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MASS APPRAISAL MODELLING IN MINSK: TESTING DIFFERENT MODELS LOCATION SENSITIVE

1. Introduction. Mass Appraisal is a valuation technique to appraise large quantities of properties with statistical and mathematical formal relationship between the price and the characteristics. Mass appraisal techniques are a field of research that applies different methodologies to define a single point estimate (The Appraisal of Real Estate, 13^{th} edition). Several contributions highlighted the possibility to classify mass appraisal method the above all is the distinction between Orthodox modeling and heretic modeling (Kauko and d'Amato, 2008) can be useful to distinguish well known and applied models from emerging approach to mass appraisal. The work is focused on a specific class mass appraisal modeling called Location Value Response Surface (O'Connor, 1982). These models have been recently applied to Bari (d'Amato, 2011). This work represents the first application of LVRS to the real estate market of the city of Minsk in Belarus. The sample was made on a database of National cadastral agency of Belarus. Data was undertook for 2011 under real transactions of dwellings in Minsk. Coordinates have been defined by means of the Google earth program.

2. LVRS: Mass Appraisal Modelling Dealing with Spatial Correlation. Location Value Response Surface (LVRS) is a mass appraisal modelling technique which was applied for the first time to the appraisal of single family houses in Lucas County, and is different approach to fixed neighbourhoods or composite submarkets analysis. This method has been applied in the U.S. (Eichenbaum, 1989; Eichenbaum, 1995). LVRS modelling can be classified in three different approaches. The first approach is based on the calculation of a location adjustment factor taking into account the spatial distribution of the selling prices. A contour plot overlying the area map shows the peaks and troughs of property values which are also called value influence centres (VICs). In general term the VIC can be defined as point(s), line(s) or area(s) in a contour map where it is possible to observe a relative maximum (positive) or a minimum (negative) location values (errors). The distance among each VIC is calculated for each obser-

*Alhough the work was made in strict cooperation between the authors the first and the second paragraph were approximately written by Nikolaj Siniak while the third and the fourth paragraph were written by Maurizio d'Amato vation. This is an important aspect because the distance can be calculated in several way and conceptually may be interesting replacing the physical distance with the time of travelling. A local adjustment factor will be calculated with a mean of 1 and a measure varying between –1 and 1.

Therefore it will become a measure of impact of location in the final regression model. In the application in Italy (d'Amato, 2011) the predictability of the model was improved. Recently was introduced the iterative location adjustment factor (d'Amato, 2010) as a way to detect and also verify the coordinates of the value influence centers.

A further approach starts running a MRA without constant. The model will present greater value of forecasting error in some areas and lower value in other areas. This forecasting error is the difference between the actual and the predicted selling in the in sample application of the model. Therefore the coordinates of each error ratio is.

The impact of each VIC on property data may use possible measures of the distance from the property to the VIC. The last approach is based on an interpolation grid, modelled to reflect the influence on each property of the location ratio factors within its proximity.

The application of this procedure is conditioned by the availability of data in all the area spatially analysed.

This premise is fundamental to analyse spatial interpolation. This process requires the surface of the *z* variable (selling price or error term) to be continuous and the data available at any location can be estimated. It must be stressed that another important premise of the application of these class of models is the detection of spatial dependency of the variable. As a consequence the value at any specific location is conditioned by the values of surrounding locations.

3. An Application of two LVRS models in Minsk. Mass Appraisal is an important research field both for academician and professional in Italy (Simonotti, 2006). Mass appraisal modelling in the last decade discovered the role of spatial correlation as an important aspect of mass appraisal modelling (Des Rosiers et al., 1999; Des Rosiers et al., 2003; Des Rosiers et al., 2005).The application started with a location blind model normally applied in context without spatial correlation. The linear form was justified by the application of a Box Cox (Box Cox, 1964) test. The variables used in the first model are the following three (table 1).

Table 1

Variables analysed in the Mass Appraisal Model

AR	Square meter of property
LEV	Level of floor
DAT	Date of sale

AR is a cardinal measure of square meter of flat, LEV is a discrete numerical variable measuring the level of the floor and, finally DAT is the date of the sale measured in months. The first regression location blind gave the results indicated in the table 2.

