# An Optimization Method to Ensure Reliability in the Assessment of Special Properties

Benedetto Manganelli[1](✉), Melania Arenas Morente[1], Giuseppe Cerullo[2], Francesco Paolo Del Giudice[1], and Francesco Tajani[2]

[1] Department of Engineering, University of Basilicata, 85100 Potenza, Italy
benedetto.manganelli@unibas.it
[2] Department of Architecture and Design, "Sapienza" University of Rome, 00196 Rome, Italy

**Abstract.** The valuation of special properties is often characterised by a high degree of complexity due to limited market comparability, functional specificity, and the subjectivity involved in the estimation of key appraisal parameters. This issue is particularly relevant in the case of socio-healthcare facilities, whose market value is commonly assessed through the Discounted Cash Flow Analysis (DCFA). This paper proposes an innovative decision-support approach method aimed at improving the transparency, consistency, and replicability of DCFA-based appraisals. The method combines the income-based valuation logic of the DCFA with goal programming techniques, in order to rationalize the determination of the main variables affecting the value and to reduce the discretionary that typically characterises such estimates. Applied to the case of Italian private nursing homes, the proposed framework is intended to support a more structured and reliable estimation process, while also considering the different perspectives of the parties involved in the transaction. The study contributes to the current debate on the valuation of special properties by offering a simple and operational method for appraisal verification.

**Keywords:** Discounted Cash Flow Analysis · Goal Programming · Socio-Healthcare Facilities · nursing homes

## 1 Introduction

Over the last few decades, major economic shocks have made clear that inaccurate real estate valuations may generate effects far beyond individual transactions, influencing credit allocation, investment choices, and, in severe cases, the stability of the wider financial system. The global financial crisis triggered by the collapse of the U.S. subprime mortgage market remains the clearest example of how weaknesses in pricing, risk assessment, and collateral appraisal can amplify systemic fragility. In the years that followed, the growing relevance of categories such as Unlikely To Pay, Non-Performing Loans, and Distressed Assets further confirmed the strategic role of valuation practices within fragile financial environments [1]. More recently, the COVID-19 pandemic showed how rapidly real estate markets can change, particularly in relation to special-purpose assets,

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2027
O. Gervasi et al. (Eds.): ICCSA 2026 Workshops, LNCS 16764, pp. 50–61, 2027.
https://doi.org/10.1007/978-3-032-30533-6_4

whose value is strongly affected by operational performance, regulatory constraints, and functional adaptability. In parallel, the current geopolitical instability connected with the war in Ukraine has contributed to a climate of caution in real estate investment, while the implementation of Next Generation EU programmes has increased the urgency of allocating resources efficiently, especially in projects involving the regeneration and enhancement of complex real estate assets.

Within this context, special properties represent one of the most challenging segments of the real estate market. These assets, often included within the broader category of Commercial Real Estate (CRE), are characterised by specific functional, technical, constructional, and dimensional features that make them difficult to compare with ordinary market products. Their value is not determined solely by location or physical characteristics, but also by the capacity of the asset to support a specific use over time, often under changing economic and social conditions. In many cases, these properties require functional reconfiguration in response to evolving demand, changing regulations, or new performance standards. As a result, their appraisal is inherently more complex than the valuation of standard residential or commercial properties, and traditional methods may prove insufficient unless supported by rigorous assumptions and well-grounded analytical frameworks.

In this context, even before the pandemic, several procedures had already been developed to make real estate appraisals more reliable [2, 3]. These include the calibration of capitalization rates within the Income Approach [4], the estimation of the marginal prices of intrinsic and extrinsic factors within the Market Approach [5], the definition of depreciation coefficients within the Cost Approach [6], and the identification of rational coefficients for estimating values other than market value [7].

Despite these advancements, the valuation of special properties still remains affected by a considerable degree of uncertainty, especially when appraisers are required to define parameters that are only partially observable in the market. The heterogeneity of these assets, the limited availability of comparable transactions, and the frequent need to interpret the effects of use, management, and transformation potential may widen the discretionary component of the valuation process. Consequently, even when the appraisal is formally structured, the final estimate may still be influenced by assumptions that are difficult to verify objectively. This issue is particularly relevant in phases of market instability, when variations in risk perception, investment behaviour, and expected performance can significantly affect real estate value judgments.

