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Computational Science and Its Applications – ICCSA 2021

21st International Conference
Cagliari, Italy, September 13–16, 2021
Proceedings, Part VI

6 Part VI

INTERNATIONAL CONFERENCE ON COMPUTATIONAL SCIENCE AND ITS APPLICATIONS
ICCSA 2021

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Preface

These 10 volumes (LNCS volumes 12949–12958) consist of the peer-reviewed papers from the 21st International Conference on Computational Science and Its Applications (ICCSA 2021) which took place during September 13–16, 2021. By virtue of the vaccination campaign conducted in various countries around the world, we decided to try a hybrid conference, with some of the delegates attending in person at the University of Cagliari and others attending in virtual mode, reproducing the infrastructure established last year.

This year's edition was a successful continuation of the ICCSA conference series, which was also held as a virtual event in 2020, and previously held in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing. China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational science is the main pillar of most of the present research on understanding and solving complex problems. It plays a unique role in exploiting innovative ICT technologies and in the development of industrial and commercial applications. The ICCSA conference series provides a venue for researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in computational science.

Apart from the six main conference tracks, ICCSA 2021 also included 52 workshops in various areas of computational sciences, ranging from computational science technologies to specific areas of computational sciences, such as software engineering, security, machine learning and artificial intelligence, blockchain technologies, and applications in many fields. In total, we accepted 494 papers, giving an acceptance rate of 30%, of which 18 papers were short papers and 6 were published open access. We would like to express our appreciation for the workshop chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2021 in particular, vitally depends on the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, organizing committee members, student volunteers, Program Committee members, advisory committee members, international liaison chairs, reviewers, and others in various roles. We take this opportunity to wholehartedly thank them all.

We also wish to thank Springer for publishing the proceedings, for sponsoring some of the best paper awards, and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website https://iccsa.org where you can find all the relevant information about this interesting and exciting event.

September 2021

Osvaldo Gervasi
Beniamino Murgante
Sanjay Misra

Welcome Message from the Organizers

COVID-19 has continued to alter our plans for organizing the ICCSA 2021 conference, so although vaccination plans are progressing worldwide, the spread of virus variants still forces us into a period of profound uncertainty. Only a very limited number of participants were able to enjoy the beauty of Sardinia and Cagliari in particular, rediscovering the immense pleasure of meeting again, albeit safely spaced out. The social events, in which we rediscovered the ancient values that abound on this wonderful island and in this city, gave us even more strength and hope for the future. For the management of the virtual part of the conference, we consolidated the methods, organization, and infrastructure of ICCSA 2020.

The technological infrastructure was based on open source software, with the addition of the streaming channels on YouTube. In particular, we used Jitsi (jitsi.org) for videoconferencing, Riot (riot.im) together with Matrix (matrix.org) for chat and ansynchronous communication, and Jibri (github.com/jitsi/jibri) for streaming live sessions to YouTube.

Seven Jitsi servers were set up, one for each parallel session. The participants of the sessions were helped and assisted by eight student volunteers (from the universities of Cagliari, Florence, Perugia, and Bari), who provided technical support and ensured smooth running of the conference proceedings.

The implementation of the software infrastructure and the technical coordination of the volunteers were carried out by Damiano Perri and Marco Simonetti.

Our warmest thanks go to all the student volunteers, to the technical coordinators, and to the development communities of Jitsi, Jibri, Riot, and Matrix, who made their terrific platforms available as open source software.

A big thank you goes to all of the 450 speakers, many of whom showed an enormous collaborative spirit, sometimes participating and presenting at almost prohibitive times of the day, given that the participants of this year's conference came from 58 countries scattered over many time zones of the globe.

Finally, we would like to thank Google for letting us stream all the live events via YouTube. In addition to lightening the load of our Jitsi servers, this allowed us to record the event and to be able to review the most exciting moments of the conference.

Ivan Blečić
Chiara Garau

Organization

ICCSA 2021 was organized by the University of Cagliari (Italy), the University of Perugia (Italy), the University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), and the University of Minho (Portugal).

