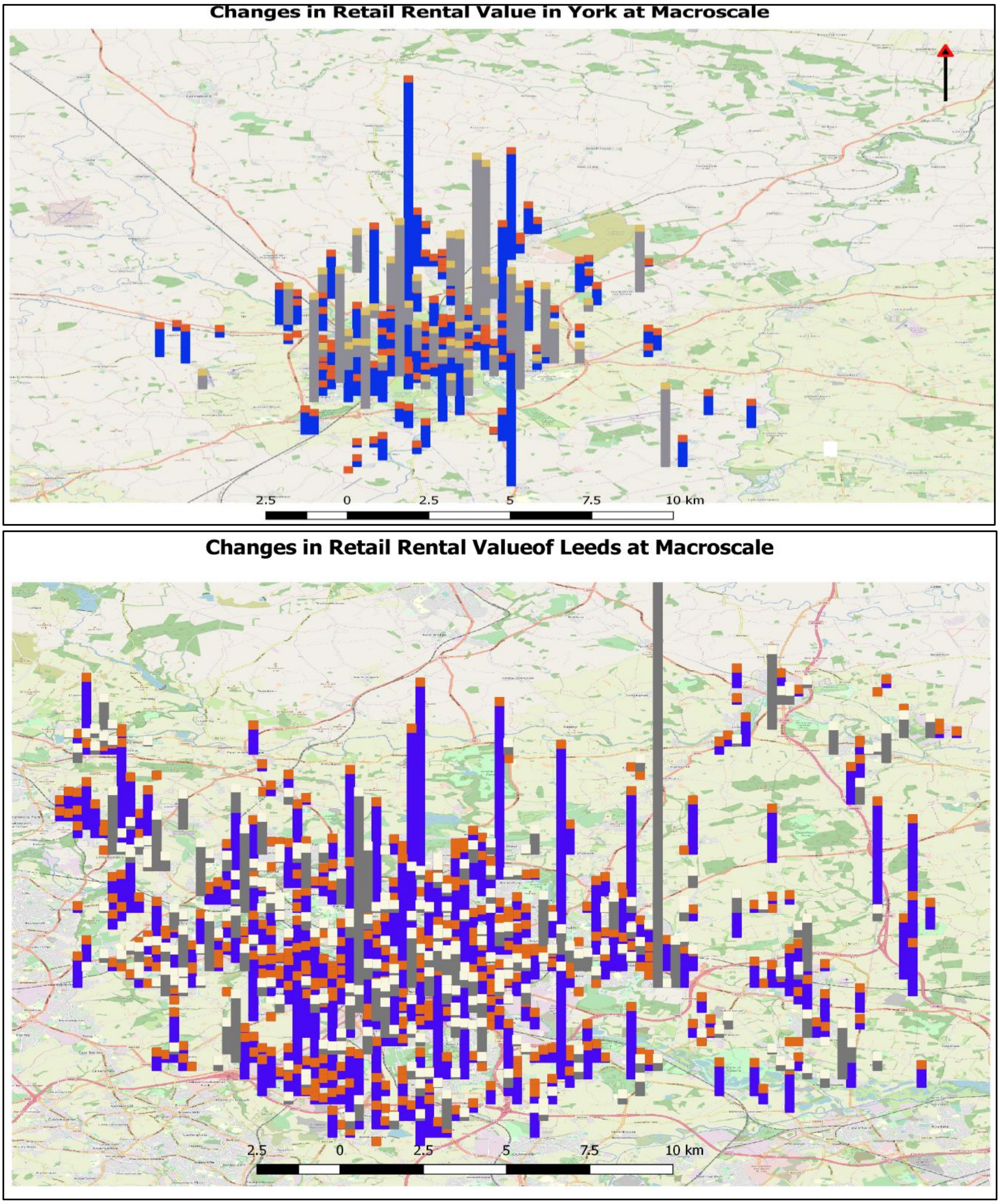


Source: Authors' own (2019)

The grid pattern output in Figure 6 styled in QGIS maintain the same trends with integration metric outputs of computed street segments on DepthMapX. Figure 6 reveals that configuration of integration metrics outputs of Leeds and York layouts are consistent in revealing centrality of spatial layouts as the most accessible part of the two cities. In other words, the integration metric output indicate centrality and accessibility pattern of the sample spatial layouts.