From this perspective, the current debate on valuation reliability appears closely connected to broader economic and institutional transformations. On the one hand, real estate markets are increasingly exposed to shocks that alter expected uses, returns, and risk profiles. On the other hand, both public and private actors are required to make decisions concerning complex properties under conditions of limited information and rapidly changing scenarios. In this framework, improving the transparency, consistency, and robustness of valuation procedures is not merely a technical matter, but also a broader economic necessity, since appraisal activities play a strategic role in supporting investment decisions, credit assessment, asset management, and effective allocation of public and private resources.

## 2 Aim

This paper investigates innovative approaches to the valuation of special properties, with particular attention to the limits of the conventional method applied, i.e. the Discounted Cash Flow Analysis (DCFA). Although the DCFA is widely used in the appraisal of this asset class, its application often depends on assumptions that are not fully verifiable, especially when defining key inputs such as revenues, operating costs, discount rates, exit yields, market trends, inflation expectations, and the time horizon of the analysis. As a result, the valuation process may become insufficiently transparent and difficult to reproduce consistently.

To address this issue, the study develops an empirical framework based on a set of appraisal case studies concerning healthcare properties located in Italy. By examining how the main variables of the DCFA are defined in professional practice, the paper seeks to identify recurring valuation patterns and to translate them into a more structured analytical model. More specifically, the research explores the use of goal programming as a decision-support tool for reducing the discretionary component of DCFA-based appraisals. Applied to the selected property type, this approach is intended to support a more transparent and consistent estimation of market value by organising the appraisal process within a clearer analytical structure. In this way, the proposed framework aims to reflect more coherently the different risk and return expectations of the parties involved in the transaction, particularly sellers and investor-buyers.

The paper is structured as follows. Section 3 presents the background to the study: taking into account a specific typology of special properties, represented by the nursing homes (RSAs), the analysis is focused on the socio-healthcare facilities, the Italian regulatory framework, the socio-demographic context, and the structure of the RSA market. Section 4 illustrates the proposed method and briefly discusses the main results. Finally, Sect. 5 summarizes the conclusions, limitations, and future developments of the research.

## 3 Background

### 3.1 Socio-healthcare Facilities

Socio-healthcare facilities are extra-hospital residential structures designed to provide integrated health and social-care services to frail, disabled, or non-self-sufficient individuals. Their primary purpose is to ensure continuity of care for persons whose needs cannot be adequately managed at home, while also supporting quality of life through assistance, supervision, and social integration.

Within this broad category, different facilities correspond to different levels of care intensity. Hospices are mainly devoted to palliative care for patients affected by incurable diseases. Nursing homes (RSAs) generally accommodate elderly persons who are fully or partially self-sufficient and primarily require hospitality and basic assistance. By contrast, residential healthcare facilities are intended for users whose conditions require a stronger integration of medical, nursing, and rehabilitative services.

In the Italian context, the RSAs represent the most relevant typology for the purposes of this paper. They are residential facilities for non-self-sufficient elderly persons and

disabled adults who require continuous medical, nursing, and rehabilitative support, combined with assistance in daily living activities. A related typology is represented by the RSAs, which mainly provide high-intensity personal and socio-rehabilitative care for older persons with severe psychophysical impairments or dementia, although with a lower level of complex healthcare than that typically associated with the RSAs.

For this reason, although the broader background includes several forms of residential care, the following discussion focuses primarily on the RSAs, as they are the socio-healthcare assets most directly aligned with the empirical and valuation scope of the paper.

### 3.2 Regulatory Framework

The regulatory framework governing residential socio-healthcare services in Italy is relatively limited at the national level and largely implemented through regional legislation. As a result, the term RSA has acquired partially different meanings across regions, with boundaries that are not always clearly distinguished from other forms of residential care, such as nursing homes, protected residences, geriatric rehabilitation institutes, and long-term rehabilitation facilities.

RSAs were introduced in Italy in the early 1990s within the multi-year healthcare investment programme established by Law No. 67/1988 and subsequently updated by Law No. 160/2019. The underlying rationale of this regulatory framework was the growing incidence of ageing and non-self-sufficiency within the Italian population, together with the need to provide extra-hospital residential care for individuals who could no longer be adequately assisted at home. In this context, residential care is understood not as a single healthcare act, but as an integrated set of health, social, protective, and hospitality services delivered on a 24-hour basis to non-self-sufficient persons in accredited facilities.

