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GIS analysis on real estate values and economic activities. The City of Swindon (UK)

Keywords: Real estate values, Spatial analysis, GIS, Density Estimation, Kriging, Swindon (UK)

Abstract¹ The paper deals with the analysis of urban values and their spatial distribution in urban areas. We propose the use of GIS and spatial analytical techniques to model real estate prices and values in an urban area, producing different shapes and interpretations of an urban area. A test is done using real estate values available at unit postcode level for the City of Swindon (UK).

INTRODUCTION

Cities are privileged places hosting human activities and generally ‘dense’ in terms of functions, services, population (Clarke, as reported in Yeates and Gardner 1976), infrastructure (Alonso 1960), etc. located – or locatable - in a given area and generally such density functions, as well as the urban land values (Knos 1962; Evans, 1985; Haggett 2001) decrease moving out from the centre.

Scholars have been debating for decades on the shape of cities and the modals behind date, spanning from circular, concentric structures to more articulated radial or polycentric ones (Hoch and Waddel 1993; Waddel, Berry and Hoch 1993). To-date the existence of a central nucleus organizing the rest of the urban space is challenged by several centres developing from planning actions as well as different characters of places, deriving from the behaviours of a living and working population.

In this paper we analyse the spatial distribution and structure of house prices, applying Geographical Information Systems (GIS) and spatial analytical techniques to highlight high value areas and promising expansion directions for the city. The *scenario* is referred to a pre-crisis situation, analysing the 2007 house price values. Such values are provided by the Land Registry and represent sales data collected on all residential housing transactions. The analysis is aimed at demonstrating the validity of GIS and spatial analytical techniques in analysing real estate data and to understand shapes and patterns in an urban environment.

In the following paragraphs the study area of Swindon is introduced with a particular attention to the redevelopment plans and the ongoing actions that will possibly affect also the real estate market in the near future. The housing market in Swindon area is then introduced with reference to the

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¹ “Introduction”, “Point pattern analysis and urban values. Data and methods”, “Results and discussion”, and “Conclusions” were realized by Giuseppe Borruso. Andrea Porceddu realized the paragraph “The Study area. The city of Swindon (UK)” and Francesco Battaglia the paragraph “The real estate market in Swindon”. Where not differently specified, the elaborations have been done using Intergraph GeoMedia Professional and GeoMedia GRID 6.1 under the RRL agreement between Intergraph and the University of Trieste.

national, UK situation. We continue our analysis focusing our attention on GIS and spatial analytical techniques as tools for modelling urban prices and understand urban form. Geostatistics is used to model such features. Discussion and concluding remarks follow at the end of the paper.

THE STUDY AREA. THE CITY OF SWINDON (UK)

The city of Swindon is located in the Unitary Authority of the Borough of Swindon, in Wiltshire County in the South-Western region of England, at the centre of an ideal rectangle with Bristol, Gloucester, Winchester and Reading as vertexes. It is connected by important transport infrastructures as the M4 motorway, the A419/A417 to Gloucester and the A420 to Oxford, as well as the railways line connecting Bristol and London. The Borough of Swindon cover an area of 230 km² and hosts a population of 201,800 people (2010 estimate) and the main centre is the large town of Swindon, laying on a narrower area of nearly 60 km² and with a population around 156,000 inhabitants.

Swindon appeared as a small market specialised in barter trade until the 19th Century when the industrial revolution invested the city. Canals' constructions (Wilts and Berks in 1810 and North Wilts in 1819) increased accessibility trade opportunities, increasing also population and changing urban structure, while rail transport boosted the town, as in 1842 a new station for the Great Western Railway opened, with the function of shunting rail flows from London to a potential new rail connection to Gloucester. It was an opportunity to develop railways-based activities, and particularly rolling stock construction and maintenance that characterized Swindon economy for more than a century until the 60s of Twentieth Century – more than 14,500 employees were busy in rail – related activities – followed by a period of dismantling of the sector between the 70s and 1986. The economy changed radically, moving from an industry-oriented one to a service and hi-tech sector based one. Banking and financial services are leaders in terms of added values although manufacturing is still important. Nowadays Swindon economic environment is based on the automotive sectors (Honda, BMW and Renault have their plants there), ICT and electronics (Motorola, Dolby labs, Intel) and on insurance, finance and counselling (Nationwide, Zurich), Pharmaceutical companies (Patheon, Catalent Pharma Solutions).

Such conversion is transforming the economy in a knowledge intensive sector. Skilled professionals in engineering, computing, biotechnologies and pharmaceuticals are in fact needed in such economy. Also, the automotive sector has contributed creating an engineering cluster with suppliers and sub-contractors serving it, as well as creating demand for logistic spaces, made possible also thanks to the good accessibility of the area.

Logistics-oriented services concentration has allowed a further agglomeration of many retail and leisure activities, which have also been attracted by the new wave of urban regeneration's plans in order to revamp local retail network². Beside the Brunel Centre (with its 100 stores) and many other traditional retail areas like the ones in Old Town, retail supply is completed by two important and peculiar commercial centres (The Parade and Swindon Designer Outlet) and many peripheral retail parks (i.e., Greenbridge, Orbital and West Swindon District Centre). Prime retail rents in central areas show average values of GBP 185 per square feet, but outside the CBD the average value presents high decline levels, with rents level far below GBP 100 per square feet.

In the pre-crisis period, Swindon economy registered good performances, growing of +3.1% per year in the 2002 – 2007 period (a higher rate than the average UK value) and with growing employment (+0.8% per year) (Office for National Statistics).