Meanwhile, the changes in retail rental value across all the sampled layouts have been computed and visualised using distinct colour columns to represent extent of positive and negative rental value changes. The heights of the columns show the extent of retail rental value changes. While the blue and grey columns represent positive and negative changes respectively. Figure 7 show the changes in retail rental value for York and Leeds at macroscale.

Figure 7: Distribution of RMV (changes in retail rental value) in York at macroscale scale.



Source: Authors' own (2019)

Similar procedures were taken in computing retail rental value changes at mesoscale for York and Leeds. The Figure 7 shows that changes (negative and positive) in retail rental value across these two cities occur haphazardly and do not follow uniform pattern. These results suggest that factors influencing changes in retail rental value are more of locational based than the overall city. To understand the spatial relationship between these changes and CMP, this study overlayed all changes in retail rental value on their corresponding spatial accessibility tiles. Details of relationship between variables can better be visualised in a motion interface in GIS (which cannot be presented on this paper). However, snapshots (maps) of relationship between CMP and RMV at both macroscale and mesoscale for York and Leeds have been presented in the subsequent result section of this paper.

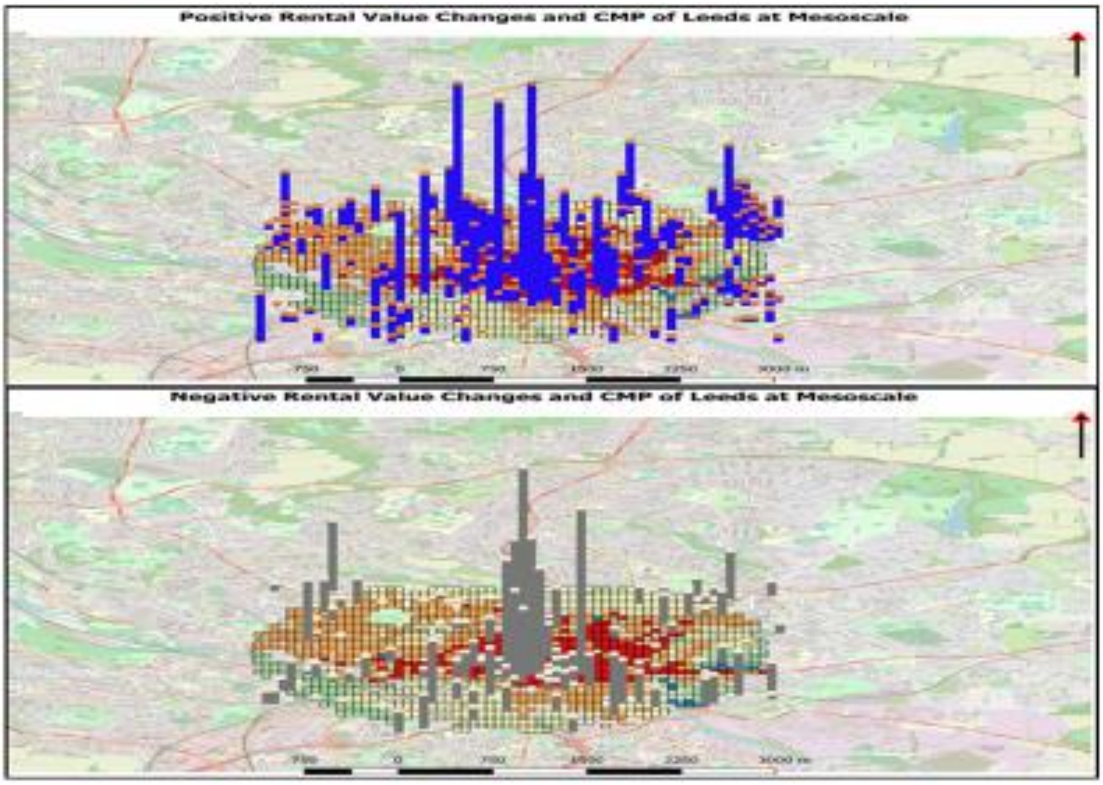
3. RESULTS: GEO-SPATIAL AND STATISTICAL ANALYSIS OF VARIABLES