Through the National Health Service, the State undertook to ensure that frail and non-self-sufficient individuals affected by chronic illness or other conditions incompatible with home-based care could access appropriate residential services. However, the organization of extra-hospital residential care falls largely within regional competence. For this reason, most national acts operate as general framework provisions aimed at guaranteeing a minimum and uniform level of assistance across the country, while their effective implementation depends on formal regional transposition. This multilevel governance has generated significant territorial heterogeneity, including differences in admission criteria, age limits, service configuration, and the degree to which partially self-sufficient persons may be accommodated.

To reduce fragmentation and define minimum standards of care, the *Livelli Essenziali di Assistenza* (LEA) were introduced by the Decree of the President of the Council of Ministers of 29 November 2001 and subsequently replaced by the Decree of 12 January 2017, which established the current framework of essential levels of care. Within this system, the State identifies the services that must be guaranteed nationwide, while the Regions are responsible for their implementation, monitoring, and integration within local health planning. Compliance with LEA standards is overseen through the national monitoring system coordinated by the competent committee for the verification of essential levels of care.

Overall, the regulatory framework may therefore be divided into two main levels. State legislation establishes the general principles concerning minimum requirements, accreditation within the National Health Service, public funding mechanisms, and the institutional responsibilities of local authorities. Regional legislation, by contrast, defines the detailed quality requirements, authorization procedures, organizational criteria, and operational rules applicable within each territorial context. This framework is also highly relevant from an economic and valuation perspective. Accredited RSA facilities operate through a mixed revenue structure based on two main components: a healthcare tariff funded by the National Health Service for beds covered by contractual agreements with the Regions, and a hospitality fee paid by the resident, with possible municipal support in cases of economic hardship. Precisely because of this revenue structure, together with the long-term demand associated with ageing, socio-healthcare facilities have progressively emerged as an asset class of growing interest for investors.

### 3.3 Socio-demographic Context

Population ageing is one of the main structural drivers behind the growing demand for long-term care services in Italy. At the beginning of 2022, people aged over 65 were more than 14 million, corresponding to 23.8% of the total population and about 3 million more than twenty years earlier. The over-80 population exceeded 4.5 million, while centenarians reached about 20,000, a figure that has quadrupled over the last two decades. Demographic projections indicate that, by 2042, the population aged over 65 may rise to almost 19 million, accounting for 34% of the total, while the old-age index is expected to increase from 187.9% in 2022 to 295.0%.

This trend is closely associated with a growing incidence of frailty and dependency. In Italy, around 4 million people currently experience severe limitations in daily activities, and 92% of them still live at home. At the same time, longer life expectancy is accompanied by an epidemiological transition in which chronic and degenerative diseases increasingly replace infectious conditions, especially among older age groups. In this context, the rise in cardiovascular, cerebrovascular, and neurodegenerative diseases, including Alzheimer's disease and related dementias, is expected to intensify the need for integrated health and social care services.

These dynamics also have significant socioeconomic implications. As the ratio between active and inactive population becomes less favourable, the burden related to care provision, long-term assistance, and welfare expenditure is expected to grow. For this reason, population ageing should be understood not only as a demographic phenomenon, but also as a structural challenge for healthcare and social policy. Strengthening territorial and residential care services is therefore essential to reduce inappropriate hospitalization and to provide adequate support for frail and non-self-sufficient older persons.

### 3.4 RSA Market

Residential socio-healthcare facilities have expanded rapidly in Italy over the last 15–20 years, mainly in response to growing demand for long-term care services. Current estimates indicate that the sector includes nearly 300,000 beds, corresponding to about 2.5%

of the elderly population, although this figure should be treated with caution because regional classification systems are not fully homogeneous.

According to the Ministry of Health, in 2020 Italy had 7,858 public and accredited private residential healthcare facilities, with a total of 262,351 beds. Accredited private providers clearly dominate the sector, accounting for 6,540 facilities out of the national total. The territorial distribution is highly uneven: 67.3% of facilities are located in Northern Italy, compared with 17.3% in the Centre and 15.4% in the South and Islands. This imbalance is even more evident in terms of bed capacity, with 197,114 beds in the North, equal to 75.1% of the national total, while the Centre and the South and Islands account respectively for 14.5% and 10.3%.