Such activities and characteristics are contributing in transforming again Swindon economy, calling

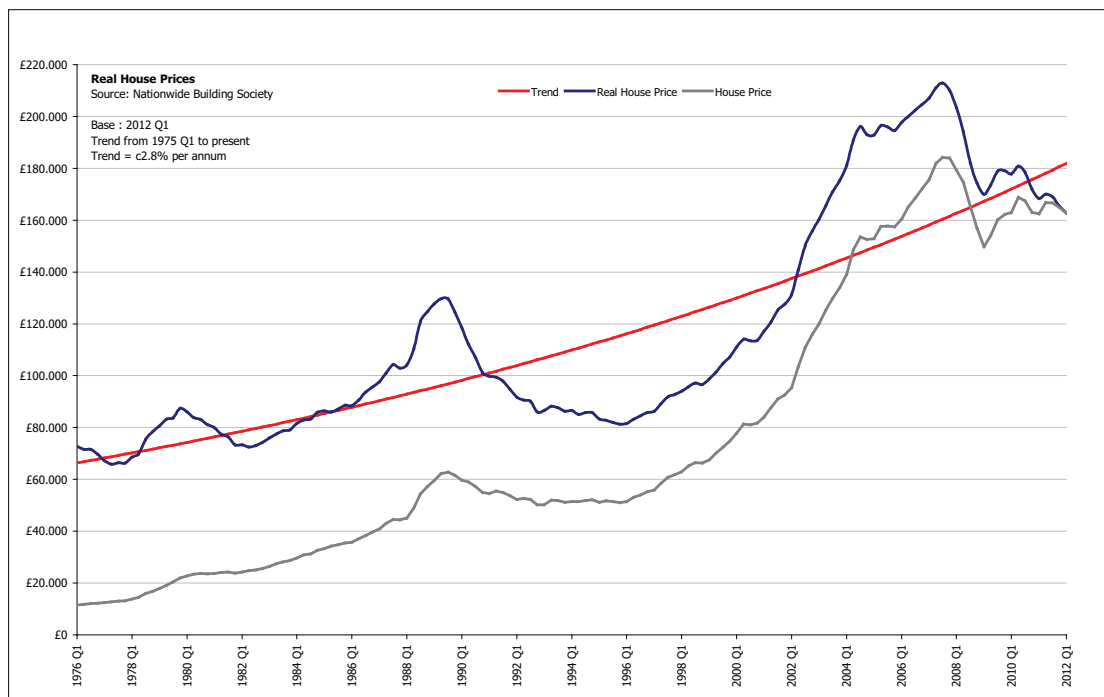
² The New Swindon Company identified 7 strategic development areas to strengthen retail and leisure services supply: Wharf Green, Canal Walk, The Parade, Regent Street (the main shopping high street), Bridge Street, Havelock Terrace and Wellington Street.

new inhabitants and making the city increase in its population – thanks also to the lower prices practiced here if compared to other locations in the UK and England. Such an increase is planned to be tackled by means of a new expansion of the town and a regenerating process involving the original town centre. A Regeneration Framework Plan for the town centre was set in 2002, originating the New Swindon Company (Now “Forward Swindon) to accomplish such a task, aimed at realizing a 1 Billion GBP investment to obtain space for new offices (nearly 1 million square feet), retail and leisure activities (more than 1 million square feet), homes (3,000 units). Such initiatives and the population growth in the area should benefit also the construction sector, both in terms of the realization of the Regeneration Framework Plan, aimed at creating new offices, services and residential accommodations. Research carried on by Real Estate Company Knight Frank foresaw in 2009 that the city’s expansion would head in the Southern part of the Borough, in an area included between the town and the M4 motorway with a horizon at 2026, although the economic recession slowed down also this project (Swindon Borough Council, 2009).

THE REAL ESTATE MARKET IN UK AND SWINDON.

The housing market in the UK is undergoing the effects of the global international financial crisis. After a period of growth (1996 – 2007) the average properties price fell steeply from the peak of the market in autumn 2007 (GBP 184,131.00 - nominal average price) to the minimum of the first quarter of 2009 (GBP 149,709.00) (Graph 1). After that low peak, the average price raised at the end of 2009 (GBP 162,116) and, although some fluctuations in 2010 and 2011 occurred, house prices are stable at nearly the same level at the beginning of 2012 (GBP 162,116 at the end of Q1). A modest +1.1 % of growth was in fact registered in 2011, while London was the best performing region with a +5.4 % annual increase.