While visualising the relationships between CMP and changes in retail rental value, global integration metrics have been adopted as CMP variable. This is because of the high visual intelligibility of global integration outputs when compared with other CMP layers such as, choice and NACH metric outputs. However, the study adopted all the CMP variables (that is, integration. choice and NACH metrics) in the statistical analysis to determine the contributory effects of CMP variables on changes in retail rental value (that is, performance of retail space) across all sampled layouts using scatter diagrams. Sections 3.1 and 3.2 respectively present results of visualization and statistical analyses of relationships between changes in retail rental value (RMV) and CMP across sampled layouts.

3.1 Visualisation of variables and spatial relationships

The spatial visualization of relationship between CMP and RMV at mesoscale and macroscale for York and Leeds have computed by overlaying variables using symmetric grid patterns. The adopted technique allows for detailed relationship investigation of variables at different scale boundaries. For example, relationship between positive (or negative) changes in retail rental value and CMP can be explored at different scales and locations within a given sampled city. This enhances visualisation of relationship between retail locations performances and configured spatial accessibility index. An example of relationship between positive and negative retail rental value changes and configured accessibility index for Leeds at mesoscale is presented in Figure 8 below.

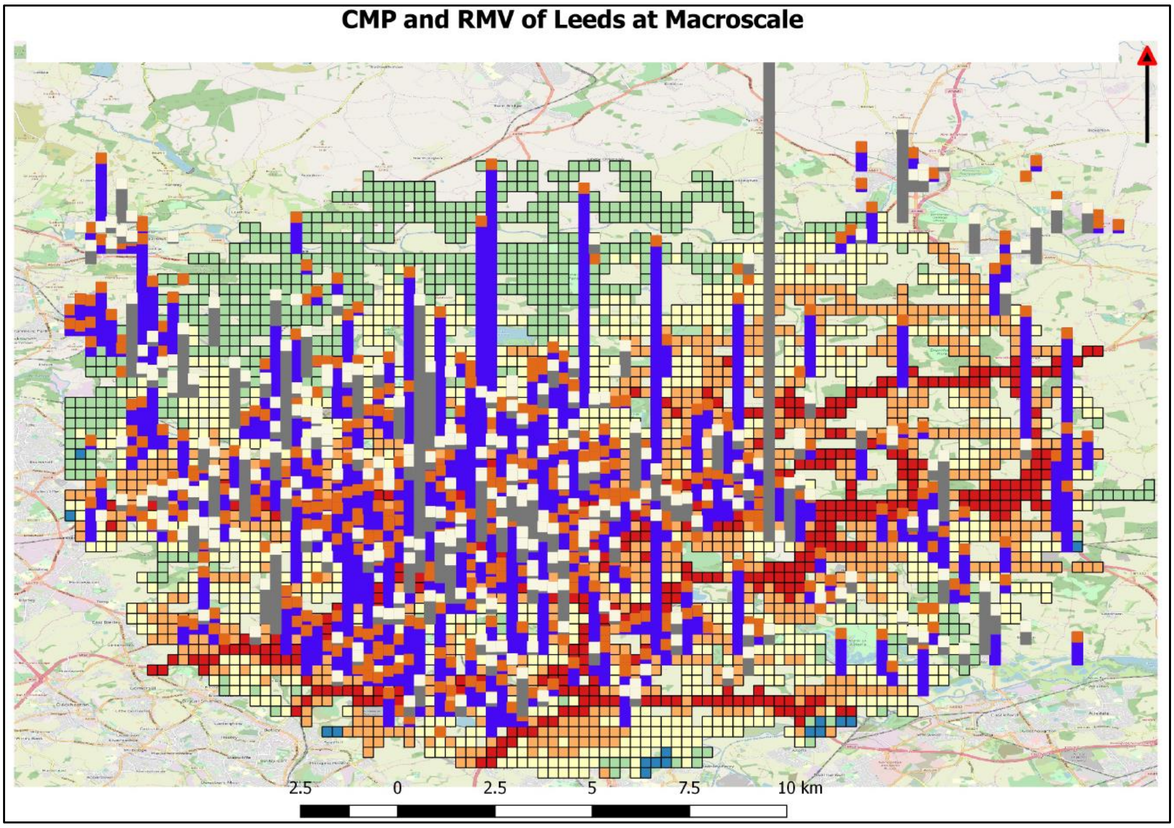
Figure 8: Spatial relationship between retail rental value changes (positive and negative) and CMP at Leeds mesoscale