A broader picture emerges from the Italian Institute of Statistics (ISTAT) data on residential socio-assistance and socio-healthcare services, which recorded 12,626 facilities and 411,993 operating beds in 2020. These data confirm the same territorial asymmetry in favour of the North. They also highlight the role of public funding: 68% of facilities located in the North receive public support, compared with 57% in both the Centre and the South and Islands; similarly, publicly funded beds account for 82% of the total in the North, 62% in the Centre, and 58% in the South and Islands.

When only beds allocated to socio-healthcare functions are considered, the national total is estimated at 318,497 units. Of these, 71.1% are concentrated in Northern Italy, while the Centre and the South and Islands account respectively for 14.3% and 14.7%. The four regions selected for the empirical focus of this study—Piedmont, Trentino, Veneto, and Tuscany—alone account for 103,524 beds, corresponding to 32.5% of the national total.

## 4 Method

Investments in socio-healthcare real estate are generally assessed based on the income-generating capacity of the underlying assets. For this reason, the market value of such properties is commonly estimated through the Income Approach, and more specifically through the Discounted Cash Flow Analysis (DCFA). This method is grounded in the assumption that an investor or developer is willing to pay for an asset an amount corresponding to the present value of all expected inflows and outflows generated by that asset over a given time horizon, discounted at an appropriately determined rate. The discount rate must reflect the intrinsic and locational characteristics of the property, since these factors directly affect the level of risk associated with the real estate operation. In essence, the method consists in capitalizing the net real estate income that the property is expected to generate over time.

The economic events of the last decades have highlighted the need for adequate professional expertise in real estate appraisal. Inaccurate valuations have produced negative effects first in financial markets and subsequently in the real economy, with many real estate assets being overvalued in relation to their actual market values. Within this context, the formalization of shared and consistent rules in the International Valuation Standards (IVS) has become increasingly important in order to establish a common language among professionals and to protect the public interest in the integrity of the valuation process [8]. Since real estate appraisal is an integral part of the wider business

environment [9], the integrity of the valuation process is essential to reduce the likelihood of systemic economic crises, such as the U.S. subprime crisis of 2007, and the related instability of financial markets that may ultimately trigger global disruptions.

The need to manage uncertainty, that is, to obtain reliable forecasts of real estate market values over the medium and long term—for example, in the case of properties used as collateral for mortgage lending—has encouraged the development and diffusion of innovative mass appraisal models. This process has also been facilitated by improvements in computing technology and by the availability of increasingly accessible software tools. Among the approaches experimented with in this field are genetic algorithms, spatial analysis models, fuzzy logic, and artificial neural networks. These models are characterised by a strong theoretical and methodological basis and are capable of automatically identifying causal relationships between explanatory variables and prices, as well as estimating real estate values in the short term [10–12].

Although these models are able to measure the marginal contribution of the factors influencing price formation, thus responding to the current need to standardize valuation procedures [13] and to reduce the excessive randomness of appraisals often associated with overconfidence in valuers' judgement [14], they are still viewed with considerable distrust by ordinary practitioners. This reluctance depends, on the one hand, on the complexity of the mathematical formalism underlying such techniques and, on the other, on the frequent scarcity of comparable market data. Such data would in fact be necessary to implement econometric procedures capable of adequately describing the price-formation mechanisms of assets within specific markets [15].

The method developed in this study draws on the operational logic of goal programming techniques. Since the 1960s, increasing attention has been devoted across different fields to the development of models based on goal programming. This approach enables the flexible and effective treatment of complex problems characterised by a high number of variables and constraints. A review of the international literature has shown that goal programming has been applied in several studies to real estate valuation, as well as to investment planning and investment appraisal [16–19].

In general terms, a goal programming problem can be interpreted as the optimal allocation of scarce resources that may be assigned to alternative uses. In this sense, a goal programming problem is characterized by resources available in limited quantities, alternative uses envisaged for such resources, constraints on the use of resources, and objective functions aimed at evaluating the contribution that each possible use of resources provides to the achievement of a predetermined goal.

In the present case, with reference to the method developed, the resources available in limited quantities are represented by the values that may be assigned to the different parameters, in relation to the sample of case studies collected, which constitutes an essential reference for replicating the ordinary behaviour of the valuer in the definition of the factors entering the DCFA. The alternative uses are represented by the economic parameters involved in the construction of the DCFA. The constraints are represented by the relationships linking the different parameters within the mathematical formulations that define a DCFA for the estimation of the market value of a special property.