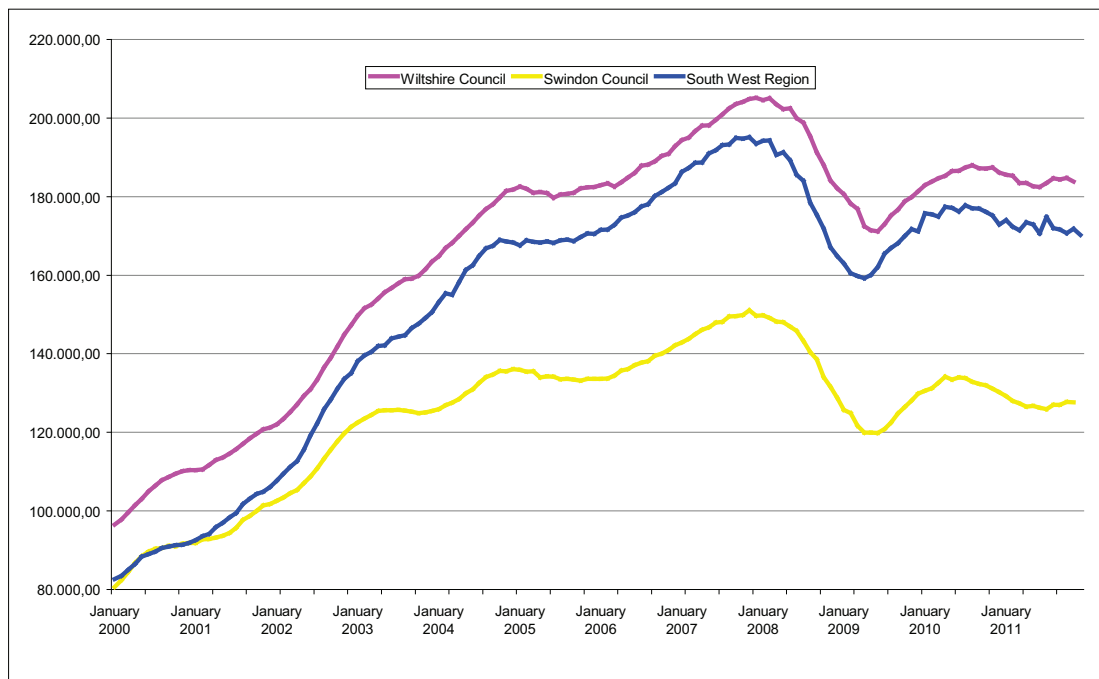
Graph 1 Nominal and Real House Prices and trend in real house prices in the UK.



Source: Nationwide Building Society. Nominal House Price is from UK All Properties series - not seasonally adjusted; House Prices adjusted for retail prices uses the Office for National Statistics Retail Price Index (RPI) to convert nominal prices to current prices.

The South Western part of England – where Swindon is located - presents some differences in real estate values. The South West experienced a +0.6% growth in Real estate values from 2010 to 2011, and Swindon appeared as the most affordable English region in terms of house price to earnings ratio (Nationwide). South West and Wiltshire present higher values than the UK datum, although the correlation between national and regional figures is very high (>0.99), the average price in this part of England is generally higher.

Graph 2 Comparison of Real House Sales Price in the UK between South West England, Wiltshire and Swindon Councils



Source: Nationwide Building Society

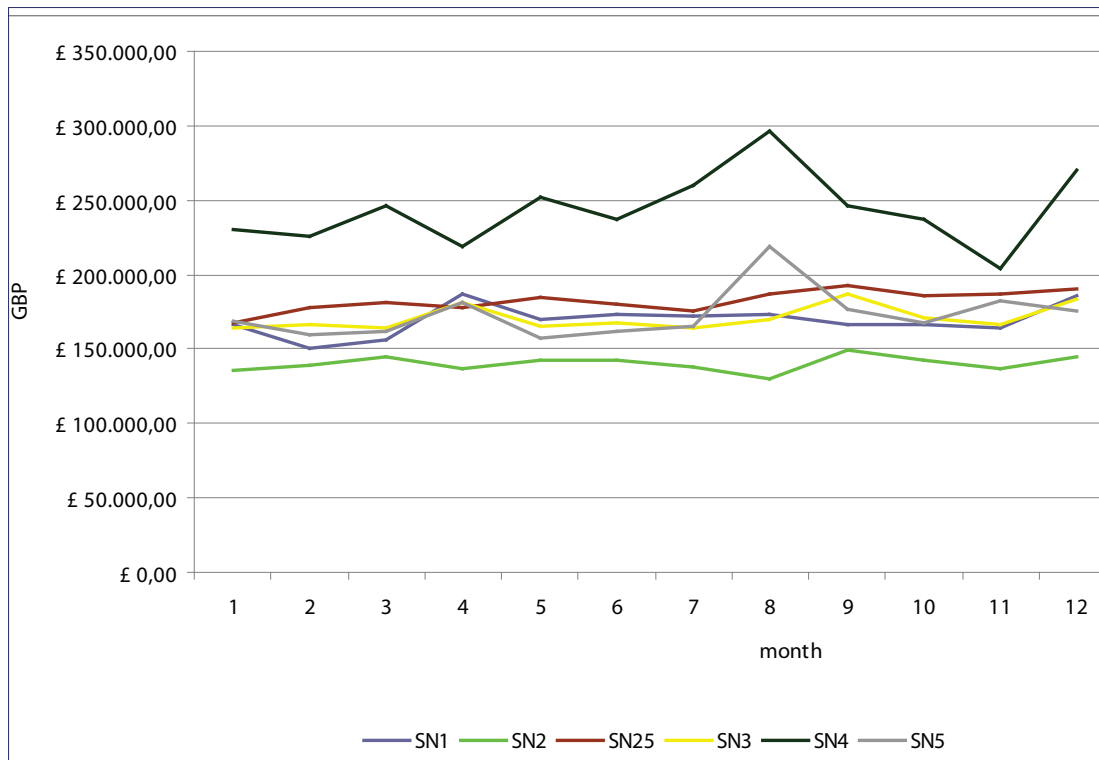
Moving to some more in depth considerations on the Swindon case, we focus on the data consistent with the pre-crisis situation, used to test our models, interesting also as they were available at unit postcode level and therefore usable both for more aggregated analysis and for examining the spatial distribution and variety of prices. Swindon does not differ too much in terms of some general characteristics from the rest of England, with semidetached and terraced houses showing similar values, although detached houses are more expensive and flats prices diverge for small amounts. Such differences can be justified observing our sample of 4,744 house sales in 2007, including only 781 detached properties, 936 flats, 1,119 semi-detached houses and 1,913 terraced ones, suggesting an extra-supply of semi-detached and terraced houses in the Swindon area.