Source: Authors' own (2019)

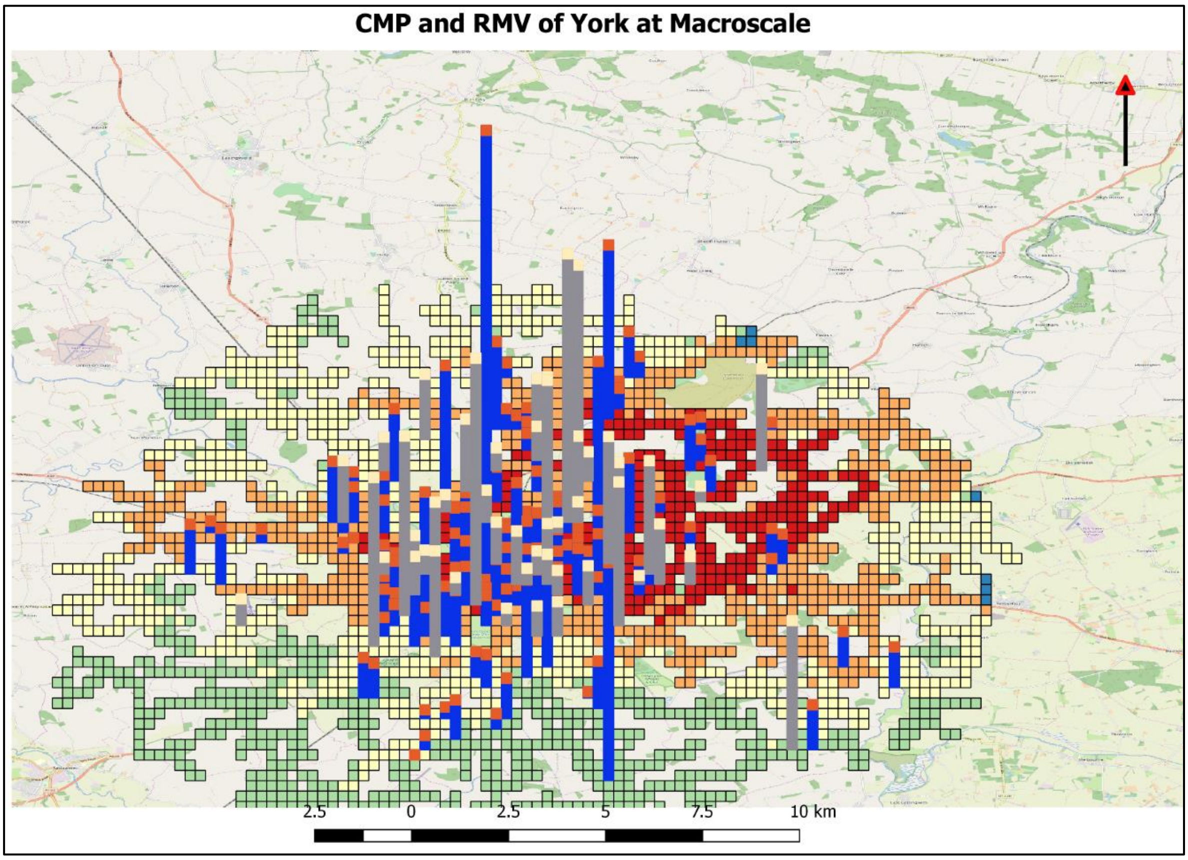
Figure 8 clearly shows that the negative rental value changes on Leeds mesoscale cluster more within the city centre, while the positive changes within the same spatial layouts are unevenly distributed. Figure 8 shows that the method of visualising relationship between RMV and CMP can be enhanced at smaller scale boundaries while revealing different types of changes. Nevertheless, comparison of relationship between the variables have been explored and presented at macroscale levels for York and Leeds. The study presents relationship between overall changes in retail rental value and CMP at macroscale for Leeds and York in Figures 9 and 10 respectively.

