AESTIMUM
CENTRO STUDI DI ESTIMO E DI ECONOMIA TERRITORIALE - Ce.S.E.T.

Firenze University Press
www.fupress.com/ceset

Citation: Salvo, F. (2023). From appraisal function to Automatic Valuation Method (AVM). The contribution of International Valuation Standards in modern appraisal methodologies. *Aestimum* 83: 47-57. doi: 10.36253/aestim-14730

Received: May 17, 2023

Accepted: January 17, 2024

Published: April 22, 2024

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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From appraisal function to Automatic Valuation Method (AVM). The contribution of International Valuation Standards in modern appraisal methodologies

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Abstract. In the real estate appraisal, as well as for any other scientific discipline, there is a continuous development of knowledge with related theoretical and applicative evolution that takes place primarily on the doctrinal level. The discipline has been object of regulatory and technological improvement aimed at concretizing and defining theoretical principles and methodologies. The functions of value appraisal, formulated in the different procedures that fall within the Market Oriented Approach indicated by the International Valuation Standard, have undergone a process of evolution that has favoured the introduction of Automated Valuation Methods (AVM). This evolution process represents an improvement of the conventional appraisal models that have improved the techniques of data retrieval and data base access and certify the reliability of the models to build efficient evaluation processes and universally recognized. This article aims at reviewing the methodological evolution in relation to the national market approach that the estimation discipline has recorded in recent years by virtue of the drafting and adoption of the International Valuation Standards.

Keywords: value function, market-oriented procedures, appraisal reports, market comparison approach, mono-parametric appraisal procedure, appraisal system model, appraisal division system, automated valuation methods.
JEL codes: B23, C01, C02, C50, R31.

1. INTRODUCTION

Over the past 20 years, the world of real estate valuation has changed dramatically in terms of rules, assessment methods and computerization of valuation procedures. During the most recent years, the rapid economic change has encouraged real estate agents around the world to emphasize real estate by adopting internationally recognized valuation standards such as: International Valuation Standard (IVS), IVSC 2022; European Valuation Standard (EVS - "The Blue Book"), TEGOVA 2020; RICS Valuation – Global Standards ("Red Book Global Standards"), RICS 2022; Uniform Standards of Professional Appraisal Practice (USPAP), The Appraisal Foundation 2023. In the particular Italian context, we can identify the subsequent standards: National Standard UNI 11612:2015 – 11558:2014; Codice delle Valutazioni Immobiliari, Tecnoborsa (2020); Linee Guida per la Valutazione degli Immobili in Garanzia delle Esposizioni Creditizie, ABI (2022), Manuale Operativo delle Stime Immobiliari (MOSI), Direzione Centrale Osservatorio del Mercato immobiliare e Servizi Estimativi dell'Agenzia del Territorio (2011).

Standards represent a set of uniform and common rules of a methodological and application nature that are systematically collected and presented (Hordijk, 2012; Manganelli, 2017). Rules, contained into international assessment standards, derive from factual models of professional practice, and consist of usually accepted common rules. Their origins and the constant link with current events lead to updates and revisions over time. Such adjustments must go hand in hand with the evolution of the real estate market. Essentially, International Valuation Standards (IVSs) regulate best practice and market data collection. Best practice guarantees the achievement of goals in the highest economy and quality. The collection of market data and information is the material basis of valuation standards (Schulte et al., 2005).

Valuations proposed by IVSs make full use of the principles and rules of the valuation methodologies. They are based on repeatable procedures that allow the definition of homogeneous processes, quantitative analysis, and quality control, guaranteeing the identification of values that should be free from errors and averting the occurrence of unforeseen complications (Simonotti, 2006). Particularly, IVSs are intended to establish issues such as: technical definitions; the evaluation criteria applicable; the qualification of evaluators and professional ethics; guidelines for application methodology.

The research in the field of appraisal has more recently develop new relevant analytical tools. Whitin the framework of point estimates, the traditional appraisal methodology has been enriched by the introduction and subsequent evolution of market-oriented procedures (Market Comparison Approach, General Appraisal System, Distribution System, Mono-Parametric Appraisal) (Simonotti, 2006).

In the area of large-scale estimates, numerous evaluation models have been tested and applied, many of which are based on the analysis of multiple regression, while others consider multilevel analyses (neighborhood, street, isolated), artificial neural networks, fuzzy logic, rough set theory (Bikdeli, 2020; Ciuna et al., 2017d; Del Giudice et al., 2017; Morano et al., 2015).

