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Determination of the parameters of automated valuation models for the hedonic property valuation of residential properties

A literature-based approach

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Abstract

Purpose – The development and testing of the hedonic methods for property valuation require statistical analysis and professional preparation of relevant databases. As a first step, the presumable relevant influencing variables (parameters) have to be determined. Previous studies have shown a large variety of parameters which overlap or deviate from each other. This study aims to collect, systematise and structure different parameters for the further development and testing of hedonic models.

Design/methodology/approach – The study comprises a detailed research and deeper analysis of previous studies regarding the hedonic valuation (mainly for residential properties). Flanking areas of examination serve, if they are appropriately suitable, as supplements (e.g. performance analysis and regression). Parameters are extracted from a wide range of literature, compared and integrated into an overall presentation of the results.

Findings – In total, 407 parameters were extracted from previous studies on hedonic valuation and performance analysis. Because of various definitions of some parameters in the literature, the current paper combined them in one meaning to avoid misunderstandings in further analysis. Higher-level (global) and lower-level (specific) parameters are contained/described in the final list. The result of this study identifies up to five levels of parameters (within the relevant hierarchy).

Research limitations/implications – The parameters have not yet been statistically tested. The relevance of individual parameters has to be tested with relevant corresponding databases and statistical methods (e.g. correlation and regression).

Practical implications – To manage larger real estate portfolios, there is a need for regular property valuations. From this perspective, there is a great interest related to the optimisation of the valuation costs, valuation quality and valuation duration. Hedonic methods are considered as an efficient way of performing these valuation tasks. However, further suitable models and parameters are needed. The study describes parameters that can be appropriate for the development of relevant models and creates a structured parameters list, providing the technical basis for the latter. This structured parameter list is substantiated by the evaluation of the existing research.

Social implications – Property values represent a significant asset for the national economy and for the individual wealth/welfare. The development of property value in a national economy is also relevant for

JEL classification – L85, D46, R15, R30, O21, G32, C50

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politics, economy and society. The use of hedonic methods and the knowledge of important individual parameters can contribute towards assessing and substantiating the effect of political decisions on the value of real estate.

Originality/value – For the first time, a comprehensive and structured analysis on the value of the relevant parameters used in hedonic methods is performed. Thereby a large number of parameters were identified which question the stability of the results in respective individual studies. In addition, the newly developed hierarchy of parameters can serve as the basis for further research.

Keywords Risk management, Planning, Controlling, Portfolio management, Hedonic models, Mass appraisal, Real estate investments, Real estate valuation

Paper type Research paper

1. Hedonic method as an approach for automated valuation in the management of residential property portfolios

Property valuation belongs to the most commonly used analytic methods in property portfolio management. Generally it is to differentiate between market value indications and estimated market values. Market value estimation is conducted as a preparation for transactions; it supports the determination of the lending value within the scope of the financing and securitisation or serve as a basis for accounting and taxation. Besides this, official, often legally regulated valuations, less formalised valuations, partly estimated value assessments and value forecasts of residential property portfolios are also performed (Schulte, 2007, p. 579; Schulte, 2008, p. 455). Fundamentally, the value assessment must be carried out sufficiently enough and as efficiently as possible.

In general, there is a strong interest in the optimisation of valuation costs, valuation quality and valuation time, especially for the management of large portfolios. Coming from the qualitative and resource-related characteristics of the single asset valuation, market players with many valuation cases (e.g. banks, property funds and property PLC's) are looking for simplifications (Schulte, 2007, pp. 579-580; Ochsner, 2014, p. 1; Trappmann and Ranker, 2008, pp. 65-67). To keep the valuation effort as low as possible, more and more computer-aided and automatic valuation models, so-called "automated valuation models (AVM)", are used. From an institutional point of view, banks, insurance companies, larger housing companies and their service providers (including the appraiser and consulting companies) are potential users.

AVMs are mostly based on hedonic models (Kauko and D′Amato, 2008, p. 3). The reason is that hedonic models are formally structured and mainly based on internally and externally available parameters. Therefore, they can be operated efficiently at a reasonable cost. The theoretical basis for these hedonic models is the "hedonic price theory" (HPT).

The HPT assumes that the value of an object (in this case real estate) is influenced by a bundle of characteristics (e.g. situation, size and facilities).

Therefore, each individual characteristic has a different influence (partial effect) on the level of the accepted price (and thus the value to be applied). The HPT assumes that goods are not homogeneous and do not have a uniform value. Rather, the value arises as the sum of partial values on the basis of several characteristics (Lancester, 1966, p. 134). In this sense, properties can be seen as different combinations of beneficial characteristics (Maier, 2011, p. 9). In the hedonic approach, economic objects are perceived heterogeneously and specifically with respect to quality and price. However, the neo-classic theory interprets certain objects as a homogeneous group and, in the event of significant differences, defines a separate economic object (Haupt, 2002, p. 18).

As properties typically count as heterogeneous objects, the hedonic models try to:

- understand the influence of quality differences on prices and explain them to third parties;
- filter out the influence of different preferences through "averaging" from the market prices and transform them into a situation of ordinary business transactions; and
- use the resulting knowledge to simulate market values (Nitsch, 2011, p. 381).

The extent of the individual characteristics of a property (the macro and micro situation, the layout, the size, the facilities, the number of rooms, etc.) represents the respective benefits of the one who has a relevant interest (e.g. tenant and investor). This does not exclude the parallel application of classic net income calculations. Investors fundamentally always rate real estate based on the annual income (cash flow, NOI). The corresponding rents, on the other hand, result, among others, from the specific characteristics of the property and subjective feeling of the fulfillment of respective requirements (Figure 1).

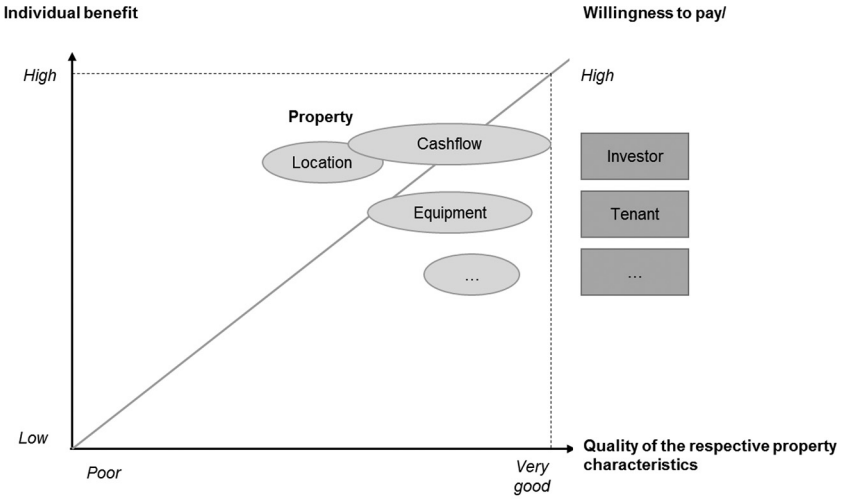
Consequently, the observable purchase price is the sum of the implicit prices for the respective characteristics or the subjective overall benefits expressed as the purchase price (Rosen, 1974, p. 34; Fahrländer, 2007, p. 18; Sanftenberg, 2015, p. 34). The linking of property characteristics and the purchase price is conducted by using the hedonic price function:

$$P = f(x_1, x_2, \ldots x_n) \tag{1}$$

where P is the dependent variable and x_1 to x_n are the independent or explanatory variables (Boyle, 1984, p. 274; Nitsch, 2013, p. 31).

2. The hedonic modelling process and the need for parameter definition

For the development of hedonic property valuation models, current transactions must be statistically analysed. The value contributions that have been assigned by the market



Source: Author's own illustration

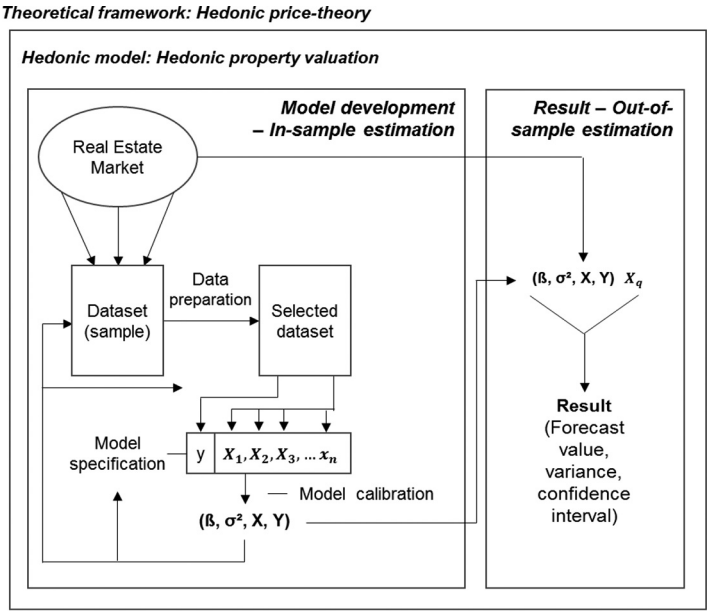
Figure 1. Derivation of the willingness to pay

players for the individual qualitative and quantitative property characteristics (explanatory variable) are to be determined (Thomas, 2011, p. 827). Thus, the existing characteristics are to be synchronised with the qualitative benefits and the respective willingness to pay.

Several iterative optimisation steps finally lead to the hedonic valuation model, which serves the determination of the value (Figure 2) (Maier and Herath, 2015, p. 4).

The definition and calibration of the models requires a lot of data sets with suitable parameters. The definition of this parameter list forms the first step in the development of the model. A stringent and subsequent derivation of less relevant parameters starting with only one target parameter "value" or "yield" following a top-down process down to parameters with a significant influence is not possible in most cases. Instead, a large number of parameters can have a high or low influence. In this context it can be noted, that the documented modelling process, within the relevant literature on hedonic models, usually comes from the theoretical representations of the HPT or hedonic regression, directly to the interpretation of the final statistical results. However, a transparent and detailed presentation of the necessary modelling steps is missing.

Central basis for the modelling is considered to be the definition of parameters and the collection of data (e.g. transaction and valuation data, as well as market and location data) (Metzner, 2013, p. 698; Maier and Herath, 2015, p. 4). For the valuation model, the criteria (respectively, the parameters) must be backed up by specific coefficients and data sources. When selecting the parameters the principles of completeness, essentiality, free of overlap and measurability must always be observed (Lifka, 2009, p. 50; Bächle, 1996, p. 130; specially for model simplification: Gäfgen, 1966, p. 205). The step-by-step determination of the model comprises, in summary, the following steps:



Source: Modelled after Maier and Herath (2015, pp. 3-4)

Figure 2.
Development of a hedonic assessment model

- parameter definition/specification;
- surveying and preparation of data;
- model specification;
- model calibration;
- measurement of the explanatory power;
- iterative model adaptation/model optimisation;
- derivation of hedonic valuation model;
- application of model/model validation (out of sample);
- interpretation of results and documentation;
- model development II – model automation;
- iterative model adaptation/model adaptation;
- verification of the automated hedonic valuation model;
- application of model/model validation (out of sample); and
- interpretation of results and documentation.

Therefore, the hedonic valuation function is developed within an iterative process. Certain tests and optimisations must be repeated several times (e.g. steps 3-6 and 10 and 11, for new data continuing from 7 to 12).

Suitable property data is central (in this case specific data for residential properties) to the development and the test of the hedonic model. In their structure, the parameter and the real estate types/markets should be differentiated as much as possible. The number of data sets has to be in line with the quantity as comprehensive as possible. Transaction data have to be preferred over valuation data because market information can be better derived from certain parameters. If these data cannot be taken from a single source, the pooling of different data sources (e.g. real estate agents, consultants, researcher, experts and investors) can be a useful alternative (Figure 3).

3. Methodology

The study comprises a detailed research and deeper analysis of previous studies for the hedonic valuation, mainly focusing on residential properties. Flanking areas of examination serve, if they are appropriately suitable, as supplements (e.g. performance analysis and regression). Parameters are extracted from the wide range of literature, compared and integrated into an overall presentation.

Basically, the individual parameters can be determined deductively or inductively. Besides the theoretical derivation, the extraction of important parameters from relevant literature sources is another possible approach. Following this approach, relevant scientific studies are evaluated, compared and, using counters, condensed into a parameter list. This

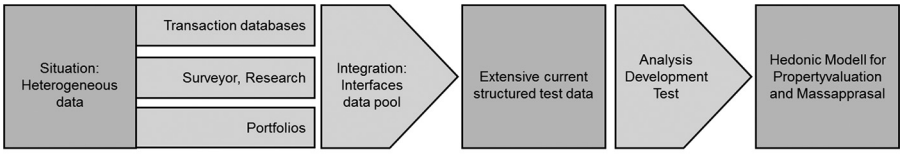


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Figure 3. Process steps in data research and integration

forms the necessary basis for later data surveys and tests. Within this process, as a first step, a very broad parameter framework was created. This is primarily based on the fundamental literature covering the subject areas of property valuation and investment.

As a next step, specific literature sources (monographs and papers) on hedonic models with the focus on residential properties were surveyed and evaluated with respect to the respective value-influencing parameters. Therefore, the fundamental parameter list serves as a collection framework and is complemented by missing parameters. In this regard, 64 international sources on hedonic models in the period 1975 to 2015 were considered (Table I).

4. Identified parameters for residential properties on the aggregated level (parameter groups)

The evaluation of previous studies gives an extensive list of parameters. The specific individual parameter can be assigned to certain thematic subgroups and upper groups in the technical assessment, thus resulting in a multilevel parameter hierarchy. Initially, it is considered to show the parameters on an aggregated level. Single parameter and global parameters mentioned in the main groups and in the assigned subgroups, have been counted. The counter in the main group can, therefore, be higher than the sum of the counters in the levels below (Table II).

From the analysis of the aggregated level, it can be derived that the parameters related to micro-location and building characteristics have a higher relevance (237 and 433 mentions, respectively). For the micro-location parameters, the focus is mainly on the geographic position, the neighbourhood and the socio-demographic structure. The most important parameters for the building characteristics are building dimensions, the equipment and the building technology.

5. Resulting parameters for residential properties on the detailed level (individual groups)

In the next step, the main levels (1. level of detail) can be broken down into further six levels.

In particular, on a macro-level, various socio-demographic parameters (e.g. income, age structure or level of education) and economic parameters (e.g. unemployment rate and employment) have turned out to be important factors for residential property. The structured and detailed parameter list shows the following individual parameters in the main group "1 micro-location" (Table III).

The analysis at a micro-level shows that the parameters, area/district (21) and the distance to the town centre/central business district (CBD) (16) are dominated by the sub parameters' existence and distance to green areas/parks (11), facilities for daily needs (12) and percentage of foreigners respectively migrants in the micro-location (10). In the second main group, "micro-location" following individual parameters could be identified (Table IV).

For the residential real estate market, such parameters, as the general space supply (3) and the corresponding price level on the real estate market (3), have proven to be important market specific indicators. The structured and detailed parameter list shows the individual parameters in the main group "3 real estate market" (Table V).

At the level of the building plot, the size of the lot is considered to be a dominating factor (32). In addition, the parking situation is also of central importance. At that, the number of garages (28) and external parking spaces (10) were given a high importance. In the main group "4 land", the structured and detailed parameter list shows the individual parameters (Table VI).

Table I. Previous studies on hedonic models with a focus on residential properties (selection)

Author/year	Title of the essay or book	Institution/series	Country	Type of source
Ziegenbein (1986)	Zur analyse der automatisiert gefuehrten kaufpreissammlungen fuer grundstücke in niedersachsen	Leibniz Universität Hannover	Germany	Monograph
Leopoldsberger (1998)	Kontinuierliche wertermittlung von immobilien	Universität Regensburg – IREBS	Germany	Monograph
Haupt (2002)	Die charakteristika des hedonischen gutes wohnung	Universität Regensburg – IREBS	Germany	Monograph
Schulz (2003)	Valuation of Properties and Economic Models of Real Estate Markets	HU Berlin	Germany	Monograph
Fahrländer (2007)	Hedonische Immobilienbewertung	Universität Bern	Switzerland	Monograph
Wersing (2011)	Real Estate Valuation and Investment	TU Berlin	Germany	Monograph
Casperlein (2011)	Verkehrsinfrastruktur und Immobilienwerte	Universität Stuttgart	Germany	Monograph
Sanftenberg (2015)	Hedonische modelle – chancen und anwendungsristriktionen für die grundstückswertermittlung	TU Berlin	Germany	Monograph
Berry and Bednarsz (1975)	A hedonic model of prices and assessments for single-family homes: Does the assessor follow the market or the market follow the assessor?	University of Wisconsin	USA	Paper
Straszheim (1974)	Hedonic estimation of housing market prices	The Review of Economics and Statistics	USA	Paper
Palmquist (1984)	Estimating the determinants for characteristics of housing	The Review of Economics and Statistics	USA	Paper
Canavaro *et al.* (1985)	Hedonic methodologies in the real estate valuation	Instituto Politécnico de Castelo Branco, Castelo Branco, Portugal	Portugal, Spain	Paper
Cronan *et al.* (1986)	The use of rank transformation and MRA in estimating residential property values with a small sample	Journal of Real Estate Research	USA	Paper
Gallimore *et al.* (1996)	Modelling the influence of location on value	Journal of Property Valuation and Investment	USA	Paper
Tse (1997)	Estimating the influence of transport on house prices: evidence from Hong Kong	Journal of Property Valuation and Investment	China	Paper
Des Rosiers *et al.* (1998)	Does drinking water quality affect house prices?	Laval University Canada/Journal of Environment and value	Canada	Paper
Watkins (1998)	Property valuation and the structure of urban housing markets	University of Aberdeen/Journal of Property Valuation	UK	Paper

(*continued*)

Table I.

Author/year	Title of the essay or book	Institution/series	Country	Type of source
Maurer *et al.* (2000)	Konstruktion transaktionsbasierter Immobilienindizes: theoretische grundlagen und empirische umsetzung für den wohnungsmarkt in Paris	Universität Frankfurt, Universität Mannheim	Germany	Paper
Franklin and Waddel (2002)	A hedonic regression of home prices in King County, Washington, using activity-specific accessibility measures	University of Washington/TRB 2003 Annual Meeting	USA	Conference paper
Bover and Velilla (2002)	Hedonic house prices without characteristics: The case of new multiunit housing	European Central Bank	GB	Paper
Diaz *et al.* (2002)	Using data-driven prediction methods in a hedonic regression problem	University of Vigo, University of Pisa	Spain, Italy	Paper
Malpezzi (2002)	Hedonic pricing models: a selective and applied review	University of Wisconsin/Journal of Housing Economics	USA	Paper
De La Paz (2003)	Determinants of housing prices in Spanisch cities	University of Alicante/Property Investment and Finance	Spain	Paper
Thwaites and Wood (2003)	The measurement of house prices	Bank of England	UK	Paper
Kauko (2003)	Residential property value and location externalities	Research Institute for Housing, Urban and Mobility Studies Delft/Journal of Property Investment and Finance	Netherlands	Paper
Sirmans *et al.* (2003)	The composition of hedonic pricing models: a review of the literature	National Center for Real Estate Research	USA	Paper
Limsombunchai *et al.* (2004)	House price prediction: hedonic price model vs. artificial neural network	Lincoln University New Zeeland/American Journal of Applied Sciences	New Zealand	Paper
Melichar *et al.* (2004)	Application of hedonic price model in the Prague property market	University of Economics, University of west Bohemia	Czech Rep.	Paper
Lisi and Iacobini (2004)	Real estate appraisals, hedonic models and the measurement of house price dispersion	Journal of Economics and Econometrics	Italy	Paper
Salvi (2004)	Ist eine höhere bauliche Nutzung wünschenswert? Evidenz aus den Preisen von Einfamilienhäusern im Kanton Zürich	ETH Zürich/Zürcher Kantonalbank	Switzerland	Paper
Sirmans *et al.* (2005)	The value of housing characteristics	Florida State University/National Center for Real Estate Research	USA	Paper

(*continued*)

Author/year	Title of the essay or book	Institution/series	Country	Type of source
Ismail and Maggreggor (2005)	Hedonic modelling of housing markets using geographical information system (GIS) and spatial statistics: a case study of Glasgow, Scotland	Universiti Teknologi Malaysia, University of Aberdeen Business School	UK	Paper
Vanderford *et al.* (2005)	A hedonic comparison of manufactored and side build houses	Providence Day School in Charlotte/Journal of Real Estate Research	USA	Paper
Hansen (2006)	Australian house prices: a comparison of hedonic and repeat-sales measures	Economic Research Department, Reserve Bank of Australia	Australia	Paper
Li *et al.* (2006)	Studies in hedonic resale housing price indexes	Lakehead University/40th Annual Meetings of Canadian Economic Association	Canada	Paper
Wieser (2006)	Wirkungen der U-Bahn auf den bodenmarkt in Wien	TU Wien Working paper	Austria	Paper
Farber and Yeates (2006)	A comparison of localized regression models in a hedonic house price context	Ryerson University	Canada	Paper
Orsland *et al.* (2007)	Housing price gradients in a region with one dominating center	Stord/Haugesund University College/Journal of Real Estate Research	Norway	Paper
Bao (2007)	Improved estimators of hedonic housing price models	University of Cambridge/Journal of Real Estate Research	GB	Paper
Pages and Maza (2007)	Analysis of house prices in spain	BANCO DE ESPAÑA	Spain	Paper
Zietz *et al.* (2008)	Determinants of house prices: a quantile regression approach	Tennessee State University, Florida State University/Journal of Real Estate Finance and Economics	USA	Paper
Ottensmanna *et al.* (2008)	Urban location and housing prices within a hedonic model	University Indianapolis, Indiana University Bloomington/Journal of Regional Analysis and policy	USA	Paper
Dübel and Iden (2008)	Hedonischer immobilienpreisindex Deutschland, isolierung qualitativer hauspreismerkmale	Bundesamtes für Bauwesen und Raumordnung	Germany	Paper
Mörbert *et al.* (2008)	Hedonische regression der wohnungsmietpreise unter berücksichtigung von lagevariablen am beispiel eines bestands im ruhrgebiet	Gesellschaft für Immobilienwirtschaftliche Forschung/Zeitschrift für Immobilienökonomie	Germany	Paper

(*continued*)

Table I.

Table I.

Author/year	Title of the essay or book	Institution/series	Country	Type of source
Langrin (2008)	A hedonic residential real estate index for Jamaica: a pilot study of the Kingston and St. Andrew Region	Bank of Jamaica	Jamaika	Paper
Cebula (2009)	The hedonic pricing model applied to the housing market of the City of Savannah and its Savannah Historic Landmark District	The Review of Regional Studies	USA	Paper
Day (2009)	Submarket identifikation in property markets: a hedonic housing price model for Glasgow. Norwich	University of East Anglia/CSERGE Working Paper	UK	Paper
Orsland *et al.* (2007)	An application of spatial econometrics in relation to hedonic house price modelling	Stord/Haugesund University College/Journal of Real Estate Research	Norway	Paper
Bourassa *et al.* (2011)	Predicting house prices with spatial dependence	University of Louisville/Journal of Real Estate Research	USA	Paper
Bohl *et al.* (2011)	Determinanten von wohnimmobilienpreisen: das beispiel der stadt Münster	Universität Münster	Germany	Paper
Diewert *et al.* (2011)	Hedonic regressions and the decomposition of a house price index into land and structure components	The University of British Columbia/Ottawa Group Meeting	Canada	Konferenz-beitrag
Lacobini and Lisi (2012)	Estimation of a hedonic house price model with bargaining: evidence from the italian housing market	Territorial Agency, Rome	Italy	Paper
Owusu-Ansah (2013)	Examination of the determinants of housing values in urban ghana and implications for policymakers	IREBS, foundation for african real estate research	Ghana	Paper
Hu *et al.* (2012)	Multivariate regression modeling for home value estimates with evaluation using maximum information coefficient	Central Michigan University, University of Alabama at Birmingham, Trent University	USA, Canada	Paper
Lisi (2013)	On the functional form of the hedonic price function: a matching-theoretic model and empirical evidence	University of Cassino and Southern Lazio/ INTERNATIONAL REAL ESTATE REVIEW	Italy	Paper
Helbich (2013)	Spatial heterogeneity in hedonic house price models: the case of Austria	Tinbergen Institute Amsterdam/Tinbergen Institute Discussion Paper	Netherlands	Paper

(*continued*)

Table I.

Author/year	Title of the essay or book	Institution/series	Country	Type of source
Kim *et al.* (2013)	Determinants of house prices in seoul: the quantile regression approach	–	South Korea	Paper
Kolbe *et al.* (2013)	Location, location, location: extracting location value from house prices	Deutsches Institut für Wirtschaftsforschung	Germany	Paper
Jiang *et al.* (2014)	A new hedonic regression for real estate prices applied to the singapore residential market	Singapore Management University	Singapore	Paper
Yayar and Demir (2014)	Hedonic estimation of housing market prices in Turkey	Erciyes Üniversitesi	Turkey	Paper
Alan *et al.* (2015)	A varying coefficient approach to estimating hedonic housing price functions and their quantiles	University of Hongkong	China	Paper
Panagiotidis and Panagiotis (2015)	On the macroeconomic determinants of the housing market in Greece: A VECM approach	Hellenic Observatory	Greece	Paper
Kolbe and Wüstemann (2015)	Estimating the value of urban green space: a hedonic pricing analysis of the housing market in Cologne, Germany	TU Berlin	Germany	Paper
Cheng and Fung (2015)	Determinants of Hong Kong's housing prices	Journal of Economics, Business and Management	China	Paper

Source: Own compilation

Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
1.	*Macro location*	1	133
1.1	Geographical macro location		5
1.2	Traffic infrastructure/accessibility		3
1.3	Economic structure	1	50
1.4	Sociodemographic structure of the macro location		66
1.5	Image of the macro location		9
2.	*Micro location*	20	237
2.1	Geographical micro location	9	56
2.2	Technical infrastructure	3	34
2.3	Social infrastructure		19
2.4	Neighbourhood	3	65
2.5	Socio-demographic structure of the micro location	5	49
2.6	Image of the micro location		14
3.	*Real estate market*	2	12
3.1	Space supply		8
3.2	Space demand	2	4
4.	*Land*	13	109
4.1	Dimension	7	29
4.2	Rights/encumbrances	2	3
4.3	Public infrastructure	1	5
4.4	Land value	3	3
4.5	Parking		57
4.6	Garden		7
4.7	Taxes		5
5.	*Building characteristics*	62	433
5.1	Type of residential	8	59
5.2	Dimension	29	148
5.3	Quality of construction and engineering	19	94
5.4	Type of construction and fit out	5	120
5.5	Visibility	1	22
6.	*Use*	8	23
6.1	Rent	3	6
6.2	Management	1	1
6.3	Units	4	16
7.	*Transaction parameters*	18	67
7.1	Acquisition	13	56
7.2	Construction costs	1	
7.3	Value parameters	4	11

Source: Own compilation, individual sources (Table I)

Table II. Quantification of the discussion on parameter groups in previous studies on investment criteria

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
001	1.	*Macro location*		
002	1.1	*Geographical macro location*		1
003	1.1.1	Location of the city		2
004	1.1.2	Neighbouring cities		1
005	1.1.3	Centre function		1
006	1.2	*Traffic infrastructure/Accessibility*		
007	1.2.1	Airport connection		
008	1.2.2	Harbour connection		
009	1.2.3	Railway connection		
010	1.2.4	Motorway		2
011	1.2.5	Motorway network		1
012	1.2.6	Road network		
013	1.3	*Economic structure*		
014	1.3.1	Economic power		
015	1.3.1.1	Gross domestic product		
016	1.3.1.2	Gross value added		
017	1.3.1.3	Goods imports		1
018	1.3.1.4	Goods exports		1
019	1.3.2	Economic growth		2
020	1.3.2.1	Δ gross domestic product		3
021	1.3.2.2	Δ gross value added		3
022	1.3.2.3	Δ goods imports		1
023	1.3.2.4	Δ goods exports		1
024	1.3.3	Economic base		3
025	1.3.4	Employment		4
026	1.3.4.1	Kind of the employment		4
027	1.3.4.2	Extent of employment		5
028	1.3.5	Unemployment	1	7
029	1.3.6	Tax revenue		3
030	1.3.6.1	Trade tax		1
031	1.3.6.2	Real estate tax		1
032	1.3.6.3	Land transfer tax		1
033	1.3.7	Commuter's amount		1
034	1.3.8	Cost of living		2
035	1.3.9	Currency/Exchange rate		1
036	1.3.10	Financing expenses/interest		3
037	1.3.11	Mortgage debts		2
038	1.3.12	Loan yield		
039	1.4	*Socio-demographic structure of the macro location*		1
040	1.4.1	Population within the city		7
041	1.4.1.1	Number of inhabitants within the city		6
042	1.4.1.2	Population development within the city		5
043	1.4.1.3	Age distribution within the city		6
044	1.4.1.5	Percentage of foreigners within the city		7
045	1.4.1.6	Migration trend within the city		2
046	1.4.1.7	Level of education within the city		6
047	1.4.1.8	Size of household within the city		4

(*continued*)

Table III. Quantification of the discussion on individual parameters in the Upper Group 1 in previous studies on investment criteria

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
048	1.4.2	Income within the city		8
049	1.4.2.1	Income development within the city		5
050	1.4.3	Social structure within the city within the city		
051	1.4.4	Consumer climate within the city		3
052	1.4.4.1	Purchasing power within the city		4
053	1.4.4.2	Centrality of purchasing power of the city		
054	1.4.3	Assets		
055	1.4.3.1	Financial assets		1
056	1.4.3.2	Real estate assets		1
057	1.5	*Image of the macro location*		1
058	1.5.1	Political situation/administration		1
059	1.5.1.1	Planning permissions		
060	1.5.1.2	Proceedings relating to permission		
061	1.5.1.3	Forced sales		1
062	1.5.1.4	Corruption		
063	1.5.1.5	Δ Corruption		
064	1.5.2	Investment climate		
065	1.5.3	Residential quality and quality of life		2
066	1.5.4	Security within the city		2
067	1.5.4.1	Criminal activity/crime rate within the city		1
068	1.5.4.2	Δ Criminal activity/crime rate within the city		1

Table III. **Source:** Own compilation, individual sources (Table I)

On the building level, the individual parameters of age/year (47), building size (39), number of bathrooms (28), bedrooms (19), type of heating (16) and air conditioning (15) are important. In the main group "5 building", the structured and detailed parameter list shows the individual parameters (Table VII).

In addition to technical and fit-out, and related building characteristics, the analysed purchase prices for residential can also be explained by utilisation and profitability parameters. In particular, the rental income (gross and net income), the floor (6) and the general location (5) of the residential unit are relevant to these parameters. For example, the location of the residential unit in a building includes the orientation in a certain compass direction. The structure and detailed parameter list in the main group "6 Use" are presented in Table VIII.

Also, transaction-related characteristics are important, e.g. the date of the transaction (11) can have an influence on the value. At the same time, there exist some influences because of certain purchase prices (52) in the market environment, especially results of valuations (market value, 14). It should be noted, that the results of various studies are influenced by varying emphases. For example, the focus of some studies was on the objective, spatial and time context for the relevant real estate market, or also with respect to contiguous markets. In the main group "7 Transaction parameter", the structured and detailed parameter list shows the individual parameters (Table IX).

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
069	2.	*Micro location*	4	11
070	2.1	*Geographical micro location*	3	10
071	2.1.1	District/part of town	3	18
072	2.1.2	Centrality of the city	2	9
073	2.1.3	City centre/CBD	1	15
074	2.1.4	Trade fair		
075	2.1.5	Visibility		
076	2.1.6	Natural disasters		1
077	2.1.6.1	Flood		1
078	2.1.6.2	Avalanches		
079	2.1.6.3	Earthquakes		2
080	2.1.6.4	Volcano eruptions		
081	2.1.6.5	Storms		
082	2.2	*Technical infrastructure*		
083	2.2.1	Transport infrastructure	1	4
084	2.2.1.1	Airport connection		2
085	2.2.1.2	Harbour connection		2
086	2.2.1.3	Railway connection		7
087	2.2.1.4	Road connection	2	7
088	2.2.1.5	Public transportation		6
089	2.2.1.6	Parking situation		2
090	2.2.2	Infrastructure of energy and water supply		
091	2.2.2.1	Electricity		2
092	2.2.2.2	District heating		
093	2.2.2.3	Gas		
094	2.2.2.4	Fresh water		1
095	2.2.3	Infrastructure of disposal		
096	2.2.3.1	Energy		
097	2.2.3.2	Rubbish		
098	2.2.3.3	Sewage		1
099	2.2.4	Communication		
100	2.3	*Social infrastructure*		3
101	2.3.1	Health care system		2
102	2.3.2	Senior citizens		1
103	2.3.3	Education		12
104	2.3.4	Administration		
105	2.3.5	Security facilities		1
106	2.4	*Neighbourhood*		6
107	2.4.1	Green space		
108	2.4.1.1	Surrounding buildings		
109	2.4.1.2	Parks/green areas		11
110	2.4.1.3	Waters		2
111	2.4.2	Demand generators		
112	2.4.3	Passer-by's frequency		
113	2.4.4	Facilities for daily needs		12
114	2.4.6	Cultural facilities and leisure facilities		6
115	2.4.7	Restaurants		3
116	2.4.8	Emissions/immissions		7

(*continued*)

Table IV. Quantification of the discussion on individual parameters in the Upper Group 2 in previous studies on investment criteria

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
117	2.4.7.1	Traffic volume		3
118	2.4.7.2	Noise	2	5
119	2.4.7.3	Air	1	6
120	2.4.8	Environmental pollution		3
121	2.4.8.1	Waters		1
122	2.4.8.2	Ground		
123	2.5	*Sociodemographic structure of the micro location*		3
124	2.5.1	Population within the district	1	4
125	2.5.1.1	Number of inhabitant's within the district		4
126	2.5.1.2	Age distribution within the district	1	4
127	2.5.1.3	Percentage foreigner/migrant/minorities within the district	1	9
128	2.5.1.4	Religion		2
129	2.5.1.5	Level of education of the local residents	1	5
130	2.5.1.6	Marital status of the local residents	1	2
131	2.5.2	Income within the district		6
132	2.5.2.1	Income development within the district		3
133	2.5.2.2	Social structure within the district		2
134	2.5.2.3	Consumption within the district		2
135	2.5.2.3.1	Purchasing power within the district		3
136	2.5.2.3.2	Centrality of purchasing power of the district		
137	2.6	*Image of the micro location*		4
138	2.6.1	Prestige		2
139	2.6.2	Appearance		1
140	2.6.3	Cleanness		2
141	2.6.4	Stay quality		1
142	2.6.5	Criminal activity/crime rate within the district		2
143	2.6.6	Δ Criminal activity/crime rate within the district		2

Source: Own compilation, individual sources (Table I)

Table IV.

From analysing the findings (Tables II-IX), explanatory parameters are most frequently used in hedonic models (Table X). This does not necessarily mean that the dependent variable (purchase price or market value) is strongly influenced by these parameters in a quantitative sense. It can be inferred that not only the frequency of use (in other models) but also the direction of the effect (positive or negative influence) can create the basis for the development of further models.

From the analysis of residential housing studies, the age of the building has been identified as the most frequent one. A similar result has been identified in an earlier study by Sirmans *et al.* (2003, p.11). In the shown list (Table X), the further five parameters are also similar to Sirmans *et.al.* (i.e. building age, building size, land area, garages and number of baths). Differences in the parameter list are related to the location parameters such as area or district or the distance to the CBD, which play a minor role in the earlier study. As an

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
144	3.	*Real estate market*		
145	3.1	*Space supply*		3
146	3.1.1	Space supply from existing buildings		1
147	3.1.1.1	Space supply		1
148	3.1.1.2	Δ Space supply		
149	3.1.1.3	Occupancy rate		
150	3.1.1.4	Vacancy		2
151	3.1.1.5	Δ Vacancies		
152	3.1.2	Space supply from development		
153	3.1.2.1	Space under construction		
154	3.1.2.2	Building space in planning		
155	3.1.2.3	Realisation horizon		
156	3.1.2.4	Construction completions		
157	3.1.3	Medium-term space supply of the market		1
158	3.2	*Space demand*		
159	3.2.1	Market prices		3
160	3.2.1.1	Top transactions		
161	3.2.1.2	Average transaction price		
162	3.2.2	Market rent	1	
163	3.2.2.1	Contracted rent		
164	3.2.2.2	Prime rent		
165	3.2.2.3	Rackrent		
166	3.2.2.4	Incentives		
167	3.2.2.5	Hotel key figures		
168	3.2.2.5.1	ARR macro		1
169	3.2.2.5.2	ARR national		
170	3.2.2.5.3	RevPAR macro		
171	3.2.2.5.4	RevPAR national		
172	3.2.3	Market yields		
173	3.2.3.1	Yield/capitalisation rate	1	
174	3.2.3.2	Prime yields		
175	3.2.3.3	Gross initial yields		
176	3.2.3.4	Net initial yields		
177	3.2.4	Multiplier		
178	3.2.5	Construction costs		
179	3.2.6	Demand		
180	3.2.6.1	Inquiries		
181	3.2.6.2	Space turnover		
182	3.2.6.3	Net space absorption		

Source: Own compilation, individual sources (Table I)

Table V. Quantification of the discussion on individual parameters in the Upper Group 3 in previous studies on investment criteria

enhancement to Sirmans *et al.* (2003), which only presented the most frequently used parameters (other parameters with a lesser value-influence were neglected), now all parameters of the hedonic models were counted.

The analysis of the previous studies on hedonic models for housing markets shows that not all parameters postulated in the general valuation and investment literature are considered in hedonic models. This can have different reasons, such as the data availability and quality, differences of markets and property types or the necessary stability of the models.

Table VI. Quantification of the discussion on individual parameters in the Upper Group 4 in previous studies on investment criteria

		List of parameters	Analysed studies	
Nr.	Hierarchy	Parameter	Discussion in monograph	Discussion in paper
183	4.	*Land*		
184	4.1	*Dimension*		
185	4.1.1	Site area	4	28
186	4.1.2	Property shape	1	
187	4.1.3	Topography	1	1
188	4.1.3.1	Development potential	1	
189	4.1.3.2	Load baring capacity		
190	4.2	*Rights/Encumbrances*	1	1
191	4.2.1	Land register entries		
192	4.2.1.1	Easements		1
193	4.2.1.2	Liens		
194	4.2.2	Hereditary construction		
195	4.2.2.1	Leasehold		1
196	4.2.2.2	Ground rent		
197	4.2.3	Old and remnant buildings		
198	4.2.4	Planning right of the property	1	
199	4.2.5	Special approval		
200	4.3	*Public Infrastructure*	1	
201	4.3.1	Accessibility		
202	4.3.2	Technical development (infrastructure)		1
203	4.3.2.1	Electrical system		1
204	4.3.2.2	Water		3
205	4.4	*Guideline land value*	3	3
206	4.5	*Parking*		5
207	4.5.1	External parking space		7
208	4.5.1.1	Open air parking spaces		10
209	4.5.1.2	Garage		28
210	4.5.2	Internal parking space		7
211	4.6	*Garden*		
212	4.6.1	Garden available		6
213	4.6.2	Garden size		1
214	4.7	*Taxes*		5

Source: Own compilation, individual sources (Table I)

6. Results and conclusions

The survey of previous studies on hedonic models for the housing market emphasises the great variety of parameters influencing the value. Despite assigning and compressing from case to case, the result is a total list of more than 400 individual parameters that have a higher or lower influence on the value of a property, respectively, on the profitability of the residential property.

As a result, the individual parameters are listed and grouped into a number of hierarchy levels. Accordingly, the total list contains main-level (global) parameters and sub-level (specific) parameters. The parameter hierarchy shown with a number of levels (depending on the segment up to five) provides a better clarity and transparency in comparison to the previous research on value-influencing parameters.

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
215	5.	*Building*		1
216	5.1	*Type of residential*		7
217	5.1.1	Building		
218	5.1.1.1	Single-family detached house	3	16
219	5.1.1.2	Semi-detached house	2	7
220	5.1.1.3	Row house	2	5
221	5.1.1.4	Multi-family house		3
222	5.1.1.5	Villa		1
223	5.1.1.6	Cottage		
224	5.1.2	Flat		4
225	5.1.2.1	Rental flat		3
226	5.1.2.2	Condominium	1	4
227	5.1.2.3	Holiday apartment		2
228	5.1.2.4	Apartment		5
229	5.1.2.5	Studio		1
230	5.1.2.6	Penthouse		1
231	5.2	*Dimension*		
232	5.2.1	Type and extent of building use	3	
233	5.2.1.1	Floor-space index	2	
234	5.2.1.1.1	Allowed floor-space index	1	
235	5.2.1.1.2	Current floor-space index	2	
236	5.2.1.2	Site occupancy index	1	
237	5.2.1.2.1	Allowed site occupancy index	1	
238	5.2.1.2.2	Current site occupancy index	2	
239	5.2.1.3	Cubic density	2	2
240	5.2.1.4	Ceiling height		1
241	5.2.1.5	Number of full storeys	1	10
242	5.2.2	Dimensions data		
243	5.2.2.1	Property size or building size	4	35
244	5.2.2.1.1	Gross building area	3	3
245	5.2.2.1.2	Net building area	4	4
246	5.2.2.2	Unit size	3	7
247	5.2.2.3	Room size		1
248	5.2.2.3.1	Bathroom size		2
249	5.2.2.3.2	Bedroom size		3
250	5.2.2.3.3	Living room size		1
251	5.2.2.3.4	Dining room size		1
252	5.2.2.3.5	Size additional rooms		
253	5.2.3	Number of units		
254	5.2.3.1	Building		
255	5.2.3.2	Building extensions		1
256	5.2.3.3	Units		5
257	5.2.3.4	Number of Rooms		7
258	5.2.3.4.1	Bathrooms		28
259	5.2.3.4.2	Sanitary facilities		2
260	5.2.3.4.3	Bedrooms		19
261	5.2.3.4.4	Living rooms		3
262	5.2.3.4.5	Dining rooms		2
263	5.2.3.4.6	Storage		4
264	5.2.3.4.7	Staff rooms		1

(*continued*)

Table VII. Quantification of the discussion on individual parameters in the Upper Group 5 in previous studies on investment criteria

	List of parameters		Analysed studies	
Nr.	Hierarchy	Parameter	Discussion in monograph	Discussion in paper
265	5.2.3.4.8	Recreation and leisure		2
266	5.2.3.4.9	Utility room		1
267	5.2.3.4.10	Porch		1
268	5.2.3.4.11	Terrace		1
269	5.2.3.4.12	Balcony		1
270	5.3	*Quality of construction and engineering*		
271	5.3.1	Time dimensions		
272	5.3.1.1	Total useful life	1	
273	5.3.1.2	Year of construction/building age	7	40
274	5.3.1.3	Year of construction of extension/ building age extension		
275	5.3.1.4	Remaining useful life	1	
276	5.3.2	Building quality	1	10
277	5.3.2.1	Standard	1	11
278	5.3.2.2	Green building certificate		
279	5.3.3	State of repair/condition	4	12
280	5.3.3.1	Renovation	1	2
281	5.3.3.1.1	Renovation frequency	1	
282	5.3.3.1.2	Date of renovation	1	
283	5.3.3.2	Refurbishment		2
284	5.3.3.2.1	Refurbishment frequency		
285	5.3.3.2.2	Date of refurbishment		
286	5.3.3.3	Deferred maintenance or maintenance backlog		2
287	5.3.4	Layout efficiency		2
288	5.3.4.1	Space efficiency		
289	5.3.4.2	Furnishing possibilities		
290	5.3.4.3	Workspace quality		
291	5.3.5	Flexibility of utilisation		
292	5.3.5.1	Third-party adaptability		
293	5.2.5.2	Divisibility of space		
294	5.3.6	Barrier-free access		
295	5.3.7	Load baring capacity		
296	5.3.8	Basements	1	13
297	5.4	*Type of construction and fit out*	2	
298	5.4.1	Roof		1
299	5.4.2	Attic	1	5
300	5.4.3	façade		8
301	5.4.4	Window		4
302	5.4.5	Doors		
303	5.4.6	Floor		1
304	5.4.6.1	Type of flooring		3
305	5.4.6.2	Standard of flooring		3
306	5.4.7	Kitchen		7
307	5.4.8	Terrace/balcony		9
308	5.4.9	Technical facilities		1
309	5.4.9.1	Heating	1	15

Table VII. (*continued*)

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
310	5.4.9.2	Air conditioning/HVAC		14
311	5.4.9.3	Building automation		
312	5.4.9.4	Elevator		6
313	5.4.9.5	Sun protection		
314	5.4.9.6	Data cabling		
315	5.4.9.6.1	Type of data cabling		
316	5.4.9.6.2	Standard of data cabling		1
317	5.4.9.7	Security		4
318	5.4.9.8	Lighting		1
319	5.4.9.8.1	Type of the lighting		
320	5.4.9.8.2	Standard of the lighting		
321	5.4.10	External areas		
322	5.4.11	Sanitary facilities		6
323	5.4.12	Waste disposal		1
324	5.4.13	Additional equipment		
325	5.4.13.1	Sport and fitness equipment		2
326	5.4.13.2	Wellness equipment		
327	5.4.13.2.1	Sauna		3
328	5.4.13.2.2	Jacuzzi		1
329	5.4.13.2.3	Pool		8
330	5.4.13.2.3.1	Outside pool		2
331	5.4.13.2.3.2	Inside pool	1	1
332	5.4.13.3	Bars		
333	5.4.13.4	Restaurants		
334	5.4.13.5	Conference equipment		
335	5.4.13.5.1	Availability		
336	5.4.13.5.2	Size		
337	5.4.14	Star category		
338	5.4.15	Fire place		11
339	5.4.16	Built-in cupboards		1
340	5.4.17	Fence		1
341	5.5	*Visibility*		1
342	5.5.1	Perceptibility		
343	5.5.2	View		7
344	5.5.2.1	Sea view	1	5
345	5.5.2.2	Mountain view		4
346	5.5.2.3	Garden view		1
347	5.5.2.4	Road view		1
348	5.5.2.5	View on industrial properties		1
349	5.5.2.6	Park view		1
350	5.5.2.7	View on rails		1

Source: Own compilation, individual sources (Table I)

Table VII.

The assignments and counters were compared with an earlier study by Sirmans *et al.* (2003), whereby a certain overlap was found without being identical. Larger deviations can be found particularly in the case of such location-related parameters, as the district or the distance to the CBD.

Nr.	Hierarchy	List of parameters Parameter	Analysed studies Discussion in monograph	Discussion in paper
351	6.	*Use*		
352	6.1	*Rent*		3
353	6.1.1	Gross rent	1	1
354	6.1.2	Net rent	1	2
355	6.1.2.1	Rent per sq m	1	
356	6.1.2.2	Passing Rent		
357	6.1.3	Dependence of the rent		
358	6.1.4	Rent review possibilities		
359	6.1.5	Hotel key figures		
360	6.1.5.1	ARR		
361	6.1.5.2	RevPAR		
362	6.2	*Management*		
363	6.2.1	Operating costs	1	
364	6.2.1.1	Management costs		
365	6.2.1.2	Operating costs		1
366	6.2.1.3	Maintenance costs		
367	6.2.1.4	Maintenance cost rate		
368	6.2.1.5	Modernisation costs		
369	6.2.1.6	Vacancy costs		
370	6.2.1.7	Occupancy rate		
371	6.2.1.8	Risk of rental loss		
372	6.2.1.9	Marketing		
373	6.2.2	Service chare agreement		
374	6.2.3	Non-recoverable costs		
375	6.3	*Units*		1
376	6.3.1	Type/quality/fit out of the units		
377	6.3.2	Type of use	1	
378	6.3.2.1	Owner occupied		1
379	6.3.2.1.1	First residence	1	
380	6.3.2.1.2	Second residence	1	
381	6.3.2.2	Rented		
382	6.3.3	Floor of the unit	1	5
383	6.3.4	Location of the units of utilisation (cardinal direction)		5
384	6.3.5	Contract terms		2
385	6.3.5.1	Minimum remaining (lease) duration		
386	6.3.5.2	Maximum remaining (lease) duration		
387	6.3.5.3	WALE		
388	6.3.5.4	Prolongation option		
389	6.3.6	Tenant's mix/allocation		
390	6.3.6.1	Tenant		
391	6.3.6.2	Branch		
392	6.3.6.3	Covenant strength		
393	6.3.6.4	Incentives		
394	6.3.6.5	Vacancy		2

Source: Own compilation, individual sources (Table I)

Table VIII. Quantification of the discussion on individual parameters in the Upper Group 5 in previous studies on investment criteria

The need for further research, specifically further development of steps in the hedonic modelling exists, especially in the test of correlations, the reduction of the list at high correlation and poor data quality and quantity and, in the examination of different quality characteristics such as residues, disruptive terms, coefficients of determination and significances (Metzner, 2013, p. 698). Furthermore, there is a general need for further research on the collection of basic data, which is still unsatisfactory as it is neither methodically nor timely consistent (Francke, 2011, pp. 412-413). The elaborate or inadequate data collection of the transaction prices and the concerned property characteristics is certainly still a large limitation of today's hedonic valuation models (Eckmann-Urbanski, 2005, p. 156). To that effect, the paper elaborates the necessary ground, with the consideration and definition of all possible value-influencing parameters, for a model-consistent data collection and transparent step-by-step modelling.

Besides, the process of implementation and interpretation is very complex and requires extensive theoretical and statistical knowledge (Eckmann-Urbanski, 2005,

		List of parameters	Analysed studies	
Nr.	Hierarchy	Parameter	Discussion in monograph	Discussion in paper
395	7.	*Transaction parameters*		
396	7.1	*Acquisition*		1
397	7.1.1	Date	5	6
398	7.1.2	Net purchase price	6	46
399	7.1.3	Acquisition costs/Purchasers On-Costs		
400	7.1.4	Transaction partners		
401	7.1.4.1	Type of purchasers	1	2
402	7.1.4.2	Type of vendors	1	1
403	7.2	*Construction costs*	1	
404	7.3	*Value parameters*		
405	7.3.1	Capitalisation rate		
406	7.3.2	Market value	4	10
407	7.3.3	Loan to value ratio		1

Source: Own compilation, individual sources (Table I)

Table IX. Quantification of the discussion on individual parameters in the Upper Group 7 in previous studies on investment criteria

Rank	Parameter	Discussion in monograph or paper
1.	Year of construction of extension/building age extension	47
2.	Building size	39
3.	Lot size	32
4.	Garage (number)	28
5.	Number of bathrooms	28
6.	District/part of town	21
7.	Number of bedrooms	19
8.	Type of residence – single family detached house	19
9.	City centre/CBD	16
10.	State of repair/condition	16

Source: Own compilation, individual sources (Table I)

Table X. Ranking of ten, most frequent parameters

p. 156). A modelling based on purely data evaluation (statistics) can lead to random results and spurious regressions. For this reason, the development of hedonic models for the housing market must always be linked to the technical (causalities in the sense of cause and effect chains) and the statistical perspectives (results of the correlation, regression). For the practical application of hedonic models, the transparent and comprehensible presentation of all modelling steps is therefore very important.

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