Figure 9: Relationship between Overall Changes in Retail Rental Value (RMV) and CMP at Leeds Macroscale



Source: Authors' own (2019)

Figure 10: Relationship between Overall Changes in Retail Rental Value (RMV) and CMP at York Macroscale



Source: Authors' own (2019)

The purple and grey columns in Figures 9 and 10 reveal the extents of positive and negative changes in retail rental value respectively on both cities. While pattern distribution of retail spaces across the two cities vary, the pattern of rental value changes also changes across the city macroscales. The figures show that distribution of retail rental value do not perfectly align with the configured integration output layer at the macroscale level. The spatial relationship between variables at the mesoscale (example), appear to show stronger relationship than variables at the macroscales. In other words, the relationship between configured accessibility index and changes in retail rental value becomes obscured as the scale boundary of analysis increases. Nevertheless, the result from Figures 8, 9 and 10 show that locations with good accessibility (red and orange tiles) have more rental value changes (both negative and positive) than segregated locations (blue and green tiles) across all scales for the two cities. This suggests that accessible locations (with potential high consumers' patronages) experience more changes in retail rental value than segregated locations on the two cities. In other words, the more accessible a city location, the greater the possibility of retail rental value changes.

However, the accessibility tiles at this level, has simply been estimated using the integration metric. To further understands the impact of other CMP variables (that is, choice and NACH) on changes in retail rental value, this study has conducted statistical analysis on variables across all sampled layouts. This was necessary to quantify the relationship between CMP and changes in retail rental value at mesoscale and macroscale for Leeds and York spatial layouts.

