Mass valuation of urban land in Ukraine: from normative to a market-based approach

Marko Kryvobokov

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Real Estate Planning and Land Law
Department of Real Estate and Construction Management
School of Architecture and the Built Environment
Royal Institute of Technology (KTH)

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Abstract

The thesis is devoted to mass valuation of urban land when land market is immature. Such situation exists in Ukraine, a country in transition to market economy. There is lack of data about sale prices for land. However, the concept of land tax exists since 1992. A so-called normative value of land is a base for land taxation. The system of normative land valuation, currently existing in Ukraine, is based on normative documents rather than on market data.

The normative valuation includes a system of coefficients and land value zones. Normative prescriptions contain some degree of freedom for expert valuation at the local level. Thus, expert approach plays a crucial role in creation of value zones and estimation of zone coefficients in a particular locality. The problematic aspect with this is stipulated by the impossibility to use market prices for land.

The aim of the thesis is to delineate an alternative market-oriented approach to mass valuation. Under the conditions of immature land market, indirect methods can be applied. The most important attributes influencing land value can be extracted from foreign developed real estate markets. The domestic apartment market, which is well developed in Ukraine, can also give data for land assessment. The underdeveloped land market stipulates the necessity to widely use mathematical analysis of location attributes instead of prices. The use of GIS is a necessary condition for high-quality creation of value zones. GIS-based modelling increases the objectivity and efficiency of the analysis. The thesis consists of four papers.

The first paper delineates the overall structure of the research and describes the methods, which can be applicable, and the criteria, which can be used to evaluate the methods. The criteria of clearness, measurability, relevance, market orientation, and simplicity rather than accuracy were chosen. The methods of analysing foreign property markets, using apartment prices, and expert valuation are evaluated, and their links with creation of value zones are discussed.

In the second paper, the location attributes, which significantly influence market value of real estate in developed markets, are extracted using meta-analysis. The lists of statistically significant attributes are derived for two real estate groups. The first group is land and residential real estate; the second group is office-commercial real estate.

The derived attributes are exploited in a particular city in Ukraine. In the third paper, the Analytic Hierarchy Process is applied to estimate the weights of location attributes influencing apartment prices. Regression modelling in the fourth paper continues the investigation of apartment prices with the focus on location attributes.

The results of the papers are summarized, including discussion of the influence of location attributes and prospects for regression modelling of land prices. The use of location attributes and weights of their influence in creation of land value zones with GIS is also discussed.

Keywords: land assessment, location attribute, expert valuation, regression, apartment prices, GIS.
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1. Introduction

Real property taxation is an important feature of human civilisation. When society achieves a certain level of development, property taxation becomes inevitable. A land tax emerges when land is conceived as a property (Vlassenko, 1999). The appearance of property taxes in ancient states from Egypt to China (Larsson, 1991) exemplifies this fact.

The attempts to abolish the property taxation as an institute took place in different countries. The former USSR is one of historically recent examples. However, nowadays the post-Soviet countries are creating the system of property taxation again. According to Vlassenko (1999), if the history is any guide, than it can be suggested that land taxes in transitional countries will soon become ad valorem.

According to Stiglitz (2000), the desirable characteristics for any tax system are economic efficiency, administrative simplicity, flexibility, political responsibility, and fairness. McCluskey et al. (1998) suggest that the main considerations in choosing a property tax base should be political credibility, administrative feasibility, and public acceptability. The most commonly applied taxed values are market value and annual rental value. Different countries have different tax bases, choosing either land value or total property value\(^1\). Thus, both land and improvements are the objects for taxation in e.g. the USA, the UK, Canada, France, and Sweden, whereas the only land is taxed in e.g. Estonia, Kenya, and Jamaica (IAAO, 1990; Vlassenko, 2001; Kayuza, 2006). Both options have positive and negative features and different viewpoints exist in this respect. For example, Bahl (1998) argues that land tax is preferable in developing and transitional countries, though this tax is difficult to apply in practice, because tax administration is weak and land markets are poorly developed.

In the 1990s, urban land became something that could be bought and sold in Ukraine. It is usually considered as one of the prerequisites for the transition to market economy. Starting from 1993, more than 20,000 non-agricultural land parcels were sold in the primary market in Ukraine. These involve land sold by the local self-governments and state authorities to the private sector. Thus, more than 150 land parcels were sold in Kiev. Actually, it is hardly possible to interpret these sale prices as representing market values. At the same time, there are few land sales in the secondary market, i.e. when purchases involve private owners as sellers and buyers. Unfortunately, data about the secondary land market in Ukraine are not collected and analysed at the state level. According to Thomas (2003), the database of comparable land sales is very limited, and the use of the sales comparison method for valuation of land is essentially untenable. He also argues that there is in effect no secondary market for land in Kiev.

A land parcel in Ukraine is legally considered as a separate object, which does not include improvements. Since 2004, there are three types of real estate objects, for which the rights can be registered:
- land parcel;
- land parcel with improvements;
- improvements (buildings, structures, apartments, premises, etc.).

Even in countries with well-developed market economy, there are not many vacant land parcels that are sold in more central locations. In Ukraine, land parcels under buildings and structures are also

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\(^1\) The third option, when a tax base includes only the value of improvements, also exists, e.g. in Tanzania (Kayuza, 2006).
sold rarely even if the improvements are privatised or sold in the secondary market\(^2\). Land use rights are usually chosen as less costly alternative to ownership rights.

According to opinion of experts, the market for land is not yet finally formed and can be considered as underdeveloped. On the other hand, according to the leading Ukrainian land valuers Drapikovsky and Ivanova (2004), the development of land market started when the first privatised apartment was sold. The apartment market in Ukraine is well developed now. The development was encouraged by the privatisation of housing stock in the 1990s. Thus, the difficult task of market valuation of land can be solved, though the indirect methods can be in the focus.

The concept of land tax, which did not exist in the USSR for many years, was introduced in Ukraine in 1992. Buildings and structures are not taxed in Ukraine. According to the Law about Payment for Land (1992), the land tax base is a normative land value. It is non-market value in nature, its calculation is regulated by the normative documents: the Order of Normative Monetary Valuation of Agricultural Land and Land of Localities (1995), the Procedure of Normative Monetary Valuation of Agricultural Land and Land of Localities (2006), and Pattern of Technical Documentation of Monetary Valuation of Land (1998). There are other situations, not prescribed by law, when a normative land value is actually used, such as market valuation of land and urban planning.

Normative valuation is a kind of mass valuation. According to the documents, a prescribed model for the estimation of normative land value must be used in a locality. The value influencing attributes prescribed by the normative documents ought to be considered in the valuation model. The locality is divided into land value zones. The base land value, which was calculated for the locality as a whole, is recalculated for each zone and finally for each land parcel using the system of zone and local coefficients. Thus, the principles of horizontal and vertical equity are assumed being considered. From the outset, the leading Ukrainian experts in land valuation agreed that normative valuation should be used only during a period of transition and should be supplemented in due course by market valuation (Drapikovsky and Ivanova, 1998).

The area of analysis is the city of Donetsk with population of over one million people. Located in the eastern part of Ukraine, it is one of the biggest regional centres, currently in transition to market economy. Starting from the 1990s, about 40 land parcels were sold out by Donetsk city council. Prices for similar land parcels in similar locations sometimes differ dramatically. The city authorities do not collect data about market prices for land in the secondary market.

As a component of the existing normative land valuation in Donetsk, a zone coefficient is a weighted average of three value influencing attributes, namely the transport accessibility of centres (weight 0.40), the level of infrastructure development (0.30), and social attractiveness (0.30). The transport accessibility of centres contains the accessibility of the city centre, employment centres, public service centres, and mass rest centres and is calculated using a gravitation model. The level of infrastructure development reflects provision of a territory with water, sewerage, gas, heating, and electricity. Social attractiveness includes employment diversity, social and urban planning conditions, and prestige. According to the normative documents, other location attributes are taken into account at the local level, increasing or decreasing a normative value. These local coefficients compose six groups, namely functional-planning, engineering-geological, engineering-infrastructure, historical-cultural, natural-landscape, and sanitary-hygienic.

The problem arises when land experts, i.e. urban planners and land managers, chose the attributes and their weights on the base of normative prescriptions and their own opinion. The initial division

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\(^2\) The exceptions are the parcels with one-family houses and dachas. However, data about actual sale prices are not collected officially.
of a city area into value zones is executed also according to the opinion of land experts prior to any calculations. Unfortunately, when there is a lack of land market data, the experts can hardly know what particular attributes are the most appropriate and how to estimate their weights properly.

The aim of this thesis is to delineate an alternative market-oriented approach to land valuation for taxation purposes in Ukraine applying the fundamental principles of mass valuation. Value influencing attributes and the degree of their influence can be extracted from the market. Value zones can be created using mathematical methods and GIS.

Mass valuation aspects set the limits of the research, where no attention is paid to the details of administering tax. The objective is not to increase or decrease a land tax, but to make it fairer. Though the concept of fairness is a complex issue (McCluskey et al., 1998; Vlassenko, 2001), the focus in the current research is limited to horizontal and vertical equity. In this context a market-based assessment is considered as fairer than a normative-based valuation. The overall result of the research can be considered as a tool for mass valuation, which provides tax administration with a possibility of modelling different outcomes and comparing them.

Generally, two separate research projects were executed, one in Ukraine and one in Sweden. The former project was a Candidate of Science study at Donetsk National Technical University in Ukraine in 2000-2004. That thesis with the subject of formalization of urban land value zoning with application of GIS-model (Kryvobokov, 2005) was defended in Ukraine in 2005 resulted with a Candidate of Science degree. The Swedish project was a PhD study at KTH in Stockholm in 2002-2006. Having different topics, but the same object of research, the two projects were to considerable degree interconnected and interdependent. Therefore some results of the Ukrainian project are described in a separate section.

2. Research structure and methodology

The general structure of the research is delineated in Figure 1. The left part describes the Swedish project, with the focus on value influencing attributes and their weights. The right part of the scheme demonstrates the main directions of the Ukrainian project, devoted to creation of land value zones with GIS. In this section, the focus is on the Swedish project. The applied methods are introduced as the “bricks” and the outcomes are shown as the ovals. The research is described from up to the down.

First, the experience of well-developed foreign real estate markets is used to extract the most important location attributes, which influence the market value of real estate. For this, the meta-analysis of existing regression models is applied. A meta-analysis can be considered as the analysis of analyses. According to Glass (1976), it is the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. Though the statistical component at this stage of the thesis is very simple, the upper “brick” includes all the steps of meta-analysis, namely the selection of studies, the identification and coding of study characteristics, the analysis itself, and the report on findings. The important weakness of the meta-analysis is that it analyses results, which have different measurement errors.

The derived list of value influencing attributes can be used in a particular city in Ukraine to estimate the degrees of the relative importance of attributes. Under the condition of immature land market it was decided to analyse apartment prices instead of land prices. For this, regression analysis and different methods of expert valuation can be applied. The criteria for evaluation of different methods are used in the research: clearness, measurability, relevance, market orientation, and simplicity rather than accuracy. The three first criteria were borrowed from Lund (1998) and the last one was borrowed from Ward (2001).
Value influencing attributes and their weights

Meta-analysis of regression models

list of attributes

Analytic Hierarchy Process
weights of attributes

Regression model of apartment prices
weights of attributes

reconciliation
weights of attributes

Creation of land value zones with GIS

Polygons of parcels and blocks

small zones

small zones

aggregated zones

aggregated zones with zone coefficients

aggregated zones

aggregated zones with zone coefficients

Figure 1. General structure of the research
The evaluation of the regression analysis and expert valuation methods using the criteria highlighted the following. Regression analysis satisfies all the criteria and should be given the higher rating. Expert valuation methods do not fully meet the criteria of clearness and relevance. However, expert valuation is useful when market is young and information is hidden.

Among the methods of expert valuation, the Analytic Hierarchy Process (AHP) is chosen as sophisticated, transparent, and not very time-consuming. The AHP, developed by Saaty (1977), is based on the splitting a goal into sub-criteria. Describing the weaknesses of the AHP, Kauko (2002) mentions that the method is not robust, very sensitive, and not “scientific” in a classic sense. Nonetheless, these are the drawbacks of many expert valuation methods. The AHP is quite widely applied in real estate research, e.g. by Kauko (2002). In the thesis, the method is used for apartment market. The questionnaire is worked out, the results are statistically analysed, and a consistency ratio is calculated. The problematic aspects of inconsistency, scale, agency effect, and nonlinearity are discussed.

Regression analysis of relation between prices and characteristics of goods can be interpreted as the estimation of the willingness to pay for different characteristics (Rosen, 1974). Hedonic models are widely applied in studies of real estate prices in general and apartment prices in particular. In the thesis, it is used for apartment asking prices. There is no agreement in the literature on the best functional form for real estate regression model (e.g. Söderberg and Janssen, 2001; O’Connor, 2002). Both linear and log-linear models are specified in the research. Distance gradients are investigated. A spatial weight matrix is used to detect the problem with spatial autocorrelation.

The outcomes of the AHP and regression analysis are the weights of the value influencing attributes in a particular city. These results are compared and discussed in context of specifying the mass valuation model for land.

As Figure 1 shows, the main outcomes of the Swedish project, i.e. attributes and their weights, can be also used in creation of land value zones with GIS, connecting the two projects. For the polygons of land parcels and blocks, the magnitudes of attributes can be calculated. Adjacent polygons with similar magnitudes of the attributes are aggregated into small zones. The two methods are applied to estimate the similarity (the right part of Figure 1): similarity in attribute space and fuzzy similarity. The strengths of both methods are that they do not need the a priori determination of the number of clusters and can be completely formalized.

The similarity in attribute space can be measured with the method of hyperspheres, based on Euclidian distance (Aprausheva, 1986 and Aprausheva, 1987). In multidimensional attribute space, the areas with the highest concentration density are considered as preliminary clusters, which boundaries are created with hyperspheres. At the next stage, the clusters are defined more exactly using gravity function.

Alternatively, the polygons with their attributes can be considered as fuzzy sets. For them, fuzzy equality can be estimated as a function of equivalency (Melikhov et al., 1990). The fuzzy sets, which are recognized as fuzzy equal, can be aggregated. The property of transitivity allows aggregating into clusters more than two zones.

Small zones can be aggregated into bigger ones using the same methods (the right part of Figure 1). At this stage, the application of attribute weights is possible, though the two mentioned methods could be used without the weights. Thus, aggregated zones with or without zone coefficients is the outcome of the Ukrainian project.
3. Summary of four papers


Paper 4 was written in co-authorship with Mats Wilhelmsson. The individual contribution of Marko Kryvobokov was the initiation of the paper, data collection, application of GIS, descriptive analysis, formulation of general proposals for initial model specifications, and discussion of the results. Mats Wilhelmsson as an expert in econometrics executed regression analysis, which included the elaboration and testing of different Ordinary Least Square (OLS) models as well as spatial autoregressive models and spatial error models; he also considerably contributed to the text.

The characteristics that influence the value of real estate are named in the literature as either factors or attributes. In Paper 1, the combination of words “value influence factor” is applied. Adair et al. (1996) and Daly et al. (2003) use more elegant alternative “value influencing factor”. However, the term “factor” usually implies the execution of the statistical algorithm of factor analysis. In the thesis, this technique is not applied. Therefore, in Paper 2, Paper 3, Paper 4, and Summary the terms “value influencing attribute” and “location attribute” are used.

Paper 1


The first paper is a detailed description of the research structure. The existing principles of normative valuation of urban land in Ukraine are analysed with the focus on value zones, the weaknesses are considered. The paper includes the general sketch of two research projects: Swedish and Ukrainian as well as description and evaluation of the methods for the former project.

Zone coefficient should reflect a ratio of land value in a particular value zone to a city average value. According to normative documents, a zone coefficient is the weighted average of the value influencing attributes within the zone. The choice of the attributes and their weights as well as the initial division of a city area into zones is executed with expert approach, which arises problems when there is a lack of land market data.

The focus on the creation of value zones is stipulated by the possibility to use market principles in this crucial step of valuation. The existing system of normative valuation can be evolutionary directed to market approach, and a zone coefficient gives such opportunity. Under the conditions of immature and weak-investigated land market the starting point can be the use of data from foreign well-developed markets. Thus, the value influencing attributes, which really work under market conditions, should be found. The goal in the research is, like in the paper of the City of Calgary Assessment Department (1998); to explain a lot with a little, therefore the focus should be on the most important attributes. After that the methods should be chosen to estimate the weights of the extracted attributes in a particular city in Ukraine. The questions of creation of value zones are

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discussed as well. For this, GIS-modelling and mathematical methods of clustering using fuzzy sets and multidimensional space of attributes are appropriate.

To extract the important attributes from well-developed real estate markets, the meta-analysis of regression models is applicable. In Paper 1, this method was named “comparative regression”. The existing regression models created for real estate values in different countries can be used as a source of information. The weights of the value influencing attributes can be calculated using the corresponding regression coefficients. However, the main outcome of the meta-analysis in this research should be the list of attributes.

To estimate the degrees of importance of value influencing attributes in one or another Ukrainian city, it is proposed to use the apartment prices and expert opinion methods. Among the latter, different methods are considered: the contingent valuation, the contingent choice, the Delphi, and the AHP. The conclusion is made about the higher rating for using apartment prices because of higher relevance and market orientation.

The weights of attributes estimated in a particular city should be compared and reconciled. The magnitude of attributes, weighted or not, can be considered as characteristics of land parcels and blocks in a city. Mathematically estimating the degrees of similarity of these characteristics, it is possible to aggregate the adjacent similar parcels and blocks into value zones using GIS-based model.

**Paper 2**

Kryvobokov, M. (2004). “What location attributes are the most important for market value? Extraction of attributes from regression models”.

The aim of the paper is the extraction of the value influencing attributes, which are the most important for market value of urban land. For this, a meta-analysis is applied for 39 sources containing 81 regression models. The majority of these sources are the studies of developed real estate markets recently published in leading property journals.

The analysed models are OLS and Least Squares corrected for heteroskedasticity. In the models, the dependent variable is a sale price, market-based assessed value, and market rent. Property types in Paper 2 are divided into two groups. The first group includes residential real estate and land. The second group is office-commercial real estate. The analysis consists of two stages: extraction of the value influencing attributes and estimation of their weights.

The focus is on external location attributes, which can be used in modelling other territories. These attributes are named in the literature as “locational”, “proximity”, “census”, “neighbourhood”, etc. All the attributes are divided into groups, e.g. central business district (CBD) accessibility, crime level, road accessibility and characteristics, etc. The task is to select only the statistically significant attributes and to exclude those considered being unimportant. The 10% significance level is chosen. For each group of attributes, the frequency of use is calculated.

The second stage is an estimation of weights of significant attributes. In the regression equation, value influencing attributes compose the independent variables. The comparative weight of an attribute can be calculated as a ratio, where the numerator is the absolute value of the corresponding

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4 The paper is accepted for publication in *Property Management*, probably in Vol. 25, No 3, 2006.
regression coefficient, and the denominator is the sum of the absolute values of coefficients for all location attributes. The units of measurement of attributes must be considered.

For linear regression the process of weights’ estimation is more manifest and clear. In logarithmic models, a regression coefficient reflects the influence of a logarithm of an attribute to a logarithm of price/constant ratio. Therefore the weights derived from logarithmic models cannot be used for a linear model specification. However, in practice the logarithmic models are used more often. Therefore these two forms of regression models are considered separately in Paper 2.

The groups of attributes, which are used most frequently for land and residential real estate in 33 sources, are the following (the order corresponds to diminishing frequency):
- CBD accessibility;
- demographic characteristics;
- water objects accessibility;
- green area accessibility;
- income level of population and prestige;
- commercial objects accessibility and characteristics;
- road accessibility and characteristics;
- planning and urban development characteristics;
- nuisance proximity;
- educational level of population;
- crime level.

For office-commercial real estate, the order of diminishing frequency for use of the most important attributes in 6 sources is the following:
- commercial objects accessibility and characteristics;
- income level of population and prestige;
- CBD accessibility;
- road accessibility and characteristics;
- water objects accessibility.

The other attributes, which are less frequently applied in both real estate groups, are the following:
- inner public transport accessibility;
- air and train accessibility;
- racial composition;
- educational facilities accessibility and characteristics;
- secondary centre accessibility;
- general level of neighbourhood quality.

The extracted weights of location attributes are compared separately for linear and logarithmic models. In both cases, generally the most important attribute is CBD accessibility, which median weights are the highest. However, the influence of important attributes very differs between models and cities. Thus, for office-commercial real estate in the Los Angeles MSA (Sivitanidou, 1997) the weight of secondary centre accessibility is equal to that of CBD accessibility, whereas e.g. for house prices in the Quebec Urban Community (Des Rosiers et al., 1996) the most important attribute is commercial objects accessibility.

Therefore the main outcome in Paper 2 is the lists of the most important location attributes. The derived attributes can be used in Ukraine and other countries in transition to increase the degree of objectivity in land assessment. It seems reasonable to begin using the attributes from the top to the bottom of the lists going down as far as resources allow. Undoubtedly, the lists of attributes are not universal. The examples of different cities demonstrate that in particular cases other attributes
should be applied. Nevertheless, the lists of attributes outlined in Paper 2 can improve assessment, making it more scientific and less of the art.

Paper 3


Paper 2 outlined the lists of the most important location attributes. The task of Paper 3 is to estimate the weights of the attributes in a particular city in Ukraine with expert valuation methods. The area of analysis is the city of Donetsk. The primary market for land in Donetsk is immature. As the apartment market is much better developed, this market is analysed. The outcomes concerning the location components of apartment prices can be used in land assessment.

The lists of attributes from Paper 2 are discussed and adapted to the conditions of Donetsk. The units of measurement are specified explicitly. Thus, the attributes analysed in Donetsk are the following:

- 1 km closer to the CBD;
- 1 km closer to the nearest secondary centre;
- 100 m closer to the nearest shop;
- 100 closer to the nearest stop;
- 1 km closer to the railway station;
- 100 m closer to the river (lake, green area);
- 1 km farther from nuisance;
- absence of traffic noise (dummy);
- decrease in crime rate by 10%;
- prestige (dummy for location in a prestigious area).

In the AHP, the weights of attributes are determined via a pair-wise comparison. A simple linear model is applied. A one-level value tree is used, i.e. the weights of the attributes are assumed to determine the location value. The direct questionnaire as an alternative to the AHP includes the assignment to state directly the percentage of influence of the attributes.

A pre-selected group of respondents is an important feature of the AHP. With the intention to choose the best experts, 20 respondents were selected, but only 17 of them responded. The respondents compose four professional groups: valuers, realtors, urban planners, and land managers.

The results of the AHP are analysed both with and without the 0.10 cut-off rule with the focus on the latter result. The statistics of the results of direct questionnaire are in general similar to that of the AHP. In both the AHP and direct questionnaire results, the highest weight is derived for prestige, the second highest weight is for the CBD accessibility, and the lowest weight is for the railway station accessibility.

At the same time, the weight of prestige in the direct questionnaire is significantly higher than that in the AHP. On the other hand, the realtors specify zero weight for the railway station accessibility in direct questionnaire, but they cannot do the same in the AHP, where the corresponding weight is of 0.01. Thus, the study illustrates that the AHP is characterised by a smoothing effect, i.e. it

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generates lower maximum weights and higher minimum weights in comparison with the direct questionnaire.

A formal heuristically chosen testing of agency effect, proposed by Kaufman and Escuin (2000), is undertaken. Thus, one tenth of the difference between maximum and minimum elicitations across the results is used as an indicator of agency effect. A difference in weights of this magnitude between any two professional groups is considered enough for an agency effect to be verified. The effect exists between all the professional groups for the majority of attributes. The highest agency effect is observed for prestige, that demonstrates the difficulty of dealing with this attribute.

The difference in the results for prestige can be interpreted from the positions of demand and supply sides. The closest to supply side urban planners undervalues prestige, when the realtors with the best knowledge of consumer demand put several times higher weight to this attribute. With the attributes of nuisance proximity and crime rate, the result is opposite. Another illustration of the agency effect is urban planners’ equal weights for the CBD accessibility and the nearest secondary centre accessibility in contrast with the opinion of the other three groups. It seems that urban planners are not “switched on” to consumer preferences, if to cite Daly et al. (2003).

In Donetsk, realtors consider the railway station accessibility as a negative attribute, whereas, according to the opinion of the other groups, its influence is positive. The complexity and contradiction of a railway station influence is discussed using findings from the literature.

Both the AHP and direct questionnaire results demonstrate the nonlinearity of the influence of distance attributes on apartment prices. The same scale of weights for the two units of measurement, namely one kilometre and one hundred metres, highlights this fact.

The main findings in Paper 3 are the following. According to expert valuation, nine of ten attributes examined in the research have significant influence (not less than 5%) on prices for location. The exception is the railway station accessibility. The application of a linear model for land assessment in Donetsk may be problematic due to nonlinearity of distance influence.

**Paper 4**


The aim of Paper 4 is to derive the weights of the relative importance of location attributes that influence the market values of apartments in Donetsk. The attributes derived in Paper 2 and already applied in expert valuation in Donetsk (Paper 3) are employed again. Investigation of apartment prices is more relevant, as well as more market oriented, than expert valuation methods, especially for residential land.

In the econometric modelling in Paper 4, two types of OLS models are specified: linear and log-linear. As a linear regression model describes the relationships more clearly in general and its results are easier to compare with the expert valuations, the focus is on this type of model. The linear models are also compared with the log-linear models.

The asking prices for apartments are chosen as a dependent variable. They are closer to sale prices than the officially registered prices. Two-room apartments in five- and nine-storey buildings are analysed as the most typical in Donetsk and located in all districts in the city. The data sample consists of 325 apartments.
The apartment characteristics included in the regression models are the following: location on the first or the top floor (dummy), the number of floors in the house (dummy), presence of a wired telephone (dummy), total area, presence of balcony and/or loggia, and an indicator of condition. All the apartments in the sample are placed as points on the vector map of Donetsk. The attributes of accessibility of the nearest shop, traffic noise, and crime rate are not included in the analysis because of insufficient available data. The following location attributes are estimated with GIS:
- distance to the CBD;
- distance to the nearest secondary centre;
- distance to the nearest public transportation stop;
- distance to the railway station;
- distance to water object and/or green area;
- distance to the nearest nuisance;
- prestige (dummy for location in a prestigious area).

Different regression models are specified and tested. Adjusted $R^2$ are usually higher for log-linear models. The estimations of variance inflationary factors (VIF) indicate no problems with multicollinearity. Moran’s $I$ statistic is applied to detect spatial autocorrelation using the row standardised weight matrix of inverse square distances. The spatial autocorrelation is detected, and two kinds of spatial regression models are estimated to correct the spatial relationship: a spatial autoregressive model and a spatial error model. However, none of the estimates for the location variables change dramatically. Hence, the OLS estimates are analysed.

The investigation of distance gradients for the CBD accessibility demonstrates that the western and northern directions from the CBD are more attractive than the southern direction.

To further investigate geographical differences in location variables, the sample is split into two different groups: apartments located within the CBD and apartments outside the CBD. For centrally located apartments the only important location attribute is the distance to the CBD, whereas for locations outside the city centre the other location attributes, such as distance to water and/or green area or to the nearest secondary centre may be of more importance.

The main findings in Paper 4 are the following. Each location variable is significant at the 5% level in at least one of the reported regression models. The only variables significant in all the models are distance to the CBD and location in a prestigious area. The coefficient for distance to the CBD is always negative; the same is true for distance to the secondary centre. One of the conclusions is that Donetsk can be described as a non-monocentric city. In different models, the significant variables of distance to water and/or green area and either nuisance proximity or distance to the nearest secondary centre have coefficients higher than that for distance to the CBD. The least important location attribute in the regression models is distance to stop, which is insignificant in all the models except one linear model.

The relative weights of significant location attributes are extracted for two linear models and compared with the findings of Paper 3. The comparison highlights the following. In all cases, the most important variable is prestige. The experts seem to undervalue prestige and overvalue distance to the CBD compared to market valuation. Distance to the railway station, which is significant in some of regression models, is the least important attribute among those, which are compared, in both regression results and expert valuation.
4. Summary of GIS project

The aim of the Ukrainian thesis (Kryvobokov, 2005) was to improve the creation of land value zones using formal approach. Under the conditions of lack of data on market value for land, the value influencing attributes are the only objects available for the analysis. Therefore, the mathematical methods for analysing the multidimensional data sets are important in Ukraine. The clustering based on the analysis of multidimensional attribute space and the fuzzy sets was applied in the project. The use of GIS is a necessary condition for high-quality creation of value zones. GIS-based modelling increases the objectivity, accuracy and efficiency of the analysis.

The idea was to begin with base territorial units. These units could be land parcels and blocks represented as polygons (see the top-right part of Figure 1). For each territorial unit, the magnitudes of attributes were estimated. The adjacent territorial units, provided that they were recognised as similar, were aggregated into zones. This aggregation could include several steps, i.e. at the next step the small zones could be aggregated into the bigger ones, and this process could be iterative. The crucial moment was a measure of similarity. For this, two methods were applied. The first one was based on Euclidian distance in multidimensional attribute space. The second method used the fuzzy equality of territorial units considered as fuzzy sets.

The experiments were executed with the vector models of two urban areas. One of them was the city of Kharkov, which is the second largest city in Ukraine. The other object was Mospino, a suburb of Donetsk. The figures in this section demonstrate the latter example.

When land parcels and blocks are used as base territorial units, they are often detached from one another. Roads usually form the gaps between them (Figure 2). To solve this problem, it was proposed to increase the territorial units by iterative buffering in order to create the areas of influence. As a result, the whole territory was divided into territorial units without gaps and overlaps (Figure 3). These territorial units could be analysed and with the help of a contiguity matrix be aggregated into zones.

Figure 2. The area initially covered by base territorial units

Figure 3. Whole coverage of the area by territorial units
The small zones in Mospino, created with expert approach, with their ordinal numbers are shown in Figure 4. Experts have aggregated them into bigger value zones by visually considering the adjacency and similarity of zone coefficients (Figure 5). Zone coefficients were calculated as a weighted average of the three attributes, namely the transport accessibility of the town centre, the level of infrastructure development, and the accessibility of public service objects. The numbers correspond to the small zones, which are aggregated. Thus, a bigger zone can contain one or several numbers. These value zones are currently used for land taxation.

The same small zones depicted in Figure 4 could be analysed differently. Thus, using the same magnitudes of attributes of the small zones and applying the method of hyperspheres in attribute space (Aprausheva, 1986 and Aprausheva, 1987), the clusters were outlined and their boundaries were precisely defined after the statistical procedure. The result is visualized in Figure 6.

Using the same initial data (Figure 4) and considering the small zones with their attributes as fuzzy sets, it was estimated the fuzzy equality according to Melikhov et al. (1990). If adjacent zones were recognised as fuzzy equal, they were aggregated. The property of transitivity allowed aggregating more than two zones. Using this algorithm, it was created the automatic GIS-based system for aggregation of territorial units. Figure 7 contains the result for Mospino.
Both maps with results of mathematical methods demonstrate similarity and difference with the value zones, created by experts and currently used in land taxation. Statistical comparison between the different methods of clustering is present in Table 1. The result of the fuzzy sets method has the best statistical characteristics. The three versions of zones (Figure 5, Figure 6, and Figure 7) were also compared geometrically, using the Congallion and Mead method (Hall, 2002), which was adapted to vector maps. According to this comparison, there is more geometric similarity between the results of expert approach and the attribute space method than between the results of expert approach and the fuzzy sets method. Using the described mathematical methods as alternatives to or supplements of the expert approach in mass valuation, a tax administration has a possibility of modelling different outcomes and comparing them.

Table 1. Statistical comparison between the methods of clustering

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Expert approach</th>
<th>Attribute space method</th>
<th>Fuzzy sets method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of zones</td>
<td>22</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Mean standard deviation</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Maximum difference between coefficients within zone</td>
<td>19%</td>
<td>26%</td>
<td>15%</td>
</tr>
</tbody>
</table>

5. Discussion

The research structure was delineated in Paper 1. The most important result of a meta-analysis, carried out in Paper 2, was the location attributes, which significantly influence the market value of real estate. Such findings are of interest in Ukraine and other countries with transition economies.

The location attributes, outlined as the most important, were examined in Donetsk applying the AHP and the direct questionnaire (Paper 3) and the hedonic model for apartment prices (Paper 4). The main results of Paper 3 are two very similar versions of the attribute weights. The results of Paper 4 are regression coefficients, which can be transformed to weights of attributes.

To the knowledge of the author, only one regression model has been created for the Donetsk apartment market before. The unpublished linear model, created by Ageev and Sizova (2004) from Donetsk National Technical University, contained three location attributes, namely distance to the CBD, distance to the main roads, and distance to the railway station. As two of these attributes were examined also in Paper 4 (2006), it is worth to compare the regression coefficients. The coefficient for distance to the CBD equals to −456 USD/km in Ageev and Sizova (2004) and −828 USD/km in model LinB in Paper 4. For distance to the railway station, the figures are −64 USD/km and −37 USD/km respectively. Thus, according to these results, the influence of the CBD increases, whereas the importance of the railway station decreases.

The influence of the railway station in Donetsk was discussed in Paper 3 and Paper 4. The experts considered this attribute as the least important (Paper 3). In different regression models in Paper 4 the influence of the railway station seemed contradictory. However, splitting the sample into two sub-samples, one for centrally located apartments and the other for apartments outside the city centre, indicated that distance to the railway station significantly influence apartment prices only for the latter sub-sample.
The above-mentioned example is noteworthy, because it highlights the conflict between the horizontal equity in mass valuation, which is understood as an overall model for the city, and the spatial non-stationarity of attribute influence. To detect local peculiarities, we can apply the geographically weighted regression (Brunsdon et al., 1996) to the previously specified global model LinB. The derived geographically weighted coefficients, estimated individually for each observation, are very different. For all the location attributes, the interquartile range of the local estimates is greater than a double standard error indicating non-stationary relationships. The highest local differences exist for distance to the CBD, water and/or green area, the railway station, and prestige. The local form of spatial analysis is not the subject of this thesis. The evaluation of the prospects of local regression modelling in Donetsk is a subject for future research.

The other problem of modelling apartment prices in Donetsk is nonlinearity that was detected in Paper 3 and Paper 4. In the latter paper, linear and log-linear regression models describe the influence of location attributes differently. In future research, more attention should be paid to nonlinear modelling. However, below we focus on the results of linear regression models, because they can be compared with the outcomes of Paper 3 and also due to use of linear approach in existing mass valuation of land in Ukraine.

The weights of location attributes from Paper 3 and Paper 4 are summarised in Table 2. The adjusted medians of the AHP and direct questionnaire from Paper 3 and the weights from two models from Paper 4 are reported. For the majority of distance attributes, distances were measured in kilometres. For three distance attributes in expert valuation, distances were measured in hundreds of metres, which is remarked in Table 2.

### Table 2. Weights of the location attributes in Donetsk

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expert valuation</th>
<th>Regression modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AHP</td>
<td>Direct</td>
</tr>
<tr>
<td>Accessibility of the CBD</td>
<td>0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Accessibility of the nearest secondary centre</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Accessibility of the nearest shop</td>
<td>0.06*</td>
<td>0.05*</td>
</tr>
<tr>
<td>Accessibility of the nearest stop</td>
<td>0.08*</td>
<td>0.04*</td>
</tr>
<tr>
<td>Accessibility of the railway station</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Accessibility of water and/or green area</td>
<td>0.06*</td>
<td>0.07*</td>
</tr>
<tr>
<td>Nuisance proximity</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>Crime rate</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Location in a prestigious area</td>
<td>0.19</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Note: N/s – statistically not significant. 
N/i – not included into the model.

* – distance was measured in hundreds of metres.

The reconciliation of the results (the bottom-left of Figure 1) in Donetsk is needed for two reasons. Firstly, a hedonic model for land prices can be specified. Though now the number of land sales in

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6 Though accessibility of the CBD, secondary centre, etc. were measured in regression models as distances to these objects, i.e. the regression coefficients were negative, they are comparable with the corresponding attributes specified in a positive way in expert valuation. For example, experts evaluated the attribute of one kilometre closer to the CBD, whereas in regression models the influence of one additional kilometre from the CBD was estimated. However, in both cases the willingness to pay for one kilometre to the CBD is examined.

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the primary market is insignificant, this number will be increasing in due course. A regression model should be used as a statistical instrument controlling the prices of privatisation. The investigation of secondary land market is the other possibility of regression application provided collection of data on sale prices. Secondly, the derived weights of attributes can be used in the normative valuation of land for estimation of a zone coefficient. This should make mass valuation of land in Donetsk more market-oriented.

According to expert valuation, the weight of the distance to stop is 0.04 or 0.08. This attribute occurred statistically insignificant in linear regression models LinB and LinB_Out as well as in all log-linear models. Thus, this attribute can be excluded in model specification.

For comparison of weights of other attributes, which are statistically significant in at least one regression model in Table 2, it is worth to compare their errors as well. For expert valuation, standard deviations are available (Paper 3). Though the weights were estimated as adjusted medians, they are very close to means. Therefore, standard deviations can be used for analysis. For regression coefficients, standard errors are available (Paper 4). To make the errors more comparable, it is better to recalculate them as percentages of the magnitudes, for which they are estimated. Thus, for expert valuation results, we can use standard deviations as percentages of weights. For regression results, standard errors as percentages of regression coefficient are estimated.

Figure 8 represents the scatter diagram of weights estimated with the AHP and their standard deviations as percentages. Analogous diagram for direct questionnaire is shown in Figure 9. Figure 10 and Figure 11 represent the scatter diagrams of regression coefficients and their standard errors as percentages.

Accessibility of the railway station (Rail), which is insignificant in model LinB, has the highest errors among the expert results (Figure 8 and Figure 9). Here, the errors of Rail exceed the weights of this attribute. In model LinB_Out (Figure 11), Rail also has the highest error equalled to 41%. In all the cases, Rail has the lowest weight. This attribute can be interpreted as the least important among the significant attributes.

Prestige has the highest weight in each method. Its error in model LinB is the second lowest (Figure 10). Though its error in model LinB_Out is quite high (33%), it is comparable with the others (Figure 11). The attribute of location in a prestigious area is the most important in Donetsk.

Accessibility of the CBD (CBL) has the least errors in regression results (Figure 10 and Figure 11), though its weights occur lower: then experts supposed them. According to regression results, the errors of accessibility of secondary centre (SecCen), accessibility of water and/or green area (Water), and nuisance proximity (Nuisance) are relatively not very high (Figure 10 and Figure 11). The analysis demonstrates the importance of these attributes, especially of Water, which is significant in both regression models.

The attributes of shop accessibility (Shop), crime rate (Crime), and traffic noise (Noise) were not included into the regression modelling. The expert valuation demonstrated that these attributes have quite considerable weights and relatively small errors. In the diagrams in Figure 8 and Figure 9, they are located within the main group. This group includes the majority of the examined attributes excluding the very important Prestige with low error and the least important Rail with high error. Therefore it is worth to examine Shop, Crime, and Noise in the prospective using regression modelling.
Though one can see the task as the estimation of some kind of the “reconciled weights” of the location attributes, it would be mathematically incorrect to estimate the average weights or weighted weights from Table 2. Two main reasons are as follows. Firstly, expert valuation and regression estimation have different types of errors. Secondly, while experts tried to evaluate the city as a whole, regression models created for different locations demonstrated very different results. Instead of applying the unique model for Donetsk, it would be more useful to recognise submarkets and evaluate them differently. The first result of geographically weighted regression is a good demonstration of such a perspective.

After the above analysis, which can be interpreted as a kind of reconciliation, a list of the most important location attributes can be proposed. Thus, the model for land prices in the city of Donetsk should include the following location attributes:
- location in a prestigious area;
- accessibility of water and/or green area;
- accessibility of the CBD;
- accessibility of the nearest secondary centre;
- accessibility of the nearest shop;
- nuisance proximity;
- traffic noise;
- crime rate;
- accessibility of the railway station.

These attributes and their weights in Table 2 contrast with the existing normative valuation of land in Donetsk. The attribute of infrastructure development, which was impossible to use in the analyses of apartment prices, should be added to the list while assessing land. The comparison of its influence with the weights of other attributes is a task for future research.

Due to the lack of data, it was impossible to analyse in Donetsk or in its suburb all the attributes listed above. The location attributes analysed in Kryvobokov (2005) were those, which are currently used in normative valuation. This allowed comparing the obtained results with the expert approach. Nonetheless, it was demonstrated the principal possibility to consider any attributes using mathematical methods and GIS tools. The methods of attribute space and fuzzy sets do not need the weights of attributes for clustering. However, both methods can carry out the analysis of weighted data as well. Thus, provided that data about the magnitudes of the attributes is collected, the links between the left part and the right part of Figure 1 would allow creation of all the versions of zones, delineated in the bottom-right part.

6. Future research

Development of mass land valuation in Ukraine implies gradual improvement on the description of spatial distribution of value and its components applying more complex modelling. In this context the stages of future research can be formulated as follows:

1. Use of all the important location attributes, which needs additional data collection. While accessibility can be relatively easily measured with GIS, more effort should be made for collection of information about crime rate and traffic noise and for analysis and classification of the CBD, secondary centres, prestigious areas, and shops. Both apartment prices and land prices should be analysed. While data about land sales is scarce, databases of apartment prices are available giving the possibilities to execute time-series analysis and to use samples, which contain much more than three hundred observations.

2. Creation of nonlinear regression models. Both expert valuation and regression modelling detected the nonlinear relationships that are natural for distance attributes. Therefore the experiments with logarithmic and Box-Cox transformations are worth to execute.

3. Application of local models using geographically weighted regression. The regression experiments with distance gradients, data sub-samples and local modelling indicated that local peculiarities are considerable. A unique model for the whole city smoothes these peculiarities that contradicts to the nature of market value. A trade-off between the principle of horizontal equity and local models will be needed.

4. Application of artificial neuron networks. Multilayer perceptron could be a useful alternative to regression modelling, whereas self-organising map could be compared with clusters of value zones created in attribute space with different methods.
7. Conclusions

The aim of this thesis was to delineate a market-oriented approach to mass valuation of land in Ukraine. This aim was achieved using the methods of meta-analysis, Analytic Hierarchy Process, and regression analysis. These methods were not directly applied to land prices. Instead, the location component of apartment prices was in the focus when the Analytic Hierarchy Process and regression analysis were used. Data from foreign real estate markets and Ukrainian apartment market used in the thesis favour the market orientation of land assessment. The methods applied in the thesis are considered as alternative to current normative valuation. Though each method has disadvantages, they objectively contribute to cognition of the nature of value, which is new for the area of study. Market approach supplemented by mathematical tools makes mass valuation more scientific and less of the art.

The results of different methods, i.e. location attributes and their weights are compared and analysed considering their standard deviations and standard errors. These results are contrasted with the existing normative valuation, but they are relevant for practical use in assessment as well as in market valuation. Firstly, a hedonic model for land prices can be specified. Though now the number of land sales in the primary market is insignificant, this number will be increasing in due course. A regression model should be used as a statistical instrument controlling the prices of privatisation. The investigation of secondary land market is the other possibility of regression application provided collection of data on sale prices. Secondly, the derived weights of attributes can be used in land assessment for estimation of a zone coefficient.

The main conclusions of the thesis can be summarised as follows:

1. As a result of a meta-analysis, it has been derived a list of location attributes, which significantly, with the 90% confidence level, influence the market value of real estate in countries with developed property markets. The list includes the accessibility of CBD, secondary centre, commercial objects, road, water object, green area, nuisance, inner public transport, air and train, as well as income level and prestige, demographic characteristics, planning and development characteristics, educational level, and crime level. These attributes can be used for analysing property markets in transitional countries.

2. With the Analytic Hierarchy Process and the direct questionnaire for apartment prices in Donetsk the influence of the location attributes was estimated, namely the accessibility of CBD, secondary centre, shop, stop, railway station, water and/or green area, nuisance, as well as traffic noise, crime rate, and prestige. Each of the attributes, with the exception of the accessibility of railway station, composes not less than 5% of price for location.

3. With the hedonic modelling of apartment prices in Donetsk the influence of the location attributes was estimated, namely the distance to CBD, secondary centre, shop, railway station, water and/or green area, nuisance, and prestige. Each location variable is significant, with the 95% confidence level in at least one of the models. The conclusion was made that Donetsk is a non-monocentric city.

4. Reconciling the results of the Analytic Hierarchy Process, the direct questionnaire, and the hedonic modelling of apartment prices in Donetsk, the list of the most important location attributes was derived, namely prestige, the accessibility of water and/or green area, CBD, secondary centre, shop, nuisance, traffic noise, crime rate, and the accessibility of railway station. The model of mass valuation in Donetsk should not be linear. The derived location attributes and their weights can be used in mass valuation of land including the formal
creation of land value zones with GIS and the first specification of a hedonic model for land prices.

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