Table 2

Output of Linear Regression Model – Location Blind

	AR	LEV	DAT	LOC
	1104.615018	160.6335218	–590.4497489	14252.03144
R^2	0.821486232			
R^2 Adj	0.819670838			
F	452.51			
t	36.48981679	3.363878518	–2.866714917	6.774942083
MAPE	0.053724601			
COD	5.268769045			
PRD	1.02120147			
AL	0.988156044			

The independent variables of the model shows significant t-student test, the model shows a R^2 adjusted of 0.8196, a mean absolute percentage error of 0.053 indicated as MAPE*. The mean absolute percentage error is indicated in the following formula below measures the accuracy of the model. In the formula below PS are predicted selling value while AS is actual selling price and n is the number of the sample.

$$\text{MAPE} = \sum_{i=1}^{n} \frac{\left| \frac{\text{PS}_i - \text{AS}_i}{\text{AS}_i} \right| 100}{n}. \quad (1)$$

It is possible to observe a COD coefficient of deviation of 5.26. COD is the ratio between the AAD average absolute deviation and the A/S median as indicated in the formula below:

$$\text{COD} = 100 \frac{\text{AAD}}{\text{A/S}}. \quad (2)$$

A PRD or price related differential of 1.021. This is and indicator addressing assessment regressivity or progressivity. An appraisal can be defined regressive if the property with the highest value properties are undervalued compared to lower value properties. Appraisal will be defined pro-

*For a list of Mass Appraisal Ratios it is possibile to read the fourth version of Italian Property Valuation Code 2011 edited by Tecnoborsa having Prof. Marco Simonotti as scientific director.

gressive if the higher value properties will be over valued compared to lower value properties. The accepted interval for this indicator varies between 0.98 and 1.3. The formula 3 indicates PRD:

$$\mathrm{PRD} = \frac{\overline{\mathrm{A/S}}}{\overline{\overline{\mathrm{A/S}}}}. \tag{3}$$

The term A/S indicates the mean while the denominator indicates the weighted mean. This indicator should be included in the following interval: 0.90 and 1.10. The last indicator is AL Appraisal level measured through the arithmetic weighted mean ratio. The accepted interval for this indicator varies between 0.98 and 1.3. All the indicators are inside the required intervals.

Spatial correlation among the observations was preliminary detected using Moran's I (Moran, 1948; Moran, 1950) test. This index measures autocorrelation between values of the x vector. It ranges from –1 to +1 and each observation is only compared with its relevant neighbourhood. Positive Moran's I indicates positive autocorrelation which means that high values for x variable or price per square meters should be located near other high values while lower price per square meters should be located near other lower price per square meters. A significantly negative Moran's I implies spatial heterogeneity, or that high values are near low, or vice versa. Moran's test formula is indicated in the formula (4):

$$I = \frac{N\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})^2}, \tag{4}$$

Where x is the variable (price per square meter), and w_{ij} represents the set of neighbours j for observation i. The final result showed positive autocorrelation. Contour map is a map created joining all the points having similar measure (similar price per square meter). In the following map is possible to observe the contour map of the part of Minsk.

The first application is the Location Value Response Surface model is based on the VIC calculation. The calculation of value influence centers is based on the kriging technique applied to price per square meters observations. Starting from the spatial distribution of the price per unit it has been possible to observe the location influence. The surface obtained allowed the application of a block kriging based on a logarithmic variogram to generate a surface in order to model location variable in this residential property market. Kriging is a spatial interpolation technique which relies on analysis of the spatial variance of a phenomenon. Spatial variability is used to build experimental variogram and observe means differentials between values. In this application the “regional” variable is the price per square meter (Cressie, 1993).

Variograms are then formally approximated with a formal function. Starting from the contour map a kriging technique allowed the creation of map of value per unit measure in the area and three different value influence centers indicated in the table 3 below. In particular a peak is an area with highest value per square meters indicates with the H in table below. The other vic are areas with the lowest level of value per square meter. They have been indicated with the letter L in the table 3.