Table 1 Average prices for postcode and urban / suburban areas (Prices in GBP)

POSTCODE AREA	TYPE				
	Detached	Flat	Semidet.	Terraced	Total
SN1 Urban	308,731.70	144,592.07	209,770.96	161,679.12	167,542.87
SN2 Urban	199,072.13	125,398.86	150,981.46	133,352.02	140,867.48
SN25 Urban	248,910.03	135,015.67	185,403.30	174,515.65	182,421.44
SN3 Peri	349,582.50	152,218.06	220,258.85	219,510.00	211,853.91
SN3 Urban	270,430.13	108,948.32	176,914.94	142,954.84	166,859.37
SN4 Sub	346,763.02	107,550.00	206,218.97	177,259.67	233,034.67
SN5 Sub	334,987.39	89,333.33	210,730.00	176,615.38	262,180.22
SN5 Urban	227,819.04	92,050.00	155,758.95	129,608.57	159,669.88
Total	267,675.12	132,725.11	178,960.41	153,021.18	173,993.76

Source: Her Majesty's Land Registry 2007

Graph 3 Comparison of average monthly house prices in Swindon, referred to postcode zones, year 2007



Source: Her Majesty's Land Registry 2007 House prices (nominal, non seasoned)

Observing the data as organized in Table 1, it results that despite the redevelopment plans put in action to revitalize the historic centre of the town (SN1 and SN2), – however still ongoing – the consumers’ attention focuses towards greenfields for developing brand new residential accommodations (SN25), consisting of detached houses separated from the city centre and the surrounding heavy industries. Furthermore, 2007 figures showed that real estate sales in the city centre decreased, after a good start, while the suburbs appear more reactive in terms of an increased demand.

POINT PATTERN ANALYSIS AND URBAN VALUES. DATA AND METHODS

The analysis was performed on different datasets, providing different images of the city, particularly in terms of the spatial distribution of the house prices. This was important both in terms of locating sales in space to derive areas of concentration of sales, and in terms of the house prices and their behaviour in the Swindon urban area. These elements were interesting in order to investigate how the redevelopment action put in place by the local authorities and regional development agencies of Swindon are actually pushing for the realization of new poles of attractions for people in terms of residentialities. The analysis was performed using different estimators, particularly based on point pattern analysis, to estimate densities of the phenomena observed and local and global estimate measure for examining house prices across the study area.

Point datasets were mainly used in the analysis, although other data were used for visualization purposes. Enumeration District data (Edline polygon) and road network data as OSCAR (© Ordnance Survey Centreline for Roads) were used. These latter data were integrated with freely available OpenStreetMap data for the Borough of Swindon area. They appeared updated but limited in their attribute’s characters, although comparable to the official OSCAR data for visualization purposes in terms of geometrical characteristics.

The analysis on house properties values was based on 4,744 records referred to year 2007 derived from Her Majesty’s Land Registry³ referred to Unit Postcode level (a total of 1,984 unit postcodes used) and organized in Flat, Terraced, Detached and Semidetached houses, with prices in GBP and containing date of selling announce and address. Data needed to be organized in spreadsheets and geocoded⁴ for elaboration in a GIS programme.

A Kernel Density Estimation was used to model the density and distribution of residential accommodation sales and the so-called ‘hot spots’ as areas presenting a higher level of concentration. The kernel is a 3-D function estimating density of events within its searching radius or bandwidth (τ) weighting them according to their distance from the estimation point (Gatrell *et al.*, 1996).

$$\hat{\lambda}(s) = \sum_{i=1}^n \frac{1}{\tau^2} k\left(\frac{s - s_i}{\tau}\right)$$

1

³ Land Registry data, accessed from “This is House Prices” website <http://www.thisishouseprices.co.uk/> on December 2008. However, “thisishouseprice” website does not produce house prices data with such a level of detail anymore, so real estate sales must be derived in other ways.

⁴ Data were geocoded using Google Earth Plus together with the website <http://www.batchgeocode.com>. The data precision and correspondence was also tested in order to avoid errors in data representation. Where the position was not available by means of one of the geocoding tools, it was decided to locate the single elements in correspondence to the closest geocoded element. To-date there is no need to perform such actions as UK made available the geographical location of unit postcode data, so the use of web – based tool for georeferencing data is no more so important.

where $\hat{\lambda}(s)$ is the intensity at location s , s_i is the observed i^{th} event, and $k(\cdot)$ is the kernel function, centred in location s , within which events s_i are counted and weighted (Gatrell, 1994).

House prices' dataset was given a particular attention in order to model spatial distribution of new houses' values over the region. As major urban redevelopment projects are on the ground, the different analyses carried on could reveal patterns and trends in the housing market of the area, although, as stated in the data description, the dataset chosen for the analysis is limited to the year 2007.

Spatial trends of prices were measured, with the value in GBP as a function of the distance from the city centre. That was possible using a bar graph showing the different frequencies for house categories at different distance classes from the centre.