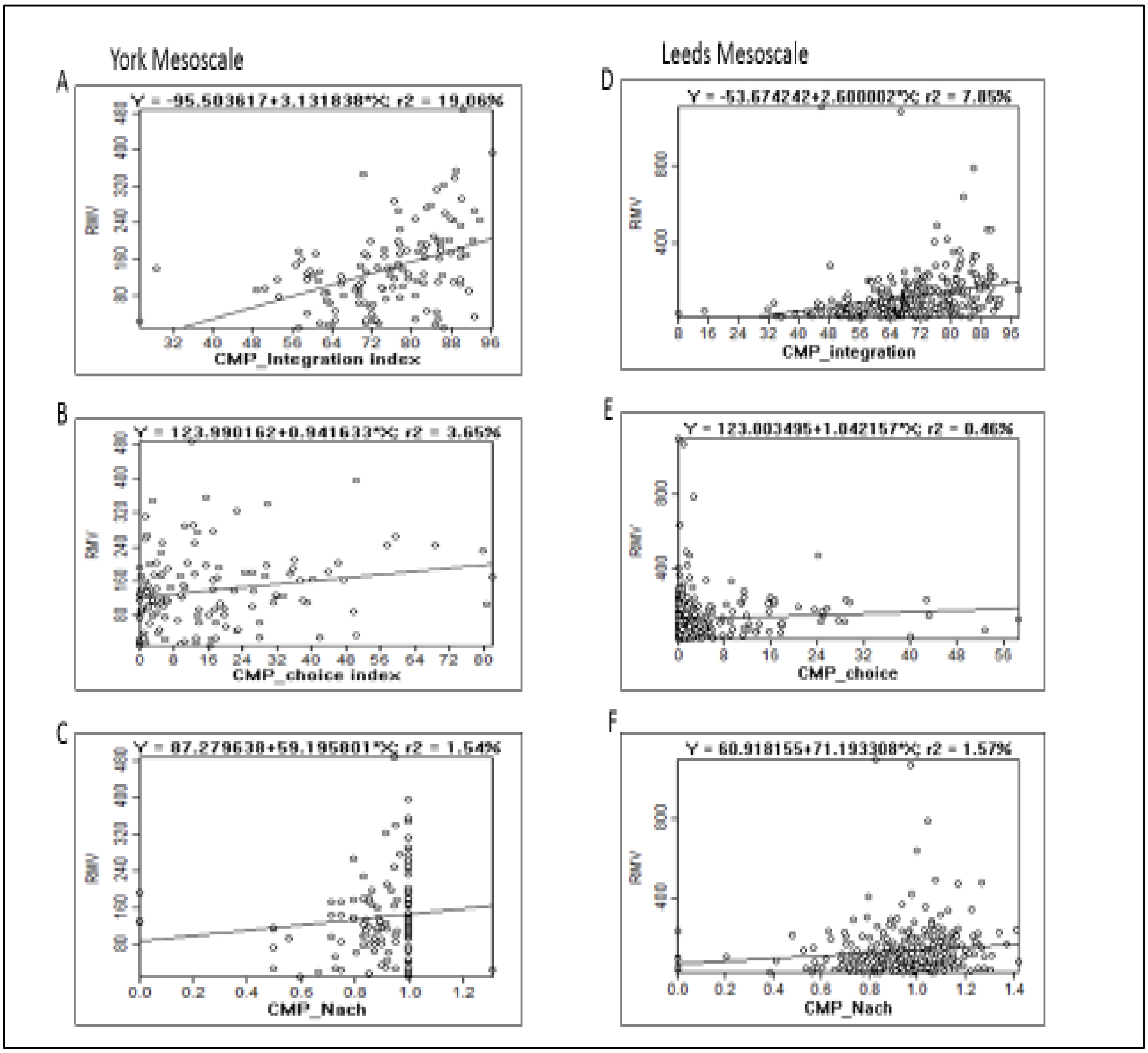
3.2 Statistical Analysis of Variables

Statistical analysis of variables are presented in scatter diagrams that show the correlation and regression outputs of group stat values of all variables at mesoscale and macroscale for York and Leeds. The logic behind this is to analyse contributory effects of CMP variables on changes in retail rental value. This study contends that establishing relevance of CMP variables on changes in retail rental value across sampled layouts will signal the most relevant CMP variables that can be adopted in modelling future performance of retail space (that is, future locational changes of retail rental value, assuming correlation exists between variables).

3.2.1. The Scatter Diagrams

A scatter diagram is a statistical tool utilised in running both correlation and regression analyses between two (or more) variables at a glance. Although this study does not focus mainly on correlation and regression analyses per se, it is assumed that computing correlation and regression analyses at various spatial scales and cities will indicate the most relevant CMP variables on retail rent changes. This is done by computing scatter diagrams showing overall relationships between variables at mesoscale and macroscale for York and Leeds. The changes in retail rental value (RMV) and CMP variables represent the independent and dependent variables respectively. As such, scatter plot diagrams showing relationships between RMV and CMP_ integration, RMV and CMP_ choice, and RMV and CMP_ NACH at mesoscale and macroscale for the two sampled cities are computed. Figure 11 compares the relationships between RMV and CMP variables (that is, integration, choice and NACH) at mesoscale for York and Leeds. Figures 11a, 11b and 11c respectively reveal the relationships (correlation and regression) between RMV and CMP_ integration, RMV and CMP_ choice, and RMV and CMP_ NACH at York mesoscale. While Figures 11d, 11e and 11f show the relationship between RMV and CMP_ integration, RMV and CMP_ choice, and RMV and CMP_ NACH at Leeds mesoscale.