Moreover, the availability of data in different formats and with a different scale of resolution as well as advances in computer technology have further transform the image of valuations by creating a link of interoperability between traditional appraisal and computer modeling. From an operational point of view, the models based on Geographic Information Systems (GIS) are particularly interesting because of the accessibility, visualization, and data storage (Arcuri et al., 2020).

The technological evolution also allows to employ innovative solutions for the automation of evaluation systems (Automated Valuation Models, AVM) (Ciuna et al., 2017a; Glumac and Des Rosiers, 2021). An AVM is a system that bases the appraisal on comparable property data and other market information, through quantitative models and computer procedures, excluding physical inspection of the property. AVMs generally use GIS environment to offer the benefit of the geographic visualization of the data and the storage of all the information related to the real estate data, namely alphanumeric data, photographs, maps of the properties.

Over the past 15 years, the refinement and flexibility of AVMs has improved the reliability and quality of cadastral estimates based on real estate data in different countries, included Italy.

American cadastral evaluators were the first to pave the way for the use of AVMs to compensate for budget, time, and personnel limitations in the analysis of real estate data for tax purposes. Cadastral offices websites of the United States have a detailed map of the properties and cadastral data with various scans. The search can be carried out directly on the map by identifying the properties for which cadastral and civic references and building and real estate data are presented. From the property sheet, it is possible to find the corresponding cadastral sheet of paper documentation and to examine recent contracts of buildings of the boundary. In the Italian context, Revenue Agency doesn't have an official website where it is possible to do this. However, there are some publicly accessible software, developed by private companies, such as STIMATRIX forMaps, that help the user to identify a property (land or building), starting from the simple address or the precise cadastral coordinates such as: Common, Section, Sheet, and Particle.

Automated assessment models are radically transforming assessment tools also in other valuation fields. Investors increasingly require reliable real estate valuations, which are immediately available and cheap. The use of AVMs is widespread in the estimates of real estate offered as collateral for loans, particularly the case of renegotiation and periodic revaluations, because it allows a rapid and economic assessment of risk; their spread is slower for new loans due to higher risk levels. It is known that the three main risk factors associated with loans secured by real estate include the value of the property, the Loan to Vale (LTV) ratio and the borrower risk profile (Agarwal, 2021). Since the LTV and the reliability of the borrower were deemed to have an equally significant impact when the value of the property on the severity and probability of default, the banks concluded that in some cases the cost and time savings of an AVM valuation outweigh the lower risk of a full inspection and traditional valuation of the property.

Some websites perform commercial real estate assessments in a geo-referenced context. The valuation system is open in the sense that the user enters the specific characteristics of their property (area, state of preservation, etc.) and the system indicates the value of the property based on the latest available real estate data. Each valuation is associated with a corresponding measure of confidence or level of uncertainty generated by the degree of correspondence of the property to be valued with comparable real estate. This provides the user with an indication of the accuracy of the assessment.

AVMs perform important instrumental tasks in the tax, administrative and commercial valuation of lands and buildings, but do not replace the professional assessment carried out by the qualified appraiser with the inspection of the property and the application of the standard appraisal methodology.

The paper aims at reviewing the methodological evolution in relation to the national market approach that the estimation discipline has recorded in recent years by virtue of the drafting and adoption of the International Valuation Standards.

The paper is structured as follows. In *Section 2*, the main relationships among the economic-appraisal quantities of the real estate market are discussed, especially the instrumental and mercantile indices and appraisal functions. In particular, in the *Sub-Sections 2.1*, *2.2* and *2.3*, the appraisal functions of the Mono-parametric Appraisal, the Market Comparison Approach, the Appraisal System Model and the Appraisal Division System are respectively presented. The evolution of these procedures and their integration into an Automated Valuation Model are given particular attention. Finally, in *Section 3*, we present the conclusions drawn from the study.

2. INSTRUMENTAL AND MERCANTILE INDICES AND APPRAISAL FUNCTIONS

In real estate sector and in professional practice, there is often recourse to some recurrent relationships among the economic-appraisal quantities of the real estate market. These ratios are of a different nature and can relate largely to unit prices of property characteristics, rates of change, percentages, and so on. In the field of real estate valuations, the main task of market relations is to make up for the lack of timely real estate data about prices and characteristics.