To help and integrate this kind of exam, local analyses were performed on house prices, to analyse where 'peaks and valleys' in house prices' distribution take place. Local techniques are focused on local variability of the phenomenon under observation, assuming the existence of a local correlation decreasing as distance from the estimated location increases (Kelly, Atkinson 1999). The local was performed interpolating data in terms of their price in GBP and position on a map. The Inverse Distance Weighting (IDW) algorithm was used to create a surface of continuous data from the initial point pattern, this latter consisting of 1,984 unit postcode points where the 4,744 sold residential properties were georeferenced. As house dimensions were not reported, it was not possible to compute relative prices per house surface. House prices for the Year 2007 were therefore considered as sample values for the study area. The IDW has been used by geographers and spatial analyst to express distance decay factors in spatial behaviours and also to compare other interpolation techniques (Watson 1992). The IDW estimates values at location z' from a set of points z_i according to their distance and can be expressed as:

$$z' = \frac{\sum_i^n (1/d_i)^p z_i}{\sum_i^n (1/d_i)^p}$$

2

where d_i is the distance from z' (estimate) to the locations z_i (set of points) and p the power of distance. The IDW algorithm is based on the assumption that closer values are more similar to each other than farther ones, and therefore it assumes weighting closer values more in interpolating data. In the present research a power function $p = 2$ is used, this allowing to estimate closer values more than farther ones.

Research is ongoing to limit such effects by using geostatistical approaches (Kelly, Atkinson, 1999) and will be implemented in future works on this topic. Here a first application of the ordinary Kriging has been tested on some of the sub-datasets derived from the house prices data list – in particular flats and detached houses – and compared to the other interpolation techniques used.

Kriging can be considered similar to IDW when used to interpolate from sparse sample data of a single variable, usually when the sample contains less than 1,000 records. While IDW is a deterministic method, Kriging depends on a statistical model, where a function is estimated starting from the data themselves to obtain the most efficient weights.

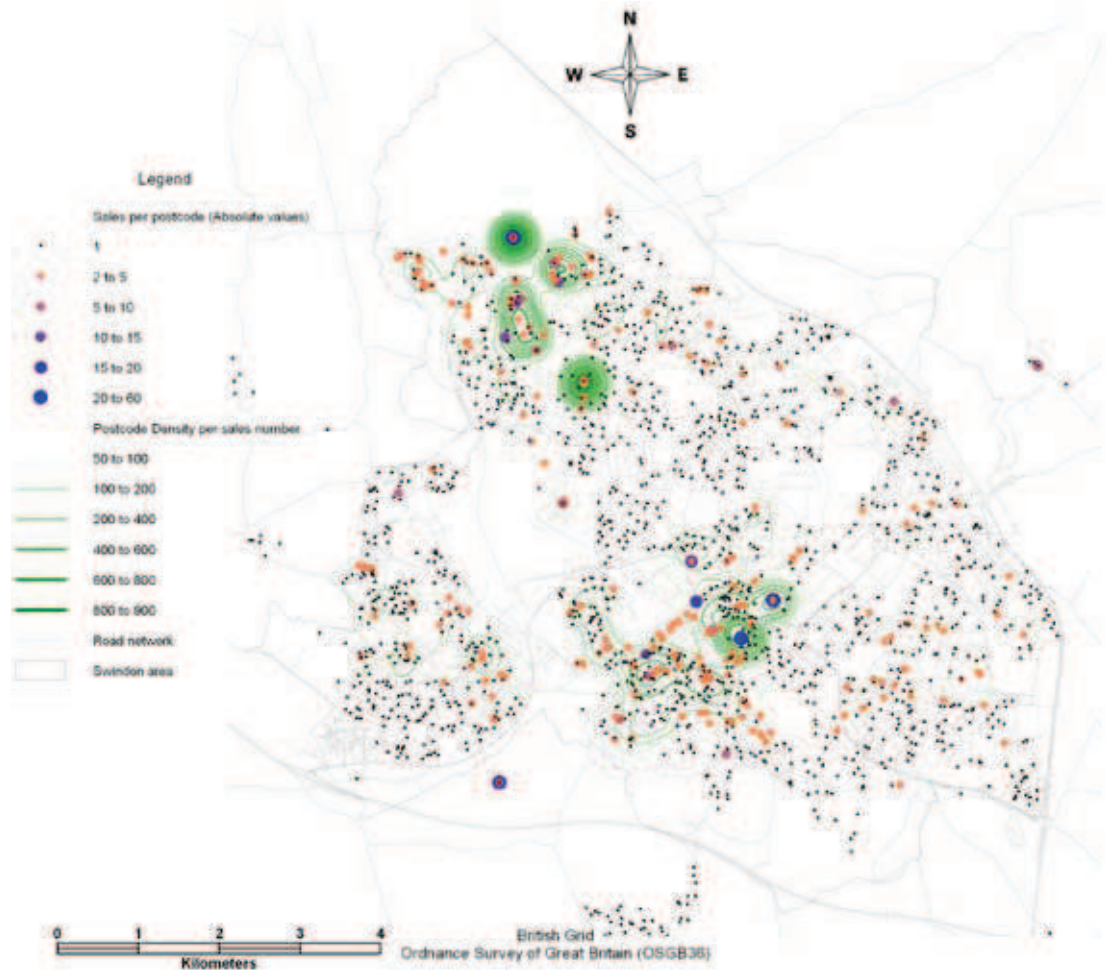
The technique provides linear unbiased estimation of values as a weighted average of observations surrounding the position of the estimate. Kriging estimates optimally by referring to the variogram, where the variance of sample values is related to a vector of distance and density of the values. In fitting the variogram, observations close to the estimate receive a higher weight than those far away. Some first applications of ordinary Kriging using a linear variogram have been carried on using the same dataset. The results produced to this point however are quite similar to those obtained by means of IDW.

RESULTS AND DISCUSSION

Density analysis.