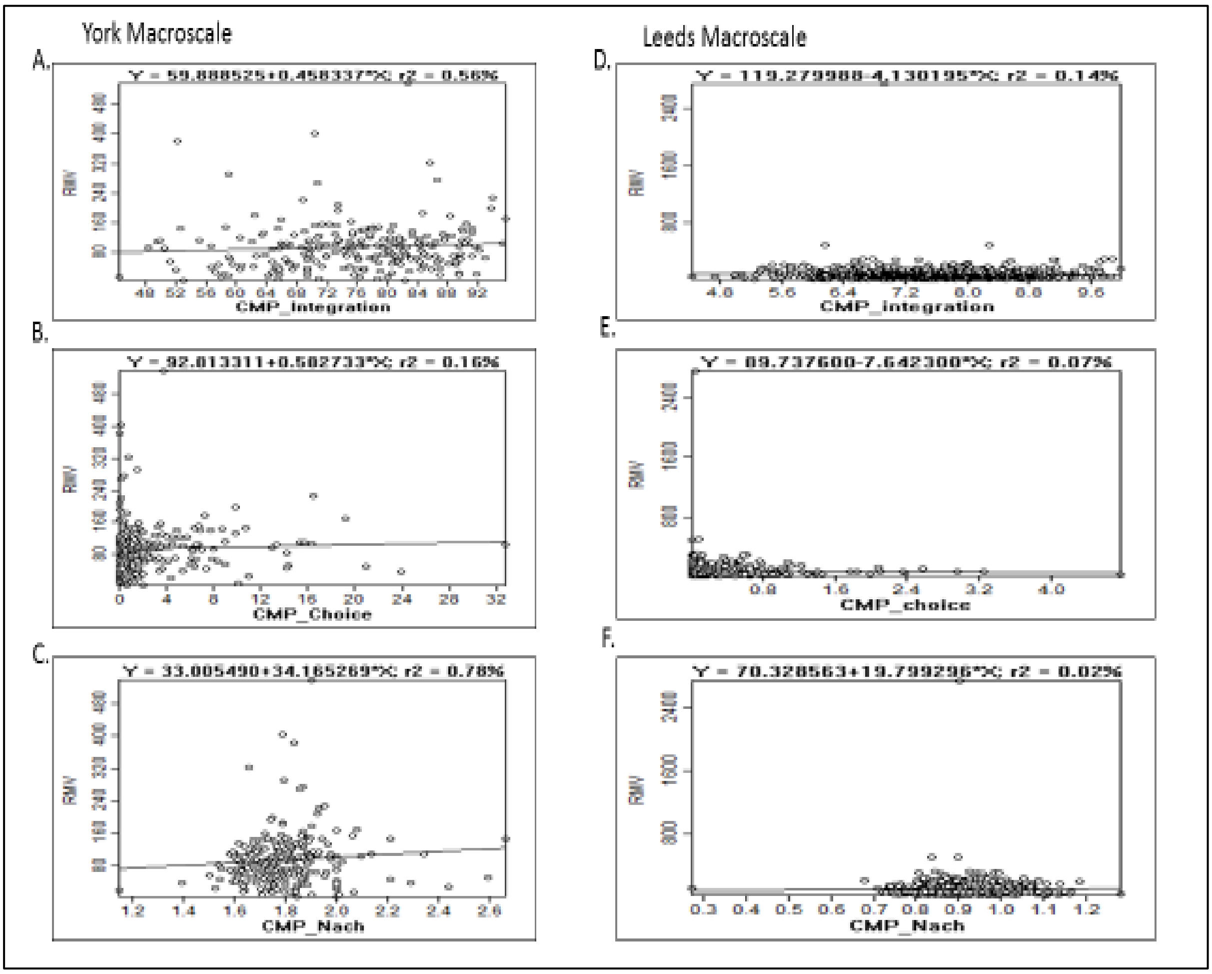
Figure 11: Comparing Statistical Relationship between RMV and CMP variables for York and Leeds at Mesoscale



Source: Authors' work (2019)