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Geomatics in Forestry and Agriculture: New Advances and Perspectives (GeoForAgr 2021)

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12th International Symposium on Software Quality (ISSQ 2021)

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10th International Workshop on Collective, Massive and Evolutionary Systems (IWCES 2021)

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Machine Learning for Space and Earth Observation Data (MALSEOD 2021)

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Contents – Part VI

An Optimization Model for Supporting the Property Asset Allocation Decision-Making Process

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Abstract. The establishment of real estate funds has made it possible to attract greater local and foreign capital in the context of the enhancement and reuse of the Italian public real estate assets. The process of optimal allocation of the financial resources available in a real estate portfolio, however, is often opaque and linked to multiple factors. The aim of this research is to define an asset allocation model capable of supporting the decision-making processes of public and private investors in the context of the creation of optimized property portfolios. By adopting the logic and principles of goal programming, the model is able to identify the best combination of properties in the portfolio by optimally managing the available financial resources of a generic institutional investor. The ability of the proposed model to be flexible and implementable in any geographical context constitutes one of the main advantages for public and private investors.

Keywords: Real estate investment · Optimization model · Asset allocation strategy · Goal programming · Real estate funds

1 Introduction

In 2019, the Italian public real estate assets surveyed by the State Property Agency was made up of more than 42,000 properties for a total value of € 61 billions [1]. However, the presence of public properties that are underutilized or unused as a result of the post-war industrialization and urbanization processes has encouraged the development of strategies aimed at their recovery and reuse [2, 3]. The enhancement of public assets is, in fact, an essential measure of the government's strategy for the country's economic development. Coverage of operating expenses, debt reduction, improved efficiency in terms of asset management and economic, social and cultural growth of the territories, are only some of the positive effects on public finance and community [4]. In a climate of uncertainty generated by the economic crisis of 2007 and exacerbated by the Covid-19

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health emergency, the involvement of investors from the private sphere to reduce the weight of these operations on the already limited public finances has represented the driver of many initiatives of urban enhancement and regeneration, that have contributed to the improvement of the livability and quality level of urban areas [5, 6].

Indeed, for national and international investors, Italian public properties are one of the most attractive asset class. In particular, a higher appreciation is shown by foreign capital which, according to the studies conducted by the IPI group, stands at 46% of capital invested in Italy in the third quarter of 2020, confirming the recent trend in the Italian market [7].

About privatization and enhancement of public real estate assets, the main regulatory reference is represented by Law no. 410/2001, which is the starting point for the spread of different operational tools aimed at the management of public asset enhancement processes [8]. Among all, real estate investment funds are designed as indivisible assets owned by different investors who, by subscribing the shares of the fund, entrust the investment and management activity to a Savings Management Company. The development of real estate funds is a significant reality in the Italian outlook, and the tax concessions issued over the years by the national legislator have contributed to its diffusion and growth [9]. At the end of 2020, the Italian real estate fund sector has € 95 billions of directly owned assets and growth in the residential and logistics sectors. The office sector is prevailing with 64% of assets under management, despite a slight decrease in the last quarter of 2020 [10].

There are different types of real estate funds, which can be classified on the basis of the way the fund was established and the type of investors participating [11]. From an economic point of view, however, the structure of a real estate fund depends on the costs and revenues relating to the real estate portfolios held. In particular, the revenues vary according to the type of strategy conducted for: i) income-producing properties, ii) splitting and divestment of portfolios or iii) property development initiatives. Similarly, costs directly depend on the management of the real estate portfolio, as well as on the amount of financial charges on any bank loan [12].

The establishment of real estate portfolios in which the relationship between the risk assumed by the investor is adequately commensurate with the expected returns is, therefore, a complex issue which, if inadequately conducted, can affect the final performance of the fund [13]. According to the majority of studies in the reference literature [14–16], the main factors that directly affect the decisions to allocate financial resources for the construction of the portfolio are:

- Correlation between the types of assets and the geographical location of the properties;
- Investment period;
- Volatility, dynamism and stability of the reference markets;
- Investor profile, in terms of risk appetite and target.