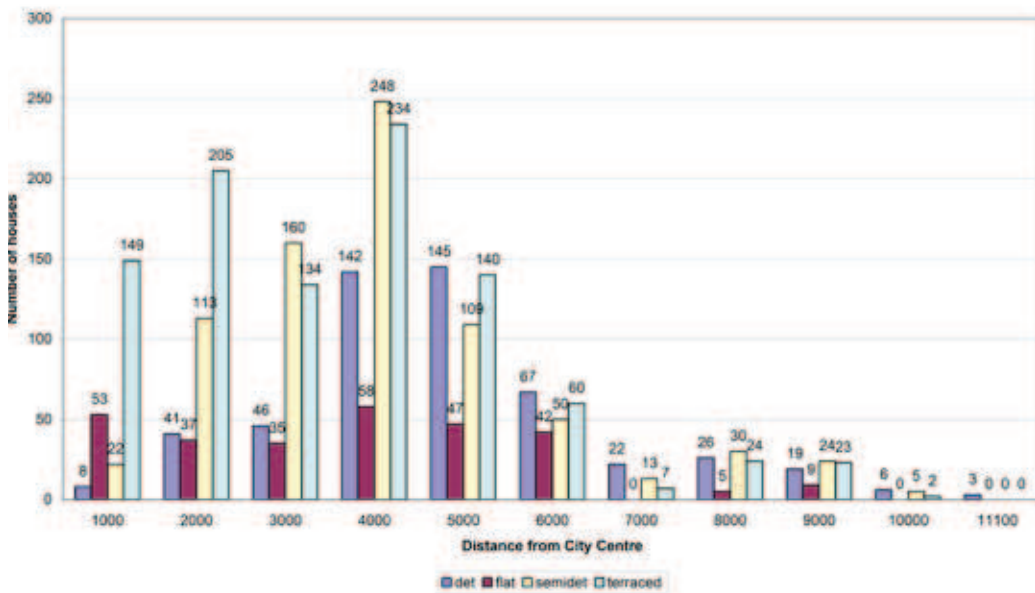
In previous analysis (Borruso, 2003; Battaglia, Borruso and Porceddu, 2010) we observed the spatial configuration of transport infrastructure concentration and urban shape by means of road network junctions. A quartic KDE was performed and a city centre with a denser network of streets and roads appeared as the city core. A quartic function is one of the most used KDE functions, with a Gaussian-like shape but assuming null values at the bandwidth extension, and weighting more the events closer to the estimation point. UK cities generally present a typical pattern of residential areas regularly organized according to a hierarchical road network. It is therefore easy to notice a relation between the urban land use and the road network pattern. We also observed (Battaglia, Borruso and Porceddu) a matching of population peaks close to high values of network density in the city centre and also in the residential areas - southwest and southeast of the urban area.

Figure 3 Kernel density estimation over 2007 house prices at UPC level.



We performed a quartic density analysis using a 500m bandwidth and a 20 m cell resolution over the spatial distribution of new houses, which displayed a series of peaks in two main areas of Swindon urban area (Figure 3). These are the Northwest part of the city, corresponding to postcode SN25, where the highest values as high as 800 events per km² are found. The concentration follows a North-Northwest – South-Southeast line. A second area can be found south of the railway line and close to the city centre, corresponding to postcode SN1. Here a smoother peak is visible, although the density estimate here counts for a maximum of 400 events per km², with the concentration of new houses following a Northeast – Southwest line.

Graph 4 House prices and distance from city centre.



Local analyses

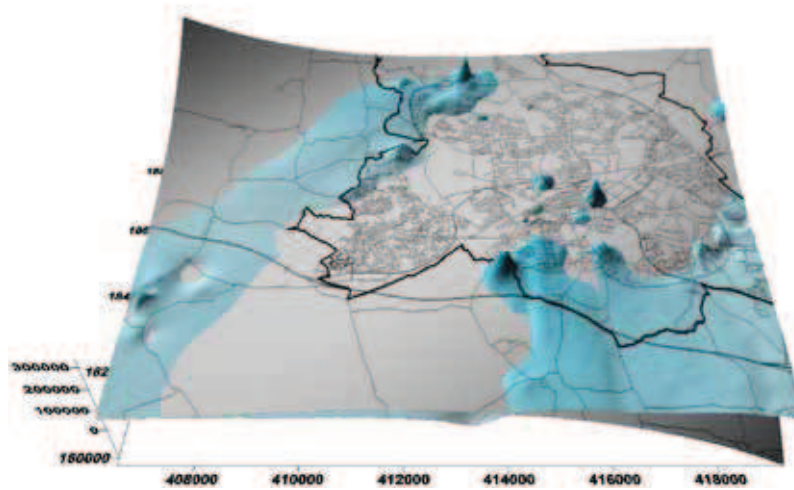
The analysis continued with the exam of the distribution of new houses – and their prices – differentiated by their category and according to the distance from the city centre (Graph 4). As anticipated in density analysis, an ideal ‘centre’ of the city was highlighted to serve as a starting point for further distance-based analysis. Doing that allowed to compute Euclidean distances for each house price value to the city centre. A first set of analysis allowed representing graphically the spatial distribution of new houses according to distance classes from the city centre.

The results were considered for the different categories of houses available. Although the new houses’ location registered span from the city centre to a distance of nearly 11 km from it, as some neighbouring satellite villages around the city of Swindon, the vast majority of events are located within 6 km from the city centre, that is the maximum distance from the border of Swindon urban area, with little figures located over such distance. That is particularly true for terraced houses (95.3% within 6 km), flats (97%), while detached and semidetached houses (87.82% and 91.77% respectively) present a wider distribution over the study region.