The figures (11a, 11b and 11c) in Figure 11 have shown that there are positive relationships between RMV and all the tested CMP variables. Nevertheless, the relationship between RMV and CMP_ integration indicates the strongest with 19.06% variability (as shown in figure 11a). Meanwhile, Figures (11d, 11e and 11f) showing relationships between RMV and CMP variables for Leeds at mesoscale have also indicated positive relationships but at lesser degrees when compared with outputs from York mesoscale. The comparison between York and Leeds at mesoscale reveals that relationship between variables (across all independent variables) are stronger at York mesoscale than Leeds mesoscale with the CMP_ integration variable showing highest variability and significance on changes in retail rental values for both cities. This suggests that CMP_ integration variable (that is, to-movement metric) has the highest contributory effect on changes in retail rental value in both cities at mesoscale. To validate this presumption, further analysis testing were conducted on the sampled cities at macroscale boundaries. Figure 12 shows comparisons of relationships between RMV and CMP variables at macroscale for both cities.

Figure 12: Comparing Statistical Relationship between RMV and CMP variables for York and Leeds at Macroscale



Source: Authors' own (2019)

Similar to Figure 11, Figure 12 has shown that there are variations in relationship outputs between RMV and CMP variables. Relationships between RMV and CMP variables at macroscale reveal that there are weak or no relationship between variables. This result shows the huge differences in variables (CMP and RMV) index across the cities at macroscales. In other words, it indicates that size of spatial boundaries thus influence relationship outputs between variables (in this case, RMV and CMP). This result corroborate existing visual relationship (in Figure 8, 9 and 10) that show that there are stronger relationships between variables at mesoscale than it is at the macroscale. Nevertheless, the CMP_ integration variable maintains it highest contributory effects on changes in retail rental value at Leeds macroscale as shown in Figure 12. While the CMP_ NACH shows the highest contributory effects on changes in retail rental value at York macroscale at about 0.78% variability compare to 0.56% of CMP_ integration. However, the CMP_ choice metric has maintained the least contribution to RMV variability in both cities at both scales.

4. CONCLUSIONS

This paper has introduced a new perspective of space syntax (spatial configuration) into the field of real estate, urban planning and other urban studies that do not traditionally recognise street networks but locations within cities. This study reveals that retail market performance and street components varies across cities. Hence, spatial relationship between changes in retail rental values and CMP variables varies across sampled spatial layouts in consistent pattern. The study has also shown that spatial extent (boundaries) of sampled layouts do affect relationship outputs of variables (in this case, CMP and RMV). As such, locational analyses of property market variables is highly recommended rather than conducting relationship analyses at citywide scales. Similarly, adopting the developed method of visualising relationships between RMV and CMP will widen applications of spatial configuration (space syntax) in the field of real estate that understands property market performance in terms of locations and not streets. This is because retail market performance judgements can be tied to consumer movement actions for property market actors to understand. As such, key real estate decisions such as, investment, development and occupation of retail space within any given city layout can be explored. This should enhance highest best use of city (centre) resources when adopted.

Further investigation in this study has shown that changes in retail rental values (that is retail space performance) across cities do not follow a uniform pattern. However, configuration of CMP through integration measure shows consistency in revealing the centrality and accessibility patterns of the entire sampled layouts.

The integration metrics has shown the highest level of significance to changes in retail rental value across most of the sampled layouts. That is, locations with high integration value have greater potential of changing rents than locations with low integration values. It is based on the statistical and geo-visualisation analyses that this paper recognises the potential of CMP_ integration in signalling future locational performance of retail space. Similarly, while this study has not distinguished between the types of retail rental value changes that integration metric influence, there is also potential to investigate how integration metrics relate and determine positive or negative changes in retail rental value. Further researches should be carried out to explore how integration metrics explain rental value changes at mesoscale and microscale (neighbourhood) analyses. Finally, this study has only focused its analyses on retail property (space) at macroscale and mesoscale. The developed methodology is applicable on all property types (e.g., residential, offices, leisure, industrial etc.) that require accessibility to function. The same developed method can also be deployed for microscale (neighbourhood) property market analysis (assuming similar datasets are available). Hence, spatial accessibility and performance of all property markets at all spatial scales can be explored using the developed techniques.

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