The correct weighting of these factors is able to create real estate portfolios optimized for the specific risk/return profile of the investor. For this reason, the need for methodologies and models capable of adequately managing the process of composing an optimal portfolio, guaranteeing the highest achievable performance and lower risks deriving from the opacity of the process, has emerged. In this way, public and private investors will be able to contribute efficiently to the implementation of initiatives to enhance public real estate assets [17–19].

2 Aim of the Work

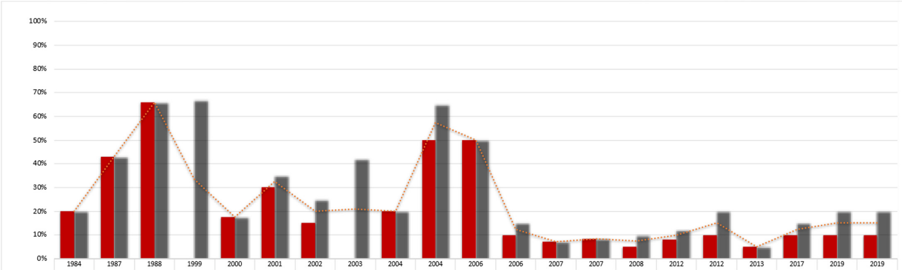
This research fits into the framework outlined. The goal is to define an asset allocation model for the definition of optimized real estate portfolios, i.e. capable of maximizing the expected return and minimizing the risk incurred. In particular, the proposed model refers to the hypothesis of a generic institutional investor who intends to allocate his available financial resources in a portfolio consisting of rented properties. The computational logic implemented is the lexicographic goal programming, a widely used mathematical approach in portfolio optimization decision making contexts. The algorithm is able to translate into mathematical terms the main risk factors that affect the performance of a real estate portfolio: geographical location, intended use, size, yield, volatility, dynamism and stability of the real estate market considered. The identification of the best combination of properties capable of ensuring an initial yield that is higher than that obtainable with reference to the municipal trade area of each property (DPR no. 138/1998), takes place taking into account the importance - in terms of weight - that the market value of each property has in the construction of the portfolio. The aspect of diversification, essential for minimizing global risk, is addressed by pursuing the minimization of the correlation among the properties of the portfolio, evaluated in terms of standard deviation of returns.

The use of the model by public and private investors would make it possible to support the decision-making process that takes place in the investment phases in the real estate market - through indirect vehicles (e.g. Real estate investment trusts, hedge funds etc.) - of available financial resources. Furthermore, the ability of the model to be flexible and implementable in any geographic context is a further advantage for operators in the sector.

The paper is structured as follows: Sect. 3 provides a brief overview on the share allocated to real estate over the years and most widely used approaches for the asset allocation problems. Section 4 describes the main features of the model. Section 5, finally, reports the conclusion of the research, in terms of potentialities, limits and possible future insights.

3 Background

The main reason for investing in the real estate sector is related to the security about the protection of the invested capital due to the fluctuation of real estate values according to the local market cycles. This condition guarantees the real value of the capital invested [20]. Due to their attractiveness, several studies have observed the optimal allocation to real estate practiced in a mixed-asset portfolio over the years [21]. In order to examine the variation of the optimal range within which, according to the Authors and the specific factors, the presence of the real estate can generate significant improvements in the overall portfolio performance, a literature analysis on a sample of twenty-one scientific papers written from 1984 to 2019 has been carried out (Fig. 1).