The fundamental objective of the optimization method is the determination, according to the operational logic of Operations Research and the DCFA technique ordinarily

employed for the estimation of Market Value, of a compromise solution for the two parties involved in the transaction, namely the seller—whose aim is the maximization of market value—and the buyer—whose aim is the maximization of return.

It is well known that risk and return are directly correlated, and that, in a DCFA applied to economic feasibility assessments, the discount rate reflects the risk premium required by the subjects investing their own resources. According to the logic of the Weighted Average Cost of Capital (WACC), the two parties involved are the investor/buyer and the bank/credit provider.

Therefore, the compromise solution is the one that allows the maximization of the two objectives, each of them relating to one of the parties involved in the transaction, as expressed in Eq. 1:

$$Max\left(i + \frac{V}{Vmax}\right) \tag{1}$$

where:

- $i$ is the discount rate, determined through the application of the WACC;
- $V$ is the unit market value of the property;
- $Vmax$ is the maximum unit market value observed within the sample of case studies for the property type under valuation.

It should be noted that the ratio between $V$ and $Vmax$, introduced in Eq. 1, is necessary in order to make the two objectives dimensionally homogeneous, namely return for the buyer and capital perceived by the seller.

The main variables of the method are $i$, $V$, , and the market rent of the property ($Ca$). Since, in a DCFA, it is standard practice to assume that market rents evolve according to a geometric progression with ratio $(1 + s)$, where $s$ is the inflation rate, it follows that the only rental variable is the market rent at time zero ($Ca_0$).

The constraints of the model are defined as follows. First, Eq. 2 identifies the interval within which the rent $Ca0$ ordinarily varies, as a function of the Gross Operating Profit (GOP):

$$40\% \cdot GOP \leq Ca0 \leq 60\% \cdot GOP \tag{2}$$

Second, Eq. 3 defines the ordinary variation interval of entrepreneurial profit, equal to the difference between $GOP$ and $Ca_0$, expressed as percentages of operating revenues:

$$8\% \cdot R \leq GOP - Ca0 \leq 15\% \cdot R \tag{3}$$

Third, Eq. 4 expresses the variation range of the discount rate, according to the minimum ($i_{min}$) and maximum ($i_{max}$) values of the rates observed in the sample of case studies for the property type to which the asset under valuation belongs:

$$i_{min} \leq i \leq i_{max} \tag{4}$$

Finally, Eq. 5 synthesizes the construction of the DCFA matrix according, in addition to the parameters defined above, to the owner's costs ($K$), the Terminal Value—equal to the ratio between the market rent in the last year of the analysis period

$\left(Ca_n = Ca_0 \cdot (1+s)^n\right)$, net of owner's costs, and a net exit rate ($r$)—discounted, and the costs of property adaptation/re-functionalization ($CAPEX$):

$$V = \sum_{t=0}^{n} \frac{Ca_t - K_t}{(1+i)^t} + \frac{Ca_n - K_n}{r \cdot (1+i)^n} - CAPEX \tag{5}$$

As summarized in Eq. 5, the market value is therefore determined by the discounted balance of rents and owner's costs over the analysis period, increased by the discounted terminal value and reduced by the capital expenditure required for the adaptation or re-functionalization of the property.

Table 1 summarizes the algorithm of the optimization method developed, while Table 2 reports, for each parameter contributing to the definition of the method, the acronym adopted, the explanation of its meaning, and the related unit of measurement.

**Table 1.** Algorithm of the Optimization Method

| Component | Specification |
|---|---|
| Variables | $Ca_0$; $i$; $V$ |
| Constraints | $40\% \cdot GOP \leq Ca_0 \leq 60\% \cdot GOP$ |
| | $8\% \cdot R \leq GOP\text{-}Ca_0 \leq 15\% \cdot R$ |
| | $i_{min} \leq i \leq i_{max}$ |
| | $V = \sum_{t=0}^{n} \frac{Ca_t - K_t}{(1+i)^t} + \frac{Ca_n - k_n}{r \cdot (1+i)^n} - CAPEX$ |
| Objective function | $Max\ (i + \frac{V}{Vmax})$ |