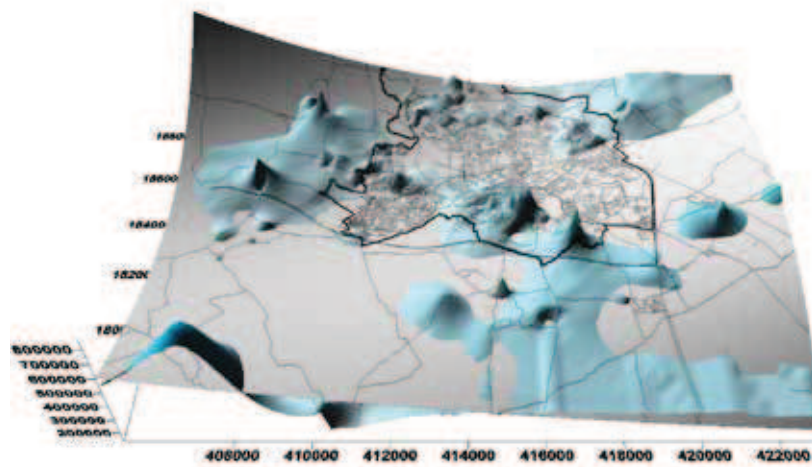
When moving to consider local analysis, the IDW displays the highest peaks in all the groups considered in the central area (SN1), particularly for semidetached and terraced houses. A second area

of high values is located in the North-western part of the study region corresponding to postcode area SN25 (Priory Vale area), to be considered as one of the more dynamic sector in terms of residential development of the Swindon area. Other areas of interest for house values are located in the North-eastern (SN3) and Western (SN5) parts of the Swindon Borough council. Out of the strict study region, some of the surrounding villages appear dynamic as location for new residential development, particularly of higher price houses. In particular Wootton Bassett and Wroughton (SN4) present high figures in terms of new realizations and, together with the other villages as Purton, Lydiard Millicent, Chiseldon, they represent the areas of high residential house prices for detached and semidetached houses.

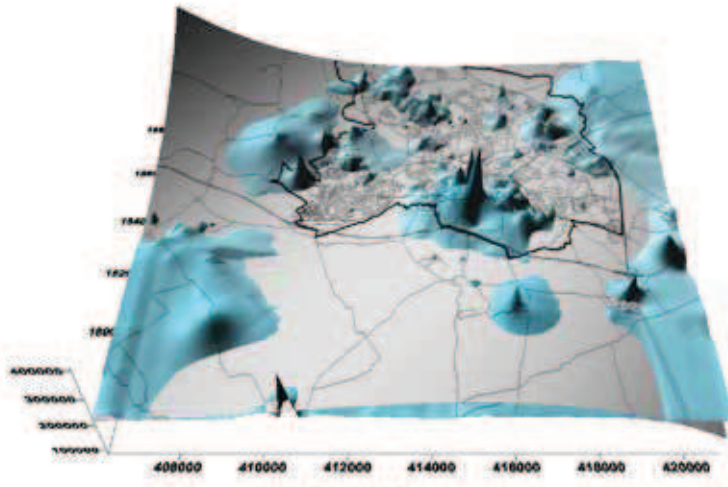
Figure 4. Global and local analysis of house prices. 3D views by elaborations using Golden Software Surfer 8.01



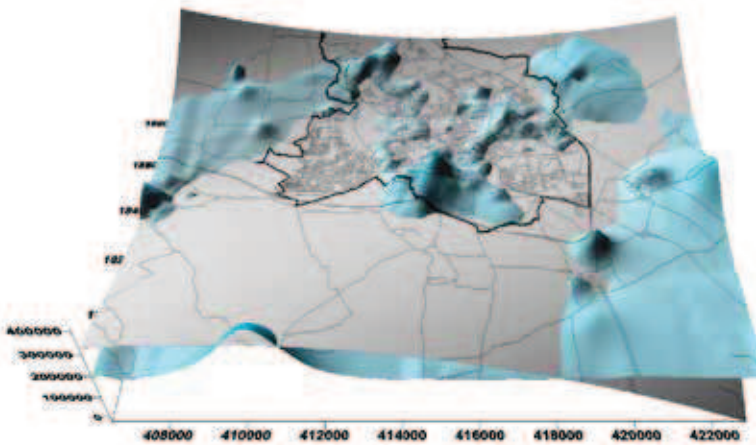
FLATS PRICE



DETACHED HOUSES PRICE



SEMIDETACHED HOUSES PRICE



TERRACED HOUSES PRICE

An ordinary Kriging relying on a linear variogram has been applied on two subsets of the original data available, as house prices for flats and detached houses. They were chosen as test point sets given their number being less than 1,000, as Kriging works well with a limited set of points, while higher figures require other families of interpolators. Graph 5 portrays the variograms for the two subsets while figure 5 maps the application of the Kriging function to the two datasets on the Swindon area. The results are similar, albeit less 'blocky', than those obtained applying the standard IDW function, and, particularly for the flats, confirming the two peaks in average prices around the city centre and North-western area of the study region, while detached houses present their peaks in the surrounding parts of Swindon urban area as well as South of the city centre itself. Additional informa-

tion is available if compared to the previous IDW plus trend surface analysis - where IDW peaks were visible as exceeding values from the trend surface itself, therefore masking the lower values – as areas of more homogenous lower values can be spotted, as, for instance, the central and around-centre areas of Swindon for detached houses.