	1984 Fogler	1987 Webb and Rubens	1988 Webb et al.,	1999 Seiler	2000 Hoesli and Mcgregor	2001 Rosen	2002 Hoesli et al.	2003 Feldman	2004 Lee	2004 Keng and Hwa	2006 Fleming and Smideasang	2006 Ramushu	2007 Clayton	2007 Morgan	2008 Hung et al.,	2012 Reddy	2012 Falk	2013 Andonov et al.,	2017 Pagliari	2019 Delfim and Hoesli	2019 Amedee-Manesme et al.,
% Min	20,0%	43,0%	66,0%	0,0%	17,5%	30,0%	15,0%	0,0%	20,0%	50,0%	50,0%	10,0%	7,3%	8,5%	5,0%	8,0%	10,0%	5,1%	10,0%	10,0%	10,0%
% Max	20,0%	43,0%	66,0%	67,0%	17,5%	35,0%	25,0%	42,0%	20,0%	65,0%	50,0%	15,0%	7,3%	8,5%	10,0%	12,0%	20,0%	5,1%	15,0%	20,0%	20,0%
Mean	20,0%	43,0%	66,0%	33,5%	17,5%	32,5%	20,0%	21,0%	20,0%	57,5%	50,0%	12,5%	7,3%	8,5%	7,5%	10,0%	15,0%	5,1%	12,5%	15,0%	15,0%

Fig. 1. Maximum and minimum percentage of the optimal real estate allocation in a mixed asset portfolio according to the survey.

The results shown in Fig. 1 highlight a wide variation of the optimal allocation range for the real estate. In particular, several Authors – [22–29] - identify the exact percentage of real estate that would be optimal to consider for investors within a mixed-asset portfolio. Other Scholars – [30–40] - establish a range within which to vary the optimal real estate allocation according to different factors, such as investors' risk aversion, investment period and asset returns.

The trend of the maximum and the minimum level percentage for the optimal real estate allocation, has undergone significant variations over the years of analysis considered. In particular, it is possible to note that starting from 2007 the percentage has significantly dropped, settling in a range that never exceeds 20%. The reason of this episode is linked to the global financial crisis triggered by the subprime mortgages, after which real estate performed poorly across different property types and locations in many countries [41, 42].

Over the years, in order to face the changing market conditions, several approaches for real estate decision making on a portfolio level have been addressed. The use of multi-criteria decision analysis and the multi-objective models for focusing the asset allocation problems has received increased attention in recent years. These methods have been suitable tools for complex asset allocation problems characterized by multiple influencing factors, uncertainties and the participation of multiple stakeholders along the process [43]. [44] perform two fuzzy mathematical programming models to overcome the drawbacks of traditional asset allocation models by including expert adjustment with vague data. [45] have treated the issue of portfolio selection by using fuzzy interactive approach, multiple goals and constraints. [46] attempts to examine whether the home asset bias in a portfolio holding is associated with higher political instability risk, and to what extent international diversification among stocks, in the presence of such risk, outperforms domestic stock portfolios by using a multi-objective approach. [47] provide for a robust multiobjective portfolio optimization with a minimum regret approach in order to incorporate future returns scenarios in the investment decision process. Some Authors choose to calculate the best efficient solutions, but many others address the efficient frontier, which is done with evolutionary or exact algorithms [48]. Approximation of the Pareto frontier and the research in the regions of investors' interests are suggested by [49]. [50], instead, try to solve multi-objective portfolio optimization problems with three or more quadratic objective functions, focusing on convex programs.

As regard to the portfolio selection process with the application of network theory, [51] establish a bridge between the modern portfolio theory framework and network theory, showing a negative relationship between optimal portfolio weights and the significance of assets in the financial market. [52] propose three different methods in order to extract the dependence structure among assets in a network context for then formulate and sort out the asset allocation problem.

4 The Model

From a computational point of view, the model consists in the resolution of an optimal allocation problem regarding the financial resources of a generic institutional investor who is interested in the construction of a real estate portfolio. In particular, the risk-return profile of the generic investor considered is represented by the core and core plus strategies, characterized by high yields and contained risks. In this case, therefore, the goal programming backpack problem ca be translated into:

- the resources available in limited quantities, i.e. the financial budget of the generic institutional investor;
- the alternative uses consisting of the various properties that can be within the real estate portfolio;
- the constraints represented by the mathematical equations and inequalities that identify the trade-offs decisions for the investor's convenience;
- the objective function, i.e. the identification of the best performing real estate portfolio with reference to the risk-return profile considered.