To provide a preliminary assessment of the effectiveness of the proposed method, a descriptive statistical analysis was carried out by comparing known values with the algorithm outputs for three key variables: market rent, discount rate, and market value. For market rent, the Mean Absolute Percentage Error (MAPE) is 5.60%, with values ranging from 0.00% to 20.00%, a median of 3.39%, and a standard deviation of 6.43%; the Mean Absolute Error (MAE) is equal to €333.86/bed, ranging from 0.00€ to 1,375.04€/bed, with a median of 283.26€/bed. For the discount rate, the MAPE is 13.95%, with a minimum of 0.44%, a maximum of 33.33%, a median of 10.20%, and a standard deviation of 11.31%; the MAE is 0.59 percentage points, with values between 0.02% and 1.50% and a median of 0.50%. For market value, the MAPE is 9.07%, ranging from 0.28% to 28.08%, with a median of 7.62% and a standard deviation of 7.71%; the MAE is 9,802.12€, with values between 393.71€ and 30,960.41€ and a median of 6,740.25€. Overall, the algorithm shows the lowest deviations in the estimation of market rent, the highest variability in the estimation of discount rates, and satisfactory performance in the estimation of market value.

**Table 2.** Parameters of the Optimization Method

| Acronym | Parameter | Unit of measurement |
|---|---|---|
| $R$ | Operating revenues | €/bed |
| $Ca_0$ | Market rent at year zero of the analysis period | €/bed |
| $GOP$ | Gross Operating Profit = Revenues − Operating costs | €/bed |
| $i$ | Discount rate | % |
| $s$ | Inflation rate | % |
| $Ca_t = Ca_0 \cdot (1+s)^t$ | Market rent at year t | €/bed |
| $K_t = K_0 \cdot (1+s)^t$ | Owner's costs at year t | €/bed |
| $n$ | DCFA analysis period | Years |
| $r$ | Going out cap rate | % |
| $CAPEX$ | Capital Expenditure | €/bed |
| $V$ | Unit market value | €/bed |
| $V_{max}$ | Maximum unit market value for the property type considered | €/bed |
| $i_{min}$ | Minimum discount rate for the property type considered | % |
| $i_{max}$ | Maximum discount rate for the property type considered | % |

## 5 Conclusions

This study developed and tested a rational method for the valuation of special properties, conceived as a support tool for checking appraisals carried out through the most widely used procedure, namely DCFA. The method was designed to address the excessive and frequent subjectivity that often affects the estimation of the main parameters involved in valuation, including revenues, costs, discount rates, capitalization rates, analysis periods, market trends, and inflation trends. By applying goal programming techniques to a sample of appraisal case studies concerning RSAs located in Italy, the research made it possible to define a simple and transparent valuation approach aimed at rationalizing the determination of these variables and at providing an objective, easily replicable methodology that can be employed by the different actors involved in the valuation of this asset class.

The tool developed may provide effective support for both public and private institutions in the rapid verification of appraisals prepared by external valuers. Where the market value estimated by the valuer differs by no more than ±15% from the output generated by the algorithm, the appraisal may be considered reliable. When this threshold is not respected, a more detailed comparison with the valuer becomes necessary in order to understand the reasons underlying the discrepancy. In this sense, the optimization algorithm may accelerate the validation process, particularly in contexts in which

time is a decisive variable for the economic feasibility of an initiative, such as urban regeneration projects, settlement transformations, and real estate leasing operations.

Moreover, recent EU prudential reforms implementing the final Basel III framework—particularly Regulation (EU) 2024/1623 of 31 May 2024, which significantly amended Regulation (EU) No 575/2013 on prudential requirements for credit institutions—have reinforced the need to anchor the relationship between mortgage lending and real estate collateral to prudent and sustainable valuation criteria over the life of the loan. Within this perspective, the logic underlying the proposed algorithm is consistent with the need to define a reliable valuation boundary, derived from validated appraisals used as benchmarks, within which the credibility of an appraisal may be tested. Owing to its operational-research structure, the model generates a control output that may support the assessment of the reasonableness and sustainability of the estimated value.

Possible developments of the research concern, first, the application of the algorithm to a broader case-study sample, so as to improve its statistical robustness, and second, its experimentation on different property uses, in order to identify possible critical issues and further applications. The main limitation of the current model lies in the size of the database, which includes 25 case studies. Although the algorithm determines endogenously the main variables influencing the estimate—namely market rent, discount rate, and market value—it still requires exogenous inputs derived from the observed sample, such as the maximum market value used in the objective function and the minimum and maximum discount rates.

In addition, given its intended purpose as a rapid and operational tool for appraisal checking, the algorithm was developed without taking into account possible goodwill or badwill effects associated with differences between in-place rents and market rents. Nevertheless, the aim of the study was to define a methodology that can be easily implemented and progressively refined according to the context considered. From this perspective, the reliability of the model is also reflected in its ability to identify valuation outliers, thereby highlighting the need for further discussion with the valuer whenever significant discrepancies emerge between the estimated value and the model output.

Finally, in order to integrate valuation issues with broader concerns related to urban sustainability, the algorithm could be further expanded through the inclusion of constraints and parameters capable of accounting for ESG criteria, which are becoming increasingly relevant in real estate appraisal practice.

## References

1. Guidelines on management of non-performing and forborne exposures | European Banking Authority. https://www.eba.europa.eu/activities/single-rulebook/regulatory-activities/credit-risk/guidelines-management-non-performing. Accessed 14 Mar 2026
2. McIntosh, A.P., Sykes, S.G.: A Guide to Institutional Property Investment. Springer, Cham (1985). https://doi.org/10.1007/978-1-349-07154-8
3. Gabrielli, L., French, N.: Pricing to market: property valuation methods–a practical review. J. Prop. Invest. Finance **39**, 464–480 (2021)
4. Manganelli, B., Tajani, F., Morano, P.: La valutazione del rischio nell'analisi finanziaria di Ellwood per la stima indiretta di immobili urbani. Aestimum **55**(2), 19–41 (2009)

5. Tajani, F., Morano, P., Salvo, F., De Ruggiero, M.: Property valuation: the market approach optimised by a weighted appraisal model. J. Prop. Invest. Finance **38**, 399–418 (2020)
6. Manganelli, B.: Real Estate Investing. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-06397-3
7. Tajani, F., Morano, P., Locurcio, M., Amoruso, P.: A logical operating model for the assessment of the forced sale value in the judicial procedures. Valori e Valutazioni (2021)
8. Gilbertson, B., Preston, D.: A vision for valuation. J. Prop. Invest. Finance **23**, 123–140 (2005)
9. French, N.: Professional standards: RICS valuer registration scheme. J. Prop. Invest. Finance **29**, 582–587 (2011)
10. Harvey, J., Harvey, J.: The economics of planning controls. Urban Land Econ., 147–165 (1996)
11. Antipov, E.A., Pokryshevskaya, E.B.: Mass appraisal of residential apartments: an application of random forest for valuation and a CART-based approach for model diagnostics. Expert Syst. Appl. **39**, 1772–1778 (2012)
12. Morano, P., Tajani, F., Locurcio, M.: GIS application and econometric analysis for the verification of the financial feasibility of roof-top wind turbines in the city of Bari (Italy). Renew. Sustain. Energy Rev. **70**, 999–1010 (2017)
13. Mansfield, J.R., Lorenz, D.P.: Shaping the future: the impacts of evolving international accounting standards on valuation practice in the UK and Germany. Prop. Manag. **22**, 289–303 (2004)
14. Jansen van Vuuren, D.: Modified sales comparison method: valuing under (un) certainty. J. Prop. Invest. Finance **35**, 101–110 (2017)
15. Tajani, F., Morano, P.: An empirical-deductive model for the assessment of the mortgage lending value of properties as securities for credit exposures. J. Eur. Real Estate Res. **11**, 44–70 (2018)
16. Colwell, P.F., Cannaday, R.E., Wu, C.: The analytical foundations of adjustment grid methods. Real Estate Econ. **11**, 11–29 (1983)
17. Vandell, K.D.: Optimal comparable selection and weighting in real property valuation. Real Estate Econ. **19**, 213–239 (1991)
18. Byrne, P., Lee, S.: Different risk measures: different portfolio compositions? J. Prop. Invest. Finance **22**, 501–511 (2004)
19. Foo Sing, T., Patel, K.: Empirical evaluation of the value of waiting to invest. J. Prop. Invest. Finance **19**, 535–553 (2001)