Graph 5. Variogram of house prices a) flats; b) detached houses

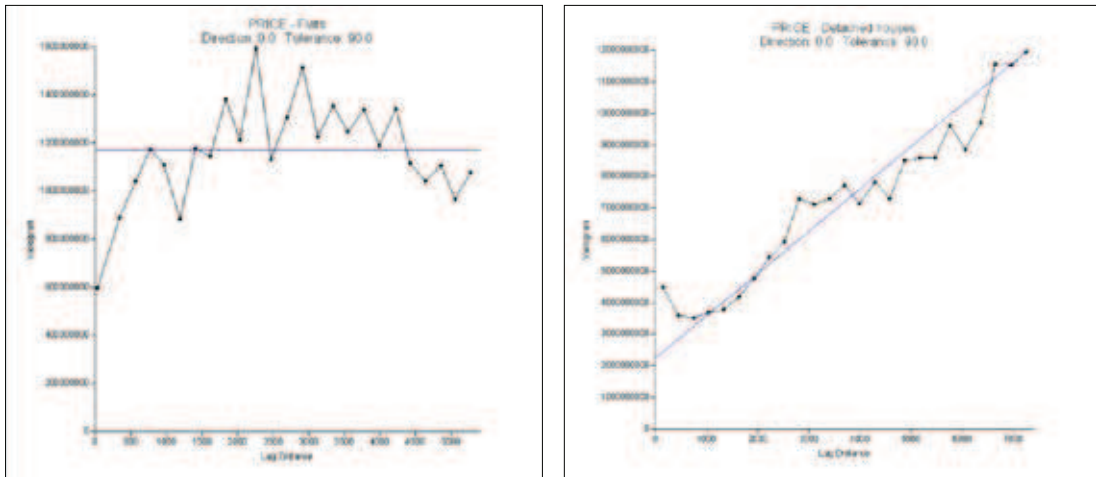
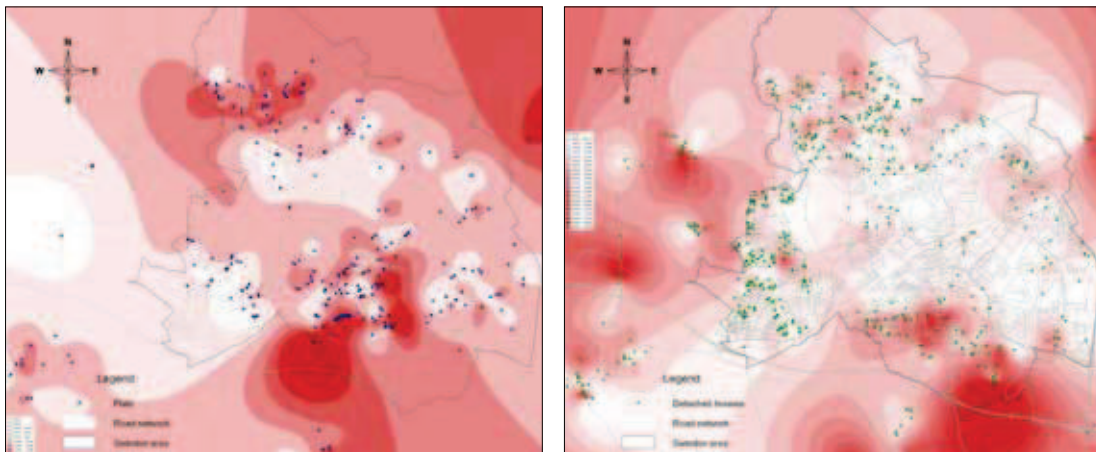


Figura 5 Ordinary Kriging on House Prices a) flats b) detached houses



CONCLUSIONS

In this paper we examined different issues concerning the spatial distribution of house prices in an urban environment. We applied spatial analytical techniques to discover urban dynamics related to real estate characteristics. The different methods were used on one side to highlight hot spots in the city of Swindon (UK) represented by the areas where a higher number of residential accommodations were offered in the year 2007. The other analysis on the point pattern or on subsets of the point pattern allowed drawing a ‘surface like’ image of the city, in terms of the variations of prices

in different parts of the city according to the different characteristics and to the distance from the centre, also differentiating the analysis for the residential accommodation category. In such sense we both applied a standard statistical analysis and also some local analysis based on interpolation methods (IDW and Kriging). In other analysis we considered also a comparison between local and global statistics.

The most dynamic areas of the city of Swindon can be located in the central and centre - south of the city and in the North-western quadrant (SN25) in terms of frequencies of houses available on sale. However, new houses on sale are located in the area surrounding the city centre at a certain distance from it – we observed a ‘divide’ in houses distribution moving out from the city centre – copying areas already noticed as presenting a quite high population density and therefore in a process of further housing development.

An ancillary objective was also represented by the possibility of implementing such a research using a limited amount of freely available data, therefore extending the potential of the combination of spatial analytical techniques for modelling urban areas and trends with a limited set of free geographical data.

This is particularly important to-date, as most industrialized countries are providing public interest data as open, allowing citizens being involved and informed of the public administration activities and also to use such data for various activities. Research is one of them and in this case it was possible thanks to the availability of house prices with detail of the address and unit postcode. An interesting observation can be also done reasoning on the publicly available data. When the house prices were downloaded we could rely on a website service collecting postcode based data from the UK Land Registry, while no cartographic data was freely available to georeference such lists of values, as postcodes as geographical features were not free. That led us to rely on web-based tools to georeference those data in terms of geographic rather than projected coordinates. In the most recent period the situation changed, as it is extremely difficult to find out house prices at unit postcode level, although it is quite easy to find them at administrative boundary level. On the other side, Ordnance Survey in the UK allowed unit postcodes as geographical features to be distributed and therefore GIS and spatial statistical analysis can be more easily computed connecting attribute data, as house prices.

The paper demonstrated also the need to combine qualitative and quantitative analysis to provide initial elements in the understanding some of the spatial issues and characteristics of an urban area in terms of house values and development.

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