The identification of properties able to be included in the optimal real estate portfolio is structured on the initial yield, the riskiness and dynamism of each property by considering the municipal trade area to which they belong. *Soft* constraints and *hard* constraints are defined depending on the risk parameter considered and their importance in the construction of the real estate portfolio.

4.1 Soft Constraint

The initial yield relating to each property eligible for the optimal portfolio is assessed with reference to the property values defined by the Real Estate Market Observatory (REMO) of the Italian Revenue Agency for each municipal trade area where are placed. According to the D.P.R. no. 138/1998, indeed, the perimeter of an urban area where the real estate market is affected in a similar way by the existing extrinsic factors is called "municipal trade area". If the purchase price of each property is lower (or equal) to the average market value detected for the municipal trade area to which it belongs and the passing rent is higher (or equal) to the average rent charged, the probability for the generic investor to acquire a high capital gain at the time of the sale is higher. For this reason, defined with ΔVm and ΔCm respectively the average variation of the market value and the rent of the *i*-th property compared to the REMO values detected, the following Eqs. (1) and (2) are obtained:

$$\Delta\mathrm{Vm} = (\mathrm{Vm_i} - \mathrm{Vm_{REMO}})/\mathrm{Vm_{REMO}} = (\mathrm{Vm_i}/\mathrm{Vm_{REMO}}) - 1 \tag{1}$$

$$\Delta\mathrm{Cm} = (\mathrm{Cm_i} - \mathrm{Cm_{REMO}})/\mathrm{Cm_{REMO}} = (\mathrm{Cm_i}/\mathrm{Cm_{REMO}}) - 1 \tag{2}$$

with:

- Vm_i is the market value of the i-th property;
- Vm_{REMO} indicates the average market value detected by the REMO in the municipal trade area considered;
- Cm_i refers to the passing rent of the i-th property;
- Cm_{REMO} is the average rent recorded by the REMO in the municipal trade area considered.

For the optimal construction of a real estate portfolio, therefore, the best condition is represented by the simultaneous minimization of the ΔVm and maximization of the ΔCm. In order to achieve this aim, it is useful to introduce two financial indicators capable of providing information about the profitability and the immediate potential yield deriving from each property: the going-in cap rate (*GICR*) and the initial yield (*IY*). Considering the incremental ratio between $\Delta GICR$ and ΔIY it is possible to write Eq. (3) relating to the variation of the initial yield:

$$\Delta\mathrm{IY} = (\mathrm{IY} - \mathrm{GICR})/\mathrm{GICR} \tag{3}$$

The *GICR* is calculated with the ratio of the average rent (ΔCm_{REMO}) and the market value (Vm_{REMO}) detected by the REMO in the municipal trade area considered. The *IY* is, instead, represented by the ratio between the passing rent (Cm_i) and the market value (Vm_i) of the *i*-th property under analysis. Through the replacement of these algebraic function in Eq. (3) it's possible to define Eq. (4), relating to the maximization of the variation in the initial yield (ΔIY) of the i-th property related to the market of the municipal trade area considered:

$$\Delta\mathrm{IY} = [(\Delta\mathrm{Cm} + 1)/(\Delta\mathrm{Vm} + 1)] - 1 \tag{4}$$

The risk borne by the generic investor must be as low as possible: it will therefore be necessary to identify dynamic markets with a low volatility of rents and market values. For this reason, the gross annual yield (Y_{ga}) per year t is introduced:

$$\mathrm{Y_{ga}} = [(\mathrm{VmR_{EMO}(t)} + \mathrm{Cm_{REMO}(t-1)})/\mathrm{Vm_{REMO}(t-1)}] - 1 \tag{5}$$

The gross annual yield of the property is calculated by considering the ratio of the sum of the hypothetical market value at the time of the sale, i.e. after one year ($Vm_{REMO}(t)$), and the rent received in the previous year ($Cm_{REMO}(t-1)$), with the purchase price $Vm_{REMO}(t-1)$. The hypothesis admits that the generic institutional investor purchases the *i*-th property at a price equal to the average market value in the municipal trade area considered in the year $t - 1$ ($Vm_{REMO}(t - 1)$), and acquires - for a period of one year from its purchase - a rent equal to the average one charged in the municipal trade area considered ($Cm_{REMO}(t - 1)$). At the end of this period, the i-th property is sold with a price that corresponds to the average market value of the municipal trade area currently practiced in the year t ($Vm_{REMO}(t)$). This assumption makes it possible to consider the real estate investment under analysis as a generic one. In other words, it is possible to avoid including in the evaluation the costs for notary fees, agency fees, ordinary maintenance etc. borne by the owner. In this way, considering that a stable market is characterized by a limited dispersion of gross annual returns, the generic institutional investor will aim to minimize the standard deviation of returns over the semesters (s) considered in the period t. At the same time, it will be necessary to maximize the average gross annual yield (Y_{aga}) achievable, therefore:

$$\sigma = \sqrt{\frac{1}{s - 1}\sum\nolimits_{t=1}^{s}\left[Y_{ga}(t) - Y_{aga}\right]^{2}} = MIN \tag{6}$$

$$Y_{aga} = MAX \tag{7}$$

The dynamism (D) of the reference market for each i-th property is evaluated through the number of transactions (NT_i) registered by the REMO for the related intended use and in the city in which is located. It is appropriate to carry out a normalization according to the resident population (RP_i) in each city in order to take into account the largest number of transactions that can take place in the most populated municipalities. Furthermore, in Eq. (8) this ratio is multiplied by 10,000, in order to obtain an easy reading and use of the data.

$$D = (NT_i/RP_i) \cdot 10,000 \tag{8}$$

The considerations addressed so far refer to the single property included in the real estate portfolio that is intended to be optimized for the generic institutional investor considered. Therefore, by indicating with p_n ($1 \le p_n \le n$, with n equal to the potential number of properties) the number of properties that will be within the portfolio and with p_{en} the maximum extent that it would be better to have by considering the available budget of the generic institutional investor, Eq. (9) is obtained:

$$\left|p_n - p_{en}\right| = MIN \tag{9}$$

Each property, however, depending on its market value can be attractive or not for the investor and, therefore, influencing their choices. To take into account the weight that the i-th property can determine in the decision-making process and, consequently, on the expected absolute yields, Eq. (10) is introduced. It defines the importance (or weight) w_i of the i-th property as the ratio between its market value MV_i and the sum of all the market values of the individual properties that constitute the real estate portfolio $\sum_{i=1}^{pn} MV_i$.

$$w_i = \frac{MV_i}{\sum_{i=1}^{pn} MV_i} \tag{10}$$

The algebraic functions previously defined in relation to the yield and risk for the individual property can be applied to the entire real estate portfolio with Eq. (11) as follows:

$$\begin{cases} \sum_{i=1}^{pn} \Delta IY_i \cdot w_i = MAX \\ \sum_{i=1}^{pn} \sigma_i \cdot w_i = MIN \\ \sum_{i=1}^{pn} \Upsilon_{aga,i} \cdot w_i = MAX \end{cases} \tag{11}$$

A similar operation can be performed with regard to dynamism D_i and the volatility σ with low standard deviations of D_i:

$$\begin{cases} \sum_{i=1}^{pn} \sigma_{D,i} \cdot w_i = MIN \\ \sum_{i=1}^{pn} D_{a,i} \cdot w_i = MAX \end{cases} \tag{12}$$

With D_{ai} is D_i average in the time period considered, whereas $\sigma_{D,i}$ indicates the standard deviation and w_i is the weight of the i-th property.

The last *soft* constraint of the model is represented starting from the introduction of the linear correlation coefficient of Bravais-Pearson (I_c), which allows to express any correlation among the properties in the real estate portfolio ($c_{i,}$). The lower the correlation among them, the lower the portfolio risk.

$$I_c = \sum_{i,j=1}^{pn} \left| c_{i,j} \right| \cdot w_i \cdot w_j = MIN \tag{13}$$

4.2 Hard Constraint

The main *hard* constraint of the model is constituted by the financial budget (FR_a) which determines the essential condition for the generic institutional investor considered. Equation (13) shows the translation of this condition into mathematical terms:

$$\mathrm{FR_a} - \sum_{i=1}^{pn} MV_i \geq 0 \tag{14}$$

The generic investor, in fact, will benefit most from the condition of equivalence (or at most a majority) between the available financial resources and the sum of the market values of the individual properties.

The last hard constraint of the model is, instead, represented by the non-negativity of the solutions and translated into algebraic terms in Eq. (15):

$$v_i \in I_0^+ = \{z \in \mathbb{R} \ni' 0 \leq z \leq \varepsilon\} \tag{15}$$

4.3 Algorithm of the Model

The binary variable x represents the i-th property and assumes a value of "1" if the property is admitted to the portfolio, on the other hand it assumes a value of "0" if the property is not included in the portfolio. The asset allocation model algorithm is summarized in Table 1.

Table 1. Algorithm of the proposed asset allocation model

Type	Mathematical function	Description
Variable	$x_i = \{0; 1\}$	Binary variable
Goal	$\sum_i \Delta IY_i \cdot w_i \cdot x_i = MAX$	Maximization of the variation in the initial yield of the i-th property with respect to the average value of the municipal trade area
Hard constraints	$FRa - \sum_i MV_i \cdot x_i \geq 0$	Budget optimization
	$v_i \in I_0^+ = \left\{z \in \mathbb{R} \ni' 0 \leq z \leq \varepsilon\right\}$	Non-negativity of the solutions
Soft constraints	$\lvert p_n - p_{ne} \rvert \geq 0$	Optimization of the number of properties in the portfolio
	$\left\lvert \sum_i \sigma_i \cdot w_i \cdot x_i - MIN\{\sigma_i\} \right\rvert \geq 0$	Preference for stable yielding real estate markets
	$\left\lvert \sum_i Y_{aga,i} \cdot w_i \cdot x_i - MAX\left\{Y_{aga}\right\} \right\rvert \geq 0$	Maximization of the average return
	$\sum_{i,j} \left\lvert c_{i,j} \right\rvert \cdot w_i \cdot w_j \cdot x_i \cdot x_j \geq 0$	Preference of properties belonging to poorly correlated real estate markets
	$\left\lvert \sum_i \sigma_{D,i} \cdot w_i \cdot x_i - MIN\left\{\sigma_{D,i}\right\} \right\rvert \geq 0$	Preference of low volatile real estate markets
	$\left\lvert \sum_i D_{a,i} \cdot w_i \cdot x_i - MAX\left\{D_{a,i}\right\} \right\rvert \geq 0$	Preference of dynamic real estate markets

5 Conclusions

Italian real estate assets attract local and foreign capital, often conveyed in indirect investment instruments such as real estate funds. However, the identification of the most appropriate asset classes, in terms of risk and target return depending on the investor profile, is a complex issue. From an economic point of view, in fact, the structure of real estate funds gets revenues from the investment strategies adopted. The composition of an optimal real estate portfolio, therefore, allows the implementation of performance of both the portfolio and the real estate fund that owns it.

This research is part of the framework outlined by defining an asset allocation model capable of maximizing the expected return and minimizing the risks incurred by a generic institutional investor interested in core and core plus investments for the available financial resources. The application of the computational logic of goal programming made it possible to develop a decision support model that the investor will have to face when identifying the optimal combination of different types of properties in the real estate portfolio. The translation into soft and hard mathematical constraints of the main risk factors influencing the optimal performance of the portfolio provided transparency and objectivity to the process. The potentialities of the proposed model is the flexibility of being applied for different size of the sample of potential properties in the available portfolio and in any geographical context represents an advantage for public and private investors.

Future insights may concern the efficacy test of the model by applying the algorithm in a real case study. In particular, the lack of georeferenced system can be improved by including GIS tools for modelling the spatial dynamics which affect the decisions of both public and private investors can be an interesting and useful development.

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