The study of the relationships and indices used in real estate activities is framed in a methodological scheme that allows to identify empirical relationships, to provide a symbolic formalization and a placement in an appropriate methodological field (Simonotti, 2001). This scope has been indicated in the appraisal functions that express in a simple way the relationship between the market price and the characteristics of the properties, using the spontaneous indications of the market and the information brought by the real estate data collected (Simonotti, 1997).

The main instrumental and mercantile indices used in the real estate appraisal are the following[1]:

– the mercantile relationship (π_i) between the prices of secondary areas (p_i) and the price of the principal area (p_1) (Simonotti, 2006):

$$\pi_i = \frac{p_i}{p_1} \tag{1}$$

– the position ratio (σ) between the hedonic price (p_1) and the average price ($\bar{p}_1$) of the surface (Simonotti, 2006):

$$\sigma = \frac{p_1}{\bar{p}_1} \tag{2}$$

– the complementary relationship (c_i) of part to the whole P that expresses the contribution of each individual characteristic (Simonotti, 2006):

$$c_i = \frac{p_i}{P} \tag{3}$$

– the corrective factor (r_j) in the sales adjustment grid (De Ruggiero and Salvo, 2011):

$$r_j = \left(\frac{x_{SUP_o} - x_{SUP_j}}{x_{SUP_j}}\right) \tag{4}$$

where x_{SUPo} and x_{SUPi} represent, respectively, the main surface of the subject (j=0) and the comparable (j) surface;

[1] The mercantile relationship and the complementary relationship belong to the real estate practice. The position relationship is a measure derived from knowledge about the real estate market. The correction coefficient in the sales adjustment grid is introduced to avoid problems of duplication in the adjustments of characteristics other than surface. The degree of similarity takes into account the degree of similarity of the comparable, while the degree of reliability assesses the reliability of the market prices of the comparable (Simonotti, 2006).

- the coefficients of similarity (gs_a^j, gs_q^j) and reliability (ga^j) (Simonotti et al., 2016):
Specifically, the similarity coefficient of a generic comparable , in terms of absolute value, can be expressed in the following way:

$$gs_a^j = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right| - \sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right|}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right|} \tag{5}$$

and the similarity coefficient gs_q^j of a generic comparable j, in terms of square standardized distances, can be expressed in the following way:

$$gs_q^j = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right)^2 - \sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right)^2}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x}_i}\right)^2} \tag{6}$$

where x_{ij} is the value of i-th characteristic of the j-th comparable property; x_{i0} is the value of i-th characteristic of the subject property; $\overline{x_i}$ is the value average of the considered characteristic; m is the number of comparables; $\sum\_j$ is the summation of terms of j comparables; n is the number of characteristics; $\sum\_i$ is the summation of terms of i characteristics.
The difference between the similarity coefficient gs_a^j and the similarity coefficient gs_q^j stems from the fact that the former is expressed in absolute value, whereas the latter is expressed in square standardized distances.

- the coefficients of reliability (ga^j) (Simonotti et al., 2016):

$$ga^j = \frac{\left(1-\left|\frac{P_{cj}-\overline{P}_{cj}}{\overline{P}_{cj}}\right|\right)^{m+1}}{\sum_{j=1}^{m}\left(1-\left|\frac{P_{cj}-\overline{P}_{cj}}{\overline{P}_{cj}}\right|\right)^{m+1}} \tag{7}$$

where p_{cj} is the value of the correct price of the j-th comparable property; $\overline{p_{cJ}}$ is the value average of the correct prices of the considered comparables; m is the number of comparables; $\sum\_j$ is the summation of terms of j comparables.

- the compound coefficient (gc^j) (Simonotti et al., 2016):
Specifically, if the similarity coefficient gs_a^j is calculated in terms of absolute value, we can express the relating compound coefficient gc_a^j in the following way:

$$gc_a^j = \frac{gs_a^j \cdot ga^j}{\sum_{j=1}^{m} gs_a^j \cdot ga^j} \tag{8}$$

and, if the similarity coefficient gs_q^j is calculated in terms of square standardized distances, we can express the relating compound coefficient gc_q^j in the following way:

$$gc_q^j = \frac{gs_q^j \cdot ga^j}{\sum_{j=1}^{m} gs_q^j \cdot ga^j} \tag{9}$$

where gs_a^j and gs_q^j are the values of the similarity coefficients of the j-th comparable; ga^j is the value of the reliability coefficient of the j-th comparable property; m is the number of comparables; $\sum\_j$ is the summation of terms of j comparables.

As it concerns appraisal functions, they allow the passage from the empirical relationships (and eventually from the quotations in absence of real estate data) to quantitative functions. Their study aims to rationalize the contingent experience with the logic of estimates in the language of models of estimative statistical analysis based on real estate data.

The formulation of the appraisal functions allows the proposition of a standard for the estimative analysis of real estate data and routine calculation (Ciuna et al., 2017c).

The analysis based on appraisal functions allows to solve many problems of real estate valuation, among which:

- the problem of measuring the parameters of the real estate market segment;
- the problem of estimating a single building by interpolation and extrapolation from the appraisal functions, known at least one property data;
- the problem of estimating the properties of the same market segment (mass appraisal);
- the statistical problem of the exogenous appraisal of the coefficients of the interpolating equation constructed on the data samples;
- the known problem of structuring and organizing appraisal functions from empirical reports, information, and market data collection.

The appraisal functions, through unit prices, aim to establish a relationship between the market price and the characteristics of real estate. In the appraisal functions, average prices and marginal prices of characteristics are composed in the functional report. Three appraisal functions have been indicated in the literature: the multiplicative appraisal function of theoretical interest; the simple and multiple linear appraisal functions (mono and pluri-parametric); the function of allocating the total price in the average prices of real estate characteristics[2].

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[2] The multiplicative appraisal function is presented as follows: $V = b_0 \cdot x_1^{b_1} \cdot x_2^{b_2} \cdot \dots \cdot x_n^{b_n}$ dove $b_0, b_1, \cdots, b_n$ represent the marginal prices of the

The appraisal functions have references to the Mono-parametric Appraisal, the Market Comparison Approach (MCA), the General Appraisal System, the Appraisal Division System, the Regression Analysis, and the Income Capitalization Appraisal. The first five procedures are part of the Market Oriented approach indicated by the International Valuation Standard (Simonotti, 2006).

2.1 The Mono-parametric Appraisal

The Mono-parametric (or synthetic) Appraisal method (Simonotti, 2006) is the most common procedure used in the professional practice of Italy for the market value assessment, even when the property to be estimated has many qualitative characteristics that affect its market value. The Mono-parametric Appraisal can lead to a reliable assessed value, when it is based on the collection of the market prices and also when a limited number of the characteristics are taken in consideration. According to IVSs, the eligibility of this method against those clustered in market comparison approach, is linked to the level of completeness of the comparison.

The Mono-parametric Appraisal requires both analysis and synthesis skills, such as the analysis of the multiple characteristics and peculiarities of the subject and the comparable, in search of similarities; and the synthesis of the complexity and plurality that contribute to the formation of the market value in a single parameter, represented by the comparison parameter. These operations obviously require considerable investigative capacity, adequate knowledge of the condition and objectives of the assessment, as well as significant market experience.

It should be noted that the Mono-parametric Appraisal can only be used scientifically and with reliable results if the characteristics of the peers are identical to those of the subject, except for the comparison parameter. Otherwise, ignoring the impact of the other characteristics in the assessment leads to an approximation of the evaluation results (Salvo et al. 2020).

The appraisal function representing the mono-parametric procedure is explained below:

$$V_0 = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} \pi_i} \cdot \pi_0 \tag{10}$$

where V_0 is the market value of the property being evaluated; P_i are the selling prices, and π_i are the comparison parameters of n comparables; π_0 is the comparison parameter of the subject property and represents the average unit price.

The evolution of scientific research in the field of appraisal has offered the possibility of applying the Mono-parametric Appraisal using measures of rationality able to synthesize the differences in the quantity of real estate characteristics in coefficients of similarity aimed at quantifying the "weight" different characteristics of the comparable in relation to the different degree of similarity and to implement the methodological approach in relation to an AVM (Ciuna et al, 2017b). AVM is a software-based tool that is used in residential and commercial real estate to determine the market value of a property (Ciuna et al., 2017b). The software uses mathematical or statistical modeling with a combination of existing databases to determine the value of a specific property.

Compared to traditional evaluation methods, AVM shows the advantage of providing reliable values, quickly, automatically, efficiently, reducing costs. This advantage arises when the base date on which the system is implemented contains accurate and reliable data, when the appraisal analysis is consistent with the foundations of the appraisal principles included in the international valuation standards, and when the modelling is adequately tested before application (Ciuna et al., 2017b; Salvo et al., 2022). A prerequisite for the application of this method is the availability of real estate data previously collected in a computer database (Ciuna et al., 2017d).

The reliability of the results produced by an AVM is obviously linked to the reliability of the real estate data available in the support database, which must be continuously monitored and updated to verify its integrity.

The implementation of the Mono-parametric Appraisal in an AVM can be carried out according to international valuation standards in operational terms, making automatic selection of comparable, data processing, the calculation of similarity and reliability coefficients and, finally, the determination and evaluation of the market value (Ciuna et al., 2017b).

The main steps of applying an AVM according to the mono-parametric procedure are as follows:

1. subject definition and map detection;
2. definition of the market segment within which comparable properties are to be recognized;
3. identification of comparable properties;
4. parameter measurements for both the subject and the comparables;
5. calculation of similarity, reliability and compound coefficients and updated average price measurements;

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property characteristics and $x_1,x_2,\cdots,x_n$ represent the property characteristics. The simple and multiple linear appraisal functions can be express as follows: the first one is $V = b_0 + b_1x_1$, and the second one is $V = b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 +\cdots+ b_n \cdot x_n$. The function of allocating the total price in the average prices of real estate characteristics can be express as follows: $V = \overline{b}_0 + \overline{b}_1 \cdot x_1 + \overline{b}_2 \cdot x_2 +\cdots+ \overline{b}_n \cdot x_n$, where the terms $\overline{b}_0,\overline{b}_1,\cdots,\overline{b}_n$ represent the average prices of the property characteristics.

6. determination of the appraisal value.

The appraisal value can be derived through the following appraisal functions:

$$V_0 = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} \pi_i} \cdot gc_a^j \cdot \pi_0 \quad (11)$$

$$V_0 = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} \pi_i} \cdot gc_q^j \cdot \pi_0 \quad (12)$$

The difference between the two functions consists in the use of the coefficient (8) in the first function and in the use of the coefficient (9) in the second one; there is not a preferable choice between them (Ciuna et al., 2017b).

2.2 The Market Comparison Approach

The MCA was proposed and used in the United States since the twenties of the last century to offer methods to reduce or eliminate subjective judgements of appraisers in the judicial field (Salvo and De Ruggiero, 2012). In Italy, the MCA was introduced with substantial changes in the methodology used in the United States, particularly in relation to the approach used to estimate the marginal price of real estate characteristics (Simonotti, 2006).

The MCA is a valuation procedure that leads to the valuation of the market value of a property through a monetary adjustment process applied to the market prices of comparable real estate considering differences that between the comparable and the property under valuation (Salvo et al., 2021).

In its traditional formulation, the main steps of the MCA appraisal procedure are the following:

1. Recording of recent sales of similar properties in the subject's market area;
2. Collection of the complete real estate data;
3. Choice of the property characteristics namely the elements of comparison;
4. Compilation of the sales summary grid;
5. Appraisal of the hedonic prices;
6. Drawing up the sales adjustment grid;
7. Reconciliation and presentation of the results.

The appraisal of hedonic prices is the central phase of the process, which is why knowledge about these prices is fundamental to calculating the adjustments (Phase 6) for each characteristic chosen. The hedonic prices appraisal is based on the principle of substitution, the principle of complementarity and the appraisal criteria (market value, cost value, processing value, complementary value, replacement value) (Herath & Maier, 2010; Lee and Whitacre, 2021; Salvo et al., 2021;).

The appraisal function used in the MCA to determine the most likely market value of a property is presented as follows:

$$V_0 = P_j + \sum_{i=1}^{n} p_{ij} \cdot \left(x_{i0} - x_{ij}\right) \quad (13)$$

where V_0 is the market value of the property being evaluated; P_j is the selling price of j-th comparable property; p_{ij} is the marginal price of the of i-th characteristic; x_{i0} is the value of i-th characteristic of the subject property; x_{ij} is the value of i-th characteristic of the j-th comparable property.

However, the application of the procedure has shown that the mathematical formulations derived from the valuation criteria for determining the marginal prices of the real estate characteristics contained some duplication, which may lead to overappraisal (or undervaluation) in property valuation (Simonotti et al., 2016).

For surface characteristics, especially, the determination of the marginal price refers to the so-called merchant price theorems[3] for the main area and some corollaries for other areas.

Subsequent studies have simplified and improved the first version of the methodology proposed by Simonotti (Simonotti, 2006) to face the issues of duplication of characteristics and reliability of sales data. The incidence of approximations was identified mathematically and resolved by observing the presence of repeated terms in the adjustment formula. As a result of this evolution, the appraisal function in the new version of the MCA, called MCA 2.0 (Simonotti *et al.*, 2016), takes the following form:

$$V_0 = P_j + \sum_{i=1}^{n} p_{ij} \cdot \left(x_{i0} - x_{ij} \cdot \left(1 + r_j\right)\right) \quad (14)$$

where V_0 is the market value of the property being evaluated; P_j is the selling price of j-th comparable property; p_{ij} is the marginal price of the of i-th characteristic; x_{i0} is the value of i-th characteristic of the subject property; x_{ij} is the value of i-th characteristic of the j-th comparable property; r_j is the corrective factor (4).

In appraisal procedures based on adjustments, the similarity and reliability of the data are reflected in the reconciliation phase of the MCA (Phase 7) which determines the market value as the expected value of the adjusted prices, and unless otherwise assumed, attribute the same probability to each correct price. Therefore, it is accepted that the values to be reconciled are derived

[3] The merchant price theorems have been theorized by Simonotti (1997). These theorems allow the hedonic price's study of the surface characteristics. Six theorems are used to evaluate the hedonic value of the main surface, and several others are used to evaluate the hedonic values of the secondary surfaces.

from similar properties, characterized by equally reliable purchase prices.

The inevitable presence of anomalies suggested the opportunity to identify a procedure that can detect and measure dissimilarities and anomalies of comparison properties, introducing in the reconciliation a measure of probability associated with each correct price, built through the quantitative measure of the level of comparability of the properties with the property to be valued.

For this purpose, the mercantile ratios identified in the similarity coefficients (absolute and squared values), the reliability coefficients and the so-called compound coefficients have been formulated.

The appraisal function, therefore, assumes the following expression:

$$V_0 = \sum_{j=1}^{m} gc^j \cdot P_{cj} \tag{15}$$

where V_0 is the market value of the property being evaluated; gc^j is the compound coefficient related to the j-th comparable property; P_{cj} is the adjusted price of the j-th comparable property.

In accordance with the international valuation principles, the market comparison approach, both in its traditional version (MCA) and in its revised version (MCA 2.0) is also suitable to be implemented in terms of automated appraisal. In the AVM framework, in fact, there are many articles about the use of the MCA that is well suited for automated real estate valuations (Stang et al., 2023). The market comparison approach, since the beginning of the computer assisted mass appraisal (CAMA) era, has been automated by various researchers and is widely used in practice, especially in North America and the UK. Usually, the designed approaches follow a process to find the most similar sales properties. The market value of the property being evaluated is then calculated by taking the mean or similarity-weighted mean of these comparable sales prices. Underwood and Moesch (1982), Thompson and Gordon (1987), Cannaday (1989), McCluskey and Anand (1999) and Todora and Whiterell (2002) all used similarity-based finding of similar properties. More recently, Salvo and De Ruggiero (2011), although it is far from the idea of defining valid valuation equations based on regression models, implement an automatic procedure with the aim of defining equations relating to the peculiarities of a market in a very limited area. The proposed method is implemented through the ArcGIS Model Builder tool and has been tested on a pilot GIS for residential properties. Brunauer et al. (2017) design an approach for valuations of self-used property based on the sales comparison method. Kim et al. (2020) used an automated sales comparison method to evaluate apartments in Korea, and found that their approach outperformed machine learning methods. Using a computer-assisted expert algorithm, Larraz et al. (2021) consider differences in characteristics compared to similar properties and their relative location.

2.3 Appraisal System Model (ASM) and Appraisal Division System (ADS)

Market oriented evaluation methods referring to appraisal functions include the Appraisal System Model (ASM) and the Appraisal Division System (ADS) (Simonotti, 2006).

The ASM is applied through the setting and the resolution of a system formed by m linear equations, one for every building of comparison (of known price), in $n+1$ unknown, represented by the market value and marginal prices of the real estate characteristics examined. The weakness of the procedure lies in the need to have an adequate data number very similar to each other to reach acceptable results both mathematically and in appraisal.

The appraisal functions that make up the ASM are explained in the following equation system:

$$\begin{cases} P_1 = V_0 + \sum_{i=1}^{n} (x_{i1} - x_{i0}) \cdot p_i \\ P_2 = V_0 + \sum_{i=1}^{n} (x_{i2} - x_{i0}) \cdot p_i \\ \quad \vdots \\ P_m = V_0 + \sum_{i=1}^{n} (x_{im} - x_{i0}) \cdot p_i \end{cases} \tag{16}$$

where $P_1, P_2, \cdots, P_m$ are the selling prices of the comparables; V_0 is the market value of the property being evaluated; p_i is the hedonic price of the of i-th characteristic; x_{i0} is the value of i-th characteristic of the subject property; $x_{i1}, x_{i2}, \cdots, x_{im}$ are the values of i-th characteristic of the comparable property.

ADS is an appraisal procedure based on the detection of similar properties of known price, carried out through the setting and resolution of a system consisting of linear m equations, one for each property of comparison (of known price) in n variables, for example, the average price of the properties in question is not known (Simonotti, 1994).

The appraisal functions that make up the ADS are explained in the following equation system:

$$\begin{cases} P_1 = \sum_{i=1}^{n} x_{i1} \cdot \bar{p}_i \\ P_2 = \sum_{i=1}^{n} x_{i2} \cdot \bar{p}_i \\ P_m = \sum_{i=1}^{n} x_{im} \cdot \bar{p}_i \end{cases} \tag{17}$$

where $P_1, P_2, \cdots, P_m$ are the selling prices of the comparables; V_0 is the market value of the property being evaluated; $\bar{p}_i$ is the average price of the of i-th characteristic; $x_{i1},x_{i2},\cdots,x_{im}$ are the values of i-th characteristic of the $1,2,\cdots,m$ comparable property.

Also, for ADS, the weakness is the need to have an adequate data number very similar to each other in order to identify acceptable results, both mathematically and in appraisal terms. The problem of the small size of the sample of similar properties has been solved through the possibility of expanding the survey sample by introducing comparison properties with a lower degree of similarity or data not always equally reliable, through the use of appropriate coefficients that can weigh the comparable differently in the comparison functions due to the different similarities in the characteristics of properties or in the reliability of prices as is the case in MCA 2.0 (Morano et al., 2019).

To achieve this aim, the ASM and the ADS have been modified by formulating, respectively, the Weighed Appraisal System Model (WASM) and Weighed Appraisal Division System (WADS) models (Tajani et al., 2020).

When similarity coefficients in absolute value are used, in the former model (WASM) the appraisal equations that make up the system assume the following formulation:

$$\begin{cases} ga^1 \cdot (P_1 - V_0) = \sum_{i=1}^{n} gs_a^j \cdot (x_{i1} - x_{i0}) \cdot p_i \\ ga^2 \cdot (P_2 - V_0) = \sum_{i=1}^{n} gs_a^j \cdot (x_{i2} - x_{i0}) \cdot p_i \\ \cdots = \cdots \\ \cdots = \cdots \\ ga^m \cdot (P_m - V_0) = \sum_{i=1}^{n} gs_a^j \cdot (x_{im} - x_{i0}) \cdot p_i \end{cases} \tag{18}$$

Otherwise, if square coefficients are used the WASM model became:

$$\begin{cases} ga^1 \cdot (P_1 - V_0) = \sum_{i=1}^{n} gs_q^j \cdot (x_{i1} - x_{i0}) \cdot p_i \\ ga^2 \cdot (P_2 - V_0) = \sum_{i=1}^{n} gs_q^j \cdot (x_{i2} - x_{i0}) \cdot p_i \\ \cdots = \cdots \\ \cdots = \cdots \\ ga^m \cdot (P_m - V_0) = \sum_{i=1}^{n} gs_q^j \cdot (x_{im} - x_{i0}) \cdot p_i \end{cases} \tag{19}$$

Similarly, in WADS model, if similarity coefficients in absolute value are used, estimate equations which compose the system take the formulation reported below:

$$\begin{cases} ga^1 \cdot P_1 = \sum_{i=1}^{n} gs_a^j \cdot x_{i1} \cdot \bar{p}_i \\ ga^2 \cdot P_2 = \sum_{i=1}^{n} gs_a^j \cdot x_{i2} \cdot \bar{p}_i \\ \cdots = \cdots \\ \cdots = \cdots \\ ga^m \cdot P_m = \sum_{i=1}^{n} gs_a^j \cdot x_{im} \cdot \bar{p}_i \end{cases} \tag{20}$$

If square coefficients are used, the WADS model became:

$$\begin{cases} ga^1 \cdot P_1 = \sum_{i=1}^{n} gs_q^j \cdot x_{i1} \cdot \bar{p}_i \\ ga^2 \cdot P_2 = \sum_{i=1}^{n} gs_q^j \cdot x_{i2} \cdot \bar{p}_i \\ \cdots = \cdots \\ \cdots = \cdots \\ ga^m \cdot P_m = \sum_{i=1}^{n} gs_q^j \cdot x_{im} \cdot \bar{p}_i \end{cases} \tag{21}$$

The Italian context has seen widespread application of the ASM and ADS models in the realm of professional practice (Simonotti, 1989). Furthermore, several official valuation manuals have highlighted its practical potential. The guidelines for the properties' valuation in guarantee of credit exposures, which were made by the Italian Banks Association (ABI, 2022), have said that the ASM and ADS are tools that can make property valuations transparent, good, and fair. The Tecnoborsa (2020) real estate valuation guide, which has integrated and aligned the International Valuation Standards with the Italian regulatory framework, has included the ASM and ADS models among the main appraisal techniques, capable of integrating the global best practices with the scientific principles and the practical realities of the Italian context. In the manual for property valuations of the Italian Revenue Agency (2011), the ASM and ADS models have been described as deterministic multi-parameter models that can be used in professional practice because they are scientifically valid and can be used in many different ways. Lastly, numerous guidelines for private entities and professional organizations have recognized the ASM and ADS as models that meets the requirements of the International Valuation Standards (OIV, 2015).

The integration of these two models into an automated valuation model is still a subject of research, but the possibility of endogenously assessing implicit prices or the average prices of the influencing factors through the detection of a few comparable data and the simplicity of the algorithm make the models suitable for automatic implementation, as well as the mono-parameter appraisal procedure or the market comparison approach.

3. CONCLUSIONS

This paper aims to provide a comprehensive overview of the methodological advancements in market approach procedures that the appraisal field has witnessed in recent times, owing to the creation and adoption of the International Valuation Standards.

The standards foundation has been operationally based on best practice. Best practices generally mean the most significant experiences, methods and techniques that have shown the best results achieved, and in fact constitute a standard. The material basis for best practice and standards is the collection of market data and information. The market data, essential for the valuation, is a complex data formed by an economic part, consisting of the price, and a technical part that considers the characteristics of the property. The correct collection of such data, in addition to ensuring a more precise measurement, determines conditions of transparency and fairness of the appraisal judgment.

Over the years, technological evolution has led to the generation of a huge amount of data that has inevitably had an impact in different sectors, including real estate and appraisal. Its processing requires technologies and resources that go beyond conventional storage and management systems (De Ruggiero et al., 2020). Market data is the necessary condition for the formulation of appraisal functions in any appraisal process used for appraisal analysis. Regarding the appraisal, the example that is increasingly consolidated among the tools for managing and analyzing such data concerns the Automated Valuation Models (AVMs). They allow to obtain an accurate appraisal in a few seconds, despite the use of numerous factors and variables that are not always easily acquired in traditional appraisals. Automated assessment models can be distinguished in models that use statistical tools such as regression and in models that use intelligent systems, such as neural networks. Both represent an improvement of conventional valuation models and are mainly used for mass evaluation or mass appraisal. Automated assessment models can be implemented by additional tools. These include Geographic Information Systems (GIS) made up of software systems capable of managing many different aspects of data, improving analytical and measurement capabilities with three-dimensional visual aids. These tools combine geographical components with statistical components of design and detection making much more interactive the use of a cartographic representation, which can, thus, be queried, read, and analyzed according to different criteria and as needed. The use of spatial analysis models shows improved predictive performance of appraisal methods.

In light of the advantages stated, the real estate valuation sector and scientific research should consider consolidation of AVMs and AI-based appraisal methods based on the market approach procedures. This can accelerate the real estate valuation procedures while pursuing an increase in the accuracy of the valuations as the main goal. In this regard, we attempted to provide insights into the development of the procedures and their use in an automated way, trying to identify the areas where further investigations are needed.

The real estate appraisal, through its evolutionary process, had as a guiding thread the need to have appraisal judgments based on procedures: transparent, traceable, verifiable, objective as indicated by IVS. Using automated procedures can, on the one hand, facilitate the achievement of these goals and, on the other hand, facilitate the appraisal activity. It should be noted that the experience and the professional skills of the valuer, which acts in the *ex ante* phase, i.e. in the construction of the scales for the measurement of the influencing factors, and in the *ex post* phase, i.e. in the empirical verification of the results obtained, remain the mandatory requirement in all the aforementioned models.

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