Table 3

Peaks in price per square meter

Lat	Lon	VIC
53.89601751	27.59489991	H
53.8961423	27.59824783	L
53.8434	27.584	L

The geographic result of the analysis is indicated in the figure 1 below.

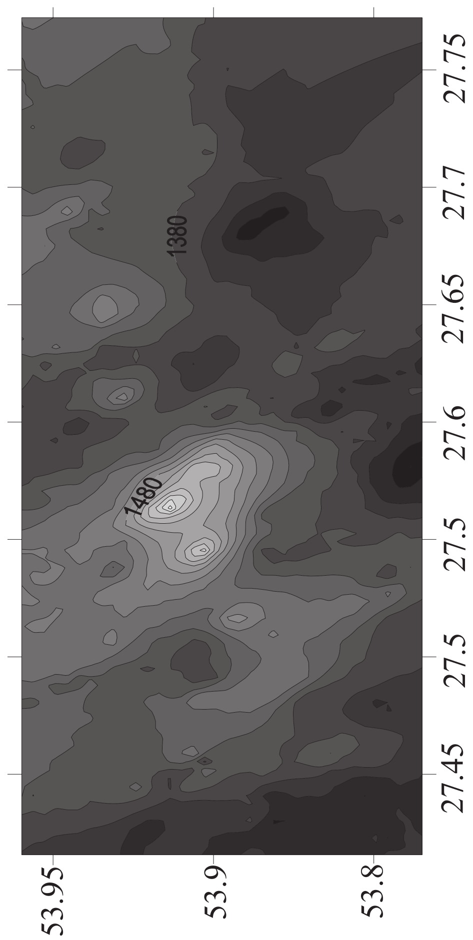

Fig. 1. Block Kriging applied to Price per Square Meter

The area is a spatial interpolation of price per unit (price per square meter) observations. The distance between each observation and the value influence centers indicated in the table 3 was included in the model with the variable LAF which means Location Adjustment Factor. The process has been described in the paragraph 2. The final results of the first LVRS model is indicated in the table 4 below.

Table 4

Output of Location Value Response Surface Model – Based on Price Per Unit Surface

	LAF	AR	LEV	DAT	LOC
	38946.09131	1130.256352	117.9569256	–478.604934	–26321.0922
R^2	0.846487007				
R^2 AdJ	0.844405475				
F	3137.519539				
t	7.008850877	39.89482014	2.629368113	–2.48895277	–4.31806497
MAPE	0.04871				
COD	4.730389821				
PRD	1.028031428				
AL	0.983305433				

The results indicated in the table 4 showed a interesting results in the quality of single parameters (t-student test), the quality of the model (F statistics) and finally an interesting R^2 Adj. It is possible to observe the increasing efficiency of the model which includes spatial components. The R2 Adj of the regression model indicated in the table 4 is 0.844. It is higher than the location blind model of table 2. It is also possible to observe an improvement in all the mass appraisal ratios indicated the beginning of this paragraph. Only the PRD is moderately higher than the model presented in the table 2. A second LVRS model is proposed. This model is based on spatial surface generated by percentage error. The percentage errors and their coordinates permitted a spatial analysis of error surface. Consequently a point kriging based on a logarithmic variogram allowed to define a surface as indicate in the following contour map.

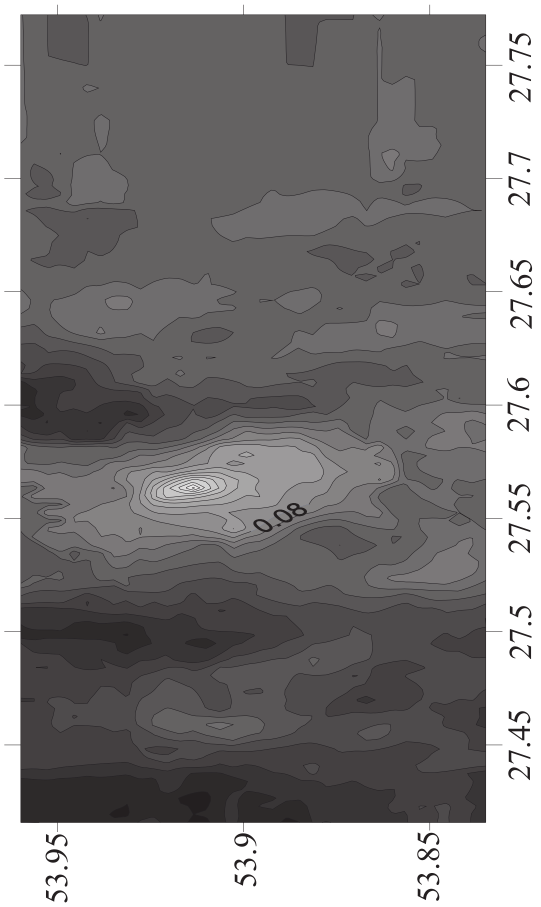

Fig. 2. Block Kriging applied to Percentage Error

In the contour map it is possible to observe several peaks. The clearest peak indicates a higher level of percentage error while the darkest value indicates a lower percentage error. The following point have been therefore selected:

Table 5

Lower and Higher Value in Error Surface

Lat	Lon	ET
53.921	27.5601	H
53.962	27.5221	L
53.864	27.634	H

In the table is indicated the Longitude and the Latitude in the final column there is also the error term. In this column the letter H means High percentage error while the letter L indicates lower percentage error. In a similar way after running a regression among coordinates and the peak of errors in the contour map it was possible to define an adjustment factor based on surface error who considered the distance between each observation and the higher and lower value in error surface.

The final results of the second LVRS model based on percentage error surface is indicated in the table below.

Table 6

Output of Location Value Response Surface Model – Based on Percentage Error Surface

	LAF - ET	AR	LEV	DAT	LOC
	–2615.26555	1121.78382	143.0117817	–493.4897	15523.62574
R^2	0.832828366				
R^2 Adj	0.830561632				
F	367.4133615				
t	–4.583402839	37.9768924	3.073173113	–2.453753	7.523858442
MAPE	0.054159142				
COD	5.303543885				
PRD	1.020301995				
AL	0.988797002				

The results indicated in the table 6 showed a interesting results in the quality of single parameters (t-student test), the quality of the model (F statistics) and finally an interesting R^2 Adj. The results showed an improvement compared to the location blind model indicated in the table 2. While the increase of R^2 Adj is lower than the model indicated in the table 4 (LVRS based on price per unit surface) the model base on percentage error showed the lower PRD.

In the table 7 below there is a comparison between the three models Location Blind, Location value Response Surface using value influence centers and location value response surface using error surface.

Table 7

Comparison Among the Three Different Mass Appraisal Models

	LOC BLIND	LVRS-VIC	LVRS-ET
R_2	0.821486232	0.84648701	0.832828366
R_2 Adj	0.819670838	0.84440547	0.830561632
MAPE	0.053167486	0.04870592	0.054320731
COD	5.268769045	4.73038982	5.317306601
PRD	1.02120147	1.02803143	1.020415778
AL	0.988156044	0.98330543	0.988905474

The table 7 compares the mass appraisal models applied in this work. The first column shows the output of a linear regression location blind model, the second column indicates the output of a location value response surface model based on price per unit surface and the third column shows the output of a location value response surface model based on error percentage surface.

The model with the highest level of R^2 is indicated in the second column. Both the LVRS model based on price per unit surface and LVRS model based on percentage error surface increased the quality of the location blind model. The best PRD is in the third column. It can be observed that the improvement are obtained dealing with spatial correlation.

4. Conclusions. At the end it is possible conclude that LVRS can be considered a useful tool for mass appraisal problem Two of the three models LVRS have been tested in the emerging real estate market of Minsk in Belarus showing good results. Among different methods LVRS based on price per unit showed the best R2 adjusted although a higher PRD.

The results showed the important role played by spatial correlation in the construction of mass appraisal models.

The application of mass appraisal modelling demonstrates the maturity of Belorussian real estate market. Further research may be required to compare the obtained results with other methods dealing with dimension such as spatial lag models, geographic weighted regression.

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