The optimal combinations of the eligible functions in multiple property assets enhancement

Francesco Tajani [a],[*], Pierluigi Morano [b], Felicia Di Liddo [b]

[a] Department of Architecture and Design, Sapienza University of Rome, Italy
[b] Department of Civil Engineering Sciences and Architecture, Polytechnic University of Bari, Italy

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ABSTRACT

The present research concerns the procedures of concessions for the improvement and exploitation of public property assets. We propose a model that helps to define the optimal combination of novel uses in public properties. This model is an answer to the need for effective strategies to find new functions for disused buildings or abandoned areas.

The model integrates the logic of the Discounted Cash-Flow Analysis (DCFA) and the goal programming for determining the new functions, to identify the macro-solution that maximizes the financial conveniences of the parties involved (Public Administration and private investor), in terms of monetary compensation for the Public Administration and return on investment for the private operator. The algorithm of the model has been applied to five existing public properties located in the city of Rome (Italy); for each property a specific procedure of concessions for the improvement of public assets can be activated and different eligible enhancement projects can be realized. The outputs generated by the optimization model are a valid decision support in all the phases of the concession procedure to identify the (public and private) strengths and weaknesses concerning the redevelopment initiatives on public properties. The effective re-use of these properties can actually help to prevent further soil consumption.

1. Introduction

The awareness that the sale of the public property assets is only an injection of liquidity, unable to improve the long-term financial capacity, is widely shared (Gilbert, 2003). This idea has determined the need to find alternative solutions able to trigger off the capacity of the public properties to be exploited. These strategies allow to achieve specific goals in the long-term (Jolicoeur and Barrett, 2005; Wills, 2009; Calabrò and Della Spina, 2018) through the transfer of the main investment risks to more qualified subjects.

In these terms, several public-private partnership (PPP) tools have been developed and tested in many countries (Tshombe and Molokwane, 2016). These cooperation forms imply a contract between a public sector authority and a private entrepreneur, in which the private investor provides public services and assumes the technical, financial and operational risk of the initiative (Koiki, 2011). The Italian public works regulation (Art.3 del D.L. No. 50/2016) has provided a PPP definition: "a written contract through which a Public Administration grants a private operator, for an established period that allows the recovery of the investment costs, a possible set of activities consisting in the construction, transformation, maintenance and management of a public work in exchange for its availability (in terms of economic exploitation or provision of a service connected to the use of the work itself) by the private entrepreneur, with the assumption of the investment risks according to the modalities established in the contract".

Therefore, the PPP procedures allow to *i)* find new forms to finance the investments and to involve specialized skills in the interventions (Kaganova and Nayyar-Stone, 2000; Spackman, 2002), *ii)* define a sustainable effort between the public and private sectors, to achieve a mutual shared goal (Okonkwo et al., 2014), *iii)* identify effective practices for property management, for new uses definition and for the territorial impacts maximization (Tajani and Morano, 2017).

Although local authorities have been testing different forms of PPP procedures for the development of urban and regional areas (Sagalyn, 2007), there is not a relevant research able to be fully informed on the results generated by their use. Thus it determines an important need to rigorously assess the current public private cooperation forms (Hodge and Greve, 2007) and to effectively manage public properties (Hanis

et al., 2010; Bourguignon, 2013).

The risk of an investment failure could be highly likely, considering the size, the location and the specific factors of the majority of the public property assets (Del Giudice et al., 2020). These properties are generally characterized by the presence of a plurality of heterogeneous intended uses and several values (historical, artistic, identity, cultural and social) that make their marketing more complicated. Moreover, especially in less dynamic and developed territorial contexts, the Public Administrations technicians do not always have the skills to evaluate the requests for the private investor or those ones made by the private subject. The consequence could be the failure of the initiative with an obvious loss of opportunity for the area of intervention.

Therefore, the decision-making process for the public property assets enhancement must carefully assess any future scenarios as well as consider the costs, the benefits and the risks of each possible solution, in order to *i)* maximize the effects on urban structures for the community, *ii)* produce new opportunities, *iii)* generate a social and economic development (Leung and Hui, 2005; Melnikas, 2005).

In Italy, the *enhancement concession* is part of the PPP procedures, regulated by Art. 3-bis of D.L. No. 351/2001, as amended and integrated by Law No. 228/2012. The *enhancement concession* transfers to a private investor the use of a public property for a fixed period (concession period), in exchange for its functional reconversion, requalification and ordinary and extraordinary maintenance. The private investor, as the "manager" (and not the "owner") of the public property, recognizes a share of the financial revenues to the public entity, in terms of financial burdens (as lump sums or annual and fixed leases) and/or of public works to be realized according to the local community. At the end of the concession period, the total availability of the property, with its improvement, comes back to the public entity.

We underline that the involvement of a private investor in an enhancement concession procedure takes place if the financial convenience of the investment is satisfied, i.e. when the initiative remunerates the initial monetary outlay and generates a profit able to compensate investment risks. The investment (worth) value [RICS, 2017] of the private subject will depend both on the specific characteristics of the entrepreneur - risk appetite, expected return on investment, "waiting time" for the recovery of the initial invested capital - and on the burdens required by the Public Administration, in public works and/or in monetary terms.

2. Aim

This research develops a model to define the optimal combination of the new intended uses for different public properties (existing buildings in disuse and abandoned urban areas) improved by concession initiatives. Borrowing the logic of the Discounted Cash-Flow Analysis (DCFA) and considering appropriate assumptions that simplify its implementation, the optimization model uses the goal programming to define the new functions of different public properties. The model aims to identify the *macro-solution* - i.e. the mix of the intended uses determined as the best one for all the properties among the eligible functions for each asset - that maximizes the financial conveniences of the parties involved (Public Administration and private investor), in terms of monetary compensation for the public entity and return on investment for the private operator.

The proposed model is characterized by the following three steps:

step 1) the introduction of the assumptions that simplify the DCFA in the cases of enhancement concession. These assumptions, avoiding the construction of the classic matrix of a DCFA, allow to determine investment performance indicators through a quick and easy equation that requires few parameters for its implementation. Thus it limits the possible "manipulation" of economic items, aimed at demonstrating the validity of the project and ensuring its approval for public fundings (Flyvbjerg, 2007);

step 2) the integration of the equation defined in the step *1)* through a goal programming algorithm, able to identify the best mixture of the projectual solutions for the parties involved;

step 3) the definition of a Pareto frontier, i.e. a range of possible scenarios, among which the best combination of the projectual solutions can be selected according to the needs (weights) of the different stakeholders involved.

The algorithm of the model is applied to five public properties located in the city of Rome (Italy). For each case study, different enhancement initiatives are proposed. These are characterized by different transformation and management costs, different revenues and different expected returns on investment.

This optimization model gives great advantages in the decision-making process of the parties involved in the enhancement of multiple public properties: *i)* Public Administrations could quickly simulate the costs/revenues balance of the initiative implemented by the private investor to assess the financial feasibility for different combinations of eligible intended uses, *ii)* the public operator may calibrate, without affecting the financial feasibility of the initiatives, the amounts and the typologies of the requests to be advanced to the private investor, depending on property's attractiveness in the reference market, *iii)* the private investor could use the optimization model to test the costs/revenues balance for different hypotheses of the initiatives. Through the model, the private investor could widen the vision of the issues related to the initiatives, outlining their strengths and weaknesses, recognizing investment risks, analyzing the most appropriate combination of the intended uses in relation to the current economic situation.

This model may represent a relevant support in the contractual phases between Public Administrations and the private operators to define an effective territorial initiatives planning both in financial terms and for the local communities. The optimization model could also contribute to simplify the negotiation phases of the initiatives working as a support in the analysis that the Public Administration and the private investor can independently develop. The model aims at verifying the already approved investments, for those the conditions of the property market and the actual effects that better solutions could generate were not be considered.

Moreover, the effective regeneration of properties in disuse and abandoned areas can help to prevent further soil consumption, according to the strategies promoted by the European Union for the achievement of a "no net land take" by 2050 (European Commission, 2016).

Finally, it should be pointed out that the assumptions considered for the application of the DCFA imply that, after having identified the best solutions among the different alternatives of property enhancement through the implementation of the proposed optimization model, the results obtained should be always integrated by a classic DCFA and appropriate risk analysis tools, in order to assess and to monitor the performance of the selected solutions over time.

The research is divided into six sections. In the first section the main background on PPP procedures and goal programming applied to the territorial investments is reported. In the second section, the step 1) of the model is implemented, highlighting the specific interpretation of the classic DCFA performance indicators that can be considered in the case of PPP procedures: the basic assumptions are introduced, the mathematical expressions for the calculation of the classic performance criteria are recalled, the equation for the simplified DCFA is determined. In the third section the step 2) of the model is implemented, the optimization model is illustrated, by specifying the variables, the constraints for the subjects involved in the initiatives and the objective function to be pursued. In the fourth section, the algorithm of the optimization model is applied to five public properties to be enhanced, located in the city of Rome (Italy): after having described each case study, the corresponding transformation and management costs, the revenues and the expected returns on investment are schematized; then, the model is implemented, by also considering different weights for the objectives to be pursued, in order to define a Pareto-optimal frontier - step 3) of the model - for the subjects involved in the initiatives. In the fifth section the

outputs obtained by the implementation of the model are discussed, and the potential value and the limitations of the proposed tool are pointed out. Finally, the conclusions of the work are drawn.

3. Background

The origins of the public-private partnership as an institutionalized tool can be traced in United Kingdom, where, after the utilization of tollgates authorized in the fourteenth century and the first urnpike model in the seventeenth century (Grimsey and Lewis, 2004), "Private Finance Initiative" tool has been set up (Corner, 2005; Adeyinka and Olugbamila, 2015). Several forms of cooperation between the public and the private subjects - project financing, public company, service contracts, operation and management contracts, leasing-type contracts, build-operate-transfer (BOT), design-build-finance-operate (DBFO) – have been subsequently developed. They have been tested in many countries, differentiated according to the agreement duration, the role and the responsibilities - and therefore the risks - in the realization and management process of the sectors (public and private) involved. (Teisman and Klijn, 2002; Kwak et al., 2009).

Verhoest et al. (2015) have outlined that a broad range of European countries - among them, Switzerland, the Czech Republic, France and Italy - have launched governmental institutional support of PPP procedures. In Italy, among these typologies, there are Complex Integrated Plan (L. No. 109/92), Urban Transformation Companies (L. No. 127/97; explanatory circular, Ministry of Public Works, No. 622/2000) and negotiated agreements (L. No. 241/90; L. No. 449/97; L. No. 662/96; L. D. No. 267/2000). In recent years, the *enhancement concession* has been characterized by a widespread application. This typology of public-private cooperation allows to transfer the management of public properties, owned by the State or local authorities, to the private subjects through public tendering procedures for a period up to fifty years. The goal is to carry out the reuse and the refurbishment of these public properties, also through the realization of new intended uses in order to trigger off widespread economic impacts for the communities.

The Social Impact Bonds (SIBs) represent a particular type of public-private cooperation that has recently spread in many countries (Disley et al., 2015). Belonging to the social impact investing category, the SIB is a financial tool configured as a partnership between different actors (public and private) aimed at promoting social welfare objectives through the involvement of private funds. It is a "pay for success" tool, i. e. the return on investment for the private operator is bound to the achievement of a specific social impact, measured by the Public Administration or by an independent valuer.

However, in the last decades the failure of numerous public initiatives carried out through the involvement of the private subjects has generated the need to elaborate appropriate performance measurement indicators to monitor the progress of the procedure in the established agreement duration (Regan et al., 2011). Yuan et al. (2009) have stated that ineffective performance measurement of public-private cooperation can determine suboptimal service quality (Liu et al., 2016). Tawalare and Balu (2016) and Sastoque et al. (2016) have schematized the project, business, economic and socio-political risks related to initiatives in which public subjects and private investors are involved. With reference to these typologies of procedures, several Authors have highlighted that in monitoring and evaluating performance constitutes the core for the project success (Love and Holt, 2000; Kennerley and Neely, 2003; Gunasekaran and Kobu, 2007; Villalba-Romero and Liyanage, 2016). Some Scholars have analyzed the investment success by integrating the measurement of project development with stakeholders' satisfaction (Savindo et al., 1992; Nguyen et al., 2004), and highlighting the importance of the "iron triangle" measures (Atkinson, 1999; Phua, 2004) in terms of time (finishing on time), cost (within budget) and quality (finished according to specifications). Liu et al. (2014) have pointed out the need to overcome some conventional financial measures as the lagging indicators (Dixon et al., 1990), both to pursue the "value for

money" in terms of customer satisfaction, pay-off strategy, quality public facilities and services (Parker, 2000; Neely et al., 2001; Akintoye et al., 2003; Zhang, 2006; Henjewele et al., 2011) and to exploit the ability of effective PPP tools to achieve sustainable synergies and sustainability goals, in terms of social, ecological and economic perspective (Labuschagne and Brent, 2005; Hueskes et al., 2017).

With regards to the application of goal programming models to territorial investments, several Authors have implemented this methodology for the maximization of social welfare (Ben-Shahar et al., 1969; Lee, 1973; Lee and Keown, 1979). Bowlin (1987) has applied the Data Envelopment Analysis method to assess possible inefficiencies in the performance of the US Air Force real-property maintenance activities. Schniederjans et al. (1995) have elaborated a goal programming model to obtain the optimal house selection decision. Tan et al. (2008) have developed a goal programming optimal bidding strategy model to determine the best resources allocation solution for an entrepreneur in bidding for construction contracts. Tajani and Morano (2015) have defined a model that, subject to the constraint of financial feasibility, allows to determine a range of possible urban parameters upon which it is possible to carry out the negotiation between public and private sectors involved in urban regeneration and social housing investments. Shen et al. (2016) have proposed a multi-attribute utility approach for the assessment of the level of sustainability performance of PPP projects.

4. The DCFA for the enhancement concession procedures

The financial sustainability of an investment is generally verified by developing a DCFA, which includes: i) the cost and revenue assessment, related to the investment realization and management phases; ii) the calculation of the cash flows generated during the analysis period for the private entity; iii) the determination of the performance indicators to verify the feasibility of the initiative. The Net Present Value (*NPV*), the Internal Rate of Return (*IRR*), and the Discounted Payback Period (*PbP*) are among the most commonly used performance criteria. In particular, a higher zero value of the *NPV* immediately confirms the investment financial convenience, whereas the *IRR* and the *PbP* must be compared with "threshold" values. The determination of these acceptability thresholds i) requires a careful market survey, for the identification of the eligible values according to the requirements of the private entrepreneur that ordinarily operates in the same sector and the risk appetites; ii) is influenced by the specific investor characteristics.

Considering that the *PbP* gives the number of years it takes to break even from undertaking the initial monetary outlays, in the DCFA development, as the discounted rate (*r*) increases, the *NPV* decreases, whereas the *PbP* grows, that is consistent with the investment risk increase.

Eqs. (1) and (2) synthesize the mathematical expressions for the calculation of the *NPV* and the *PbP*. The meaning of the parameters in the two equations has been reported in Table 1.

$$\sum_{t=1}^{T} \frac{F_t}{(1+r)^t} - K = NPV \tag{1}$$

$$\sum_{t=1}^{PbP} \frac{F_t}{(1+r)^t} - K = 0 \tag{2}$$

Table 1
Parameters for the calculation of the DCFA evaluation criteria *NPV* and *PbP*.

NPV	Net Present Value of the investment
r	discounted rate
PbP	Discounted Payback Period (< T)
F_t	cash flow of the investment in the period t
K	realization cost of the investment
T	analysis period of the investment

The implementation of the DCFA has the advantage to define the financial conveniences of the parties involved (private investor and Public Administration) through an appropriate interpretation of the evaluation indicators. Having assessed the transformation costs, the management costs and the revenues of the initiative, and set the actualization rate of the cash flows equal to the expected return on investment (*r*) for the private subject, the *NPV* constitutes the maximum amount that the public entity may require to the private investor in monetary terms and/or in terms of public works of equivalent value to be realized for the local community. Thus, the amount of the *NPV* will represent a relevant data for Public Administrations in terms of convenience of the initiative (Tajani et al., 2019).

In fact, if the *NPV* is positive, the financial threshold for the private entrepreneur will be satisfied, and the value of *NPV* will represent an extra-profit for the private investor over the minimum expected return on investment (= *r*). Therefore, the Public Administration can formulate its requests based on this extra-profit monetary amount, guaranteeing financial sustainability of the initiative for the private investor.

On the other hand, monetary burdens required that are higher than the calculated *NPV* do not ensure the financial convenience of the initiative for the private entrepreneur.

Furthermore, in the case of the enhancement concession of public property assets, it is possible to assume that investment cash flows that occur after the *PbP* - as the difference between revenues generated by the initiative and management costs - are periodically constant. In fact, after the *PbP* it is very likely that the investment will have reached its fully operational activity; moreover, there will not be a terminal value of the investment, as the enhanced property will come back to the public owner at the end of the concession period. Therefore, by subtracting Eq. (2) to Eq. (1) and considering that *NPV* represents the extra-profit of the private investor, i.e. the maximum amount that can be required by the Public Administration, Eq. (3) can be obtained.

$$\sum_{t=PbP+1}^{T} \frac{F_t}{(1+r)^t} = NPV \tag{3}$$

For the constancy of the cash flows after the *PbP*, Eq. (3) is equivalent to Eq. (4).

$$F_t \cdot \frac{(1+r)^{(T-PbP)} - 1}{r \cdot (1+r)^T} = NPV \tag{4}$$

Within the enhancement concession of public property assets, the model formulated in Eq. (4) can be used in three different ways: option I), set the *NPV*, i.e. the financial burden required by the Public Administration to the private investor, it is possible to determine the combinations [*r-PbP*] of financial sustainability for the private investor; option II), set the minimum return on investment expected by the private subject (*r*), the equation allows to determine the [*PbP-NPV*] combinations; option III), fixed the time period in which the private entrepreneur intends to recover the invested capital (*PbP*), the equation returns the combinations of [*r-NPV*]. This last condition has been considered for the elaboration of the optimization model presented as follows.

In Table 2 the three options of the model have been summarized.

5. The optimization model for the definition of the best enhancement concession initiatives

Starting from Eq. (4) and considering the option III) for its

implementation, an optimization model has been developed, by borrowing the operative logics of goal programming methods.

In general terms, a goal programming problem can be translated into the identification of the optimal allocation of scarce resources that can be destined to alternative uses. Thus, a goal programming problem is defined by: resources available in limited quantities; alternative uses provided for them; constraints to the use of resources; objective functions, to assess how the possible use of resources contributes to achieve a specific objective.

In particular, for the developed optimization model the goal programming problem can be explained as follows: *i)* resources available in limited quantity are represented by the different public properties to be enhanced; *ii)* the alternative uses correspond to the various - public and private - intended uses that can be realized in the different properties; *iii)* the constraints are represented, in mathematical terms, by the conveniences of the total initiative for the private investor and the Public Administration; *iv)* the objective functions reflect the goals pursued by the parties involved in terms of maximization of respective financial returns expected by the redevelopment initiative.

In this research, the optimization model applies the *branch and bound* algorithm (Parker and Rardin, 2014; Wolsey, 1998). Based on a partition and branching mechanism of the sets of solutions and the calculation of a limit value of the objective function, the branch and bound algorithm proceeds for a partial exploration of the feasible solutions. Increasing the number of the *n* alternative intended uses for each public property to be enhanced and the number of the *m* public properties involved in territorial redevelopment initiative, the combinations to be examined are so numerous that the enumeration of the solutions could be impossible to determine. Thus, the branch and bound algorithm decomposes the domain solutions into subsets whose intersection is not relevant and whose union coincides with the starter set. The best combination is sought in the subsets obtained through a strategy that aims to verify whether the partition should be further subdivided or may be excluded from further analysis.

The formulation of the algorithm of the optimization model requires the definition of the variables, the objective function and the constraints as follows.

5.1. Variables, objective function and constraints of the optimization model

The implementation of the branch and bound algorithm provides the introduction of a binary variable x_{ij}, associated to the *i*-th (*i* = 1, …, *n*) redevelopment project and referred to the *j*-th property to be enhanced (*j* = 1, …, *m*). In the branch and bound method, x_{ij} represents the branching variable, which assumes a value "1″ if the *i*-th enhancement solution for the *j*-th property satisfies the objective function, and a value "0″ otherwise.

It is evident that the realization of the *i*-th enhancement solution on the *j*-th public property excludes the possibility to realize the other *n-1* redevelopment projects on the same *j*-th property. Therefore, the first constraint of the model can be defined through Eq. (5), to ensure that the branching variable x_{ij} takes the value "1″ for only one of the *n* redevelopment projects eligible for the *j*-th public property to be enhanced[1]:

$$\sum_{i=1}^{n} x_{ij} = 1 \quad j = 1, …, m \tag{5}$$

The objective function of the optimization model pursues the maximization of the financial conveniences of the entire redevelopment

Table 2
Modalities of application of Eq.(4) in the enhancement concession initiatives.

Option	Parameter to be set	Outputs
I	*NPV*	*r-PbP*
II	*r*	*PbP-NPV*
III	*PbP*	*r-NPV*

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[1] It is evident that the number of the eligible redevelopment projects for the *j*-th public property to be enhanced could be different from the number concerning the *k*-th public property. In order to avoid to excessively complicate the explanation of the optimization model, the same number "*n*" of eligible enhancement projects has been assumed for each *j*-th public property.

initiative for both the parties involved in the enhancement concession procedure of multiple public properties located in a specific territorial area. In particular: *i)* for the private investor, considering that the financial feasibility of each *i*-th enhancement project eligible for the *j*-th property can be measured in terms of return on the sustained investment costs ($r_{ij} \cdot K_{ij}$), the financial convenience of the entire enhancement initiative (*R*) is equal to the sum of the returns on investment (expressed in currency) corresponding to the *m* enhancement solutions selected as the "best" ones - in terms of financial convenience for the private investor - for the *m* properties; *ii)* for the Public Administration, the financial convenience is expressed by the sum of the *m* values of NPV_{ij} obtained through Eq. (4) for each *i*-th enhancement project selected as the "best" one - according to the public needs - for the *j*-th property: this amount (= *N*) represents the maximