Weight Coefficients in the Appraisal System Approach

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Abstract. Among the market oriented appraisal methods, an interesting possibility is represented by the application of the Appraisal System Approach, whose reliability is linked to the availability of an adequate number of comparison data needful to allow the mathematical resolution of the system itself.

The present contribution intends to investigate the possibility of applying the Appraisal System Approach also in case of special appraisal (dissimilar data or not equally reliable ones), using coefficients that can weight the comparables differently in comparison functions due to the different similarities in property characteristics or pricing reliability

Keywords: Appraisal system approach · Similarity degree · Prices reliability

1 Introduction

The possibility to apply the Appraisal System Approach (ASA) is due to the availability of an adequate number of comparables, proportionate to the amount of the unknowns and to allow the mathematical resolution of the system itself.

The number of surveys required for the application of the procedure must also be determined by taking into account that some system equations are sometimes not usable for appraisal because they are redundant.

While a determined or oversized system should lead to logically and practically consistent results, the same cannot be said about an underdeveloped system for which, while there is a possibility to trace a mathematically correct solution through the generalized reverse technique, nothing can be said about the goodness of the solution and its valuation significance.

It is clear then that as much higher the number of data available is, closer to the "true" the results will be.

An opportunity is to broaden the survey sample by introducing dissimilar comparison properties or data that are not always equally reliable, using coefficients that can weight the comparables differently in comparison functions due to the different similarities in property characteristics or pricing reliability.

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In this work we first show the traditional application of the appraisal system approach (par. 3.1), in the light of the literature background inherent to atypical markets (par. 2). Then, we describe the proposed approach named WASA - Weighted Appraisal System Approach (par. 3.2) and the construction of the similarity coefficients and reliability ones (par. 3.2.1). After showing the WASA implementation (par. 3.2.3), the methodology has been applied to a case study (par. 4).

2 Literature Review

The International Valuation Standards (IVS) indicates as internationally recognized appraising methods the Market Oriented Approach, the Income Approach, the Cost Approach. When real estate market is active and all necessary market data are available, you may choose the best method for solving the case scenario based on the appraisal purpose and data availability (prices, incomes and costs).

Real estate appraisal methods intend to control as much as possible subjectivity in property valuation.

In this perspective, the Appraisal System Approach [1] is able to appraise property values and hedonic prices in a really automatic way, without any individual personal contribution, just occurring the solution of a linear equations system.

The main limit of this method is the necessity to have an adequate number of comparables, in order to have almost a determined system.

The problem is that the Appraisal System is a theoretical approach structured on the hypothesis of perfect competition market, while in real markets properties transactions are far from this assumption, approaching the conditions of monopolistic competition. More, in some atypical markets data are not available, so ASA system can't be applied.

The issue of limited data quantities in calculating market values and hedonic prices is well known in the real estate literature.

Many studies have been done about lack of data when calculating property price indexes [2–7].

However, these methodologies have some drawbacks, because they are statistical methods (with all their relative limitations) instead of proper appraising tools. Although it is evident the need to perform significance tests, it is important to underline that a statistically correct result may be not always significant by an appraisal point of view.

Therefore, alternative models may be more suitable to use, because they are based on linear equations systems [8].

Another possibility relates to the possibility to use similarity and reliability coefficients [9] in order to increase the number of properties in the comparables sample, introducing also dissimilar properties.

Some studies have been done about measurements of rationality about similarity and reliability degree in appraisal methodologies based on adjustments [10], investigating also the possibility to use the mono-parametric method in atypical markets thanks to reliability coefficients [11].

3 Methodology

3.1 Appraisal System Approach (ASA)

The appraisal system is a methodological approach able to determine a property value and features' hedonic prices on the basis of the solution of a linear equation system.

The ASA is set up starting from the generic appraisal function, for which the price of a property depends on its real estate characteristics, so:

$$P_j = f\left(x_{j1}, x_{j2}, \cdots, x_{jn}\right); \tag{1}$$

$$P_j = p_1 x_{j1} + p_2 x_{j2} + \cdots + p_n x_{jn}; \tag{2}$$

where x_{ji} (with i = 1..n) values represent the amount of the i real estate characteristics and p_i represent the related hedonic prices.

The price changes presented by two different j and k properties are consequence and function of the differences between the amounts of the related real estate characteristics:

$$P_k = p_1 x_{k1} + p_2 x_{k2} + \cdots + p_n x_{kn}, \tag{3}$$

so that,

$$P_j - P_k = p_1(x_{j1} - x_{k1}) + p_2(x_{j2} - x_{k2}) + \cdots + p_n(x_{jn} - x_{kn}). \tag{4}$$

therefore, it can be stated that equals properties are priced the same.

The comparable function (4) can be written also for the comparison between the subject and the generic comparable property of the comparables samples as:

$$P_j - V = p_1(x_{j1} - x_{01}) + p_2(x_{j2} - x_{02}) + \cdots + p_n(x_{jn} - x_{on}), \tag{5}$$

where x_{0i} (with i = 1..n) values represent the amount of the subject's real estate characteristics and V is the appraised market value of the subject.

The appraisal system is based on equations related to the comparisons between the property being appraised and every single real estate property of a comparables sample.

The appraisal system implements a set of m pairwise comparisons function related to the comparisons between the property being appraised and every single j real estate property of a comparables sample (j = 1..m):

$$\begin{cases} P_1 = V + \sum_{i=1}^{n} (x_{1i} - x_{0i}) \cdot p_i \\ P_2 = V + \sum_{i=1}^{n} (x_{2i} - x_{0i}) \cdot p_i \\ \ldots = \ldots \\ \ldots = \ldots \\ P_m = V + \sum_{i=1}^{n} (x_{mi} - x_{0i}) \cdot p_i \end{cases} \tag{6}$$

where P_j are the known sales prices.

In matrix form the (6) becomes:

$$P = D \cdot p, \tag{7}$$

in which:

- p is the appraisal vector and P the known sales prices vector:

$$p = \begin{bmatrix} V \\ p_1 \\ p_2 \\ \dots \\ p_n \end{bmatrix}; \quad P = \begin{bmatrix} P_1 \\ P_2 \\ \dots \\ \dots \\ P_n \end{bmatrix}; \tag{7}$$

- D is the differences matrix

$$D = \begin{bmatrix} 1 & d_{11} & d_{12} & \dots & d_{1n} \\ 1 & d_{21} & d_{22} & \dots & d_{2n} \\ \dots & & & & \\ 1 & d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix}, \tag{8}$$

where $d_{ji} = x_{ji} - x_{0i}$.

The resolution of the system is performed through the application of the least squares method when the system is determined:

$$p = D^{-1} \cdot P, \tag{9}$$

otherwise it is performed through the application of the Moore-Penrose technique:

- if $m < n + 1$ then

$$p = D^T \cdot \left(D \cdot D^T\right)^{-1} \cdot P; \tag{10}$$

- if $m > n + 1$ then

$$p = \left(D^T \cdot D\right)^{-1} \cdot D^T \cdot P. \tag{11}$$

3.2 Weighted Appraisal System Approach (WASA)

As we have already said, the ASA approach well works in the hypothesis of perfect competition markets, when a lot of data are available, where transactions are transparent and more other idealistic conditions. The real estate markets are far from this, usually approaching to the monopolistic competition. The ASA approach continues to well work also in real markets but only when you have so much data you can implement the linear equation system using equally reliable comparables.

In atypical markets, and moreover when lack of data, the appraisal system approach can lead to uncertain results. The idea is to formally rewrite the system using measurements of similarity and reliability as weight coefficients, in order to differently weight the comparables functions in relation to respective similarity and reliability degree.

Similarity and Reliability in Sample Comparables

The central question of the application of market oriented methods is the need to identify a comparison sample of properties similar to the subject. A first consideration is due to "the similarity degree" of the properties in the sample. A second consideration relates to prices data which, although corresponding to the definition of market value, may also be affected by contingent circumstances and present a different "reliability degree" for the purposes of valuation [10].

A similarity coefficient provides a measure of the degree of similarity between the comparables, giving values between 0 and 1, the first corresponding to observations with no common elements, the second relating to the surveys that perfectly meet the criterion used to measure the similarity. The similarity coefficients usually reported in literature can be divided into symmetrical coefficients and asymmetrical ones. While using symmetrical coefficients, null values are interpreted as the absence of the corresponding characteristic (for example, the absence of the garage), and therefore the null data have the same comparative value of the others; in the case of asymmetric coefficients, the null value indicates the absence of information (for example, it was not possible to measure the surface of the garage). A further distinction is between binary coefficients and semi-quantitative or quantitative coefficients: the former are useful in situations where it is sufficient to establish the presence or absence of the characteristic, the latter are functional to interpret and numerically compare observations of quantitative data. Quantitative coefficients are not numerous because, in the presence quantitative data, it is usually preferred the use of distance measures which return a null value for identical observations and a variable value for different observations. The similarity measures can be obtained as 1 minus the distance coefficients. The distance coefficients are usually symmetrical and treat the 0 value as an actual measurement instead of a lack of information.

In the real estate sector, the observations consist of quantitative and semi-quantitative data, so that it is possible to measure the similarity degree through symmetrical distance measurements.

Therefore, a measure able to detect the similarity of individual properties in the real estate sample has its foundation in the "closeness" between the amounts of property characteristics: greater comparability means greater proximity of the amounts of the real estate characteristics, less comparability means more distant amounts. The measure of the "degree of similarity" of comparable properties may, therefore, be expressed as a function of the difference between the amounts of the i-th feature of the comparable and those of the subject.

This difference can be expressed in terms of absolute value in the following way:

$$gs_a^{j^*} = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right| - \sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right|}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right|}, \tag{12}$$

where $gs_a^{j^*}$ is the indicator of the degree of similarity of a j* generic property of comparison and $\bar{x}_i$ is the average of the considered characteristic [9].

The difference between the amount of the i-th feature of the comparable and that corresponding to the subject can also be expressed in terms of square standardized distances, as follows:

$$gs_q^{j^*} = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right|^2 - \sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right|^2}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{X_{ij}-X_{i0}}{\bar{X}_i}\right|^2}, \tag{13}$$

where $gs_q^{j^*}$ is the degree of similarity of a generic property of comparison j [9].

The need to assess the degree of reliability is related to the presence of any abnormal market prices for comparables. The anomaly exists if the following assumptions hold: (a) prices were collected in the same market segment of the subject; (b) prices are recent and obey the definition of market value, (c) prices were obtained following a consistent methodology and gathered from common and comparable sources. The methodological condition concerns the possibility for the evaluator to exclude, by a feedback, anomalous prices, and related properties from the comparable sample when the corresponding correct prices exceed the threshold of divergence. Under these assumptions and in accordance with the methodological condition, the measurement of the degree of reliability of the test operates within the range of divergence and, possibly, in the neighborhood of the extreme threshold.

The measure of the "degree of reliability" in each property of comparison, in relation to the sale price, is determined by the following formula:

$$ga^{j^*} = \frac{\left(1 - \left|\frac{P_{cj^*}-\bar{P}_{cj}}{\bar{P}_{cj}}\right|\right)^{m+1}}{\sum_{j=1}^{m}\left(1 - \left|\frac{P_{cj^*}-\bar{P}_{cj}}{\bar{P}_{cj}}\right|\right)^{m+1}} \tag{14}$$

where P_{cj^*} is the sale price of the j*sale and $\bar{P}_{cj}$ is the average sale price [10].

The variation function has an almost linear trend taking values between 0 and 1/(m–1): the greater the difference between the correct price and the correct price of the comparable average of the sample, the lower the reliability of the corresponding correct price.

WASA Implementation

According to the fact that reliability coefficients relate to prices and similarity ones to property characteristics, the ASA may be rewritten as:

$$\begin{cases} ga^{1^*}(P_1 - V) = \sum_{i=1}^{n} gs_q^{1^*}(X_{1i} - X_{0i}) \cdot p_i \\ ga^{2^*}(P_2 - V) = \sum_{i=1}^{n} gs_q^{2^*}(X_{2i} - X_{0i}) \cdot p_i \\ \ldots = \ldots \\ \ldots = \ldots \\ ga^{m^*}(P_m - V) = \sum_{i=1}^{n} gs_q^{m^*}(X_{mi} - X_{0i}) \cdot p_i \end{cases} \tag{15}$$

where using square coefficients, or

$$\begin{cases} ga^{1^*}(P_1 - V) = \sum_{i=1}^{n} gs_a^{1^*}(X_{1i} - X_{0i}) \cdot p_i \\ ga^{2^*}(P_2 - V) = \sum_{i=1}^{n} gs_a^{2^*}(X_{2i} - X_{0i}) \cdot p_i \\ \ldots = \ldots \\ \ldots = \ldots \\ ga^{m^*}(P_m - V) = \sum_{i=1}^{n} gs_a^{m^*}(X_{mi} - X_{0i}) \cdot p_i \end{cases} \tag{16}$$

where using absolute coefficients.

In matrix form we have:

- the unknown vector p

$$p = \begin{bmatrix} V \\ p_1 \\ p_2 \\ \ldots \\ p_n \end{bmatrix} \tag{17}$$

- the differences matrix D

$$D = \begin{bmatrix} ga^{1^*} & gs_q^{1^*}(x_{11} - x_{01}) & \ldots & gs_q^{1^*}(x_{1n} - x_{0n}) \\ ga^{2^*} & gs_q^{2^*}(x_{21} - x_{01}) & \ldots & gs_q^{2^*}(x_{2i} - x_{0n}) \\ \ldots & \ldots & & \ldots \\ ga^{m^*} & gs_q^{m^*}(x_{mn} - x_{0n}) & \ldots & gs_q^{m^*}(x_{mi} - x_{0n}) \end{bmatrix} \tag{18}$$

- the sales prices vector P

$$P = \begin{bmatrix} ga^{1^*} \cdot P_1 \\ ga^{2^*} \cdot P_2 \\ \ldots \\ \ldots \\ ga^{m^*} \cdot P_m \end{bmatrix} \tag{19}$$

Nothing changes about system solution, so that least squares method is used when the system is determined, otherwise it is performed through the application of the Moore-Penrose technique.

Case study and Results

The methodology proposed in this paper has been tested on a sample of properties located in the city of Cosenza, Italy.

The methodology has been applied to a sample of 9 comparables, real estate properties that have been sold in the last year (2017); real estate data have been acquired from the Observatory of Real Estate Market, an Italian real estate market observatory instituted by University of Calabria.

All data relate to segment of the used market for condominiums in multistory buildings. Properties are physically, technically, economically and functionally similar, the use is exclusively the housing one, and motivations of purchase and sale are usually attributable to transfer. The shape of the market is restricted due to monopolistic competition, in which franchise agents are the most common form of intermediation.

From the survey forms associated with each real estate datum, information about real estate features deemed relevant in the mechanism of price formation in the study area were acquired. More specifically, the variables considered in the sample are:

Sale Price (SPR): measured in €, indicates the true price paid in the real estate transaction updated to the appraisal time;

Principal surface (SUP): measured in square meters, is the amount of the principal surface;

Balconies surface (SUB): measured in square meters, is the amount of the balconies surface;

Garage surface (SUG): measured in square meters, is the amount of the garage surface;

Restrooms (RES): n° measured, indicates the number of toilets;

Floor Level (LEV): indicates the apartment floor level, measured with an ordinal scale;

Energy class level (ECL): it is possible to assign a score ranging from a minimum of 1 to a maximum of 8 corresponding to the standard energy classification of buildings (from A + to G);

Maintenance and conservation status (MSC): measured with a scale score, was attributed 0 to indicate a state of poor maintenance, 1 for mediocre maintenance, 2 for adequate maintenance, 3 for a discrete state, 4 if the maintenance status is good, 5 if the maintenance condition is excellent.

In Table 1 collected data are reported; in Table 2 sample statistics are reported.

The methodology has been tested considering every single property as a subject of unknown sale price, appraising its value both with the ASA and the WASA and comparing it with the real known sale price.

Table 1. Data table

Sale price and characteristics	A	B	C	D	E	F	G	H	I
SPR (€)	200.000,00	160.000,00	147.000,00	150.000,00	167.000,00	200.000,00	175.000,00	140.000,00	190.000,00
SUP (sqm)	140	140	130	95	107	136	115	128	120
SUB (sqm)	20	25	15	15	25	32	12	20	15
SUG (sqm)	20	0	0	22	30	0	0	25	35
REST (n°)	2	2	2	1	2	2	2	1	2
LEV (n°)	3	1	3	4	1	3	4	5	3
ECL (score)	1	2	2	3	2	3	4	1	3
MSC (score)	3	1	2	3	2	3	3	0	3

Table 2. Sample statistics

Sale price and characteristics	Average or frequency
SPR (€)	150.888,89
SUP (sqm)	123,88
SUB (sqm)	20,50
SUG (sqm)	12,13
REST (1,2)	2-7
LEV (1,2,3,4,5)	2-0-4-2-1
ECL (1,2,3,4)	2-3-3-1
MSC (0,1,2,3)	1-1-2-5

Observing Table 3 you can notice that values appraised with WASA are more stable than those calculated with the ASA. In fact, ASA values sometimes are extremely far from reality, not only from a numerical point of view, but above all in terms of appraisal significance.

Table 3. Divergence between appraised values and sale prices

Subject	Appraised values		Sale prices	Divergence between appraised values and sale prices	
	WASA	ASA		WASA divergence	ASA divergence
A	182.565,44	162.672,73	200.000,00	0,10	0,23
B	188.740,68	87.800,74	160.000,00	0,18	0,82
C	169.699,75	168.434,06	147.000,00	0,15	0,15
D	178.178,35	381.850,29	150.000,00	0,19	1,55
E	184.807,58	727,53	167.000,00	0,11	228,54
F	187.289,65	268.572,04	200.000,00	0,07	0,34
G	129.203,24	146.764,52	175.000,00	0,35	0,19
H	142.732,22	–91.850,29	140.000,00	0,02	–2,52
I	185.106,55	237.999,95	190.000,00	0,03	0,25

The question is far more complex in terms of hedonic prices, which are really variable both in the WASA and ASA, although this variability is more contained in when using the weight coefficients respect to the traditional approach.

4 Conclusion

The possibility to apply the Appraisal System Approach (ASA) is due to the availability of an adequate number of comparables, proportionate to the amount of the unknowns and to allow the mathematical resolution of the system itself. Also when you have a sufficient data sample, it is not said that the system leads to probative results in terms of appraisal significance. A good opportunity is to use weight coefficients able to take into account the dissimilarities and anomalies present in the sample, useful on the one hand to avoid the exclusion of some comparable from the sample, on the other to improve the quality of the obtained results.

It is clear that the results of the WASA approach cannot be accepted in deterministic terms but interpreted in probabilistic ones, as also the ASA approach requires, but the use of the proposed methodology can extend the applicability fields of the ASA, and it can be proposed as a useful tool to implement Automated Valuation Methods such the computer assisted ones (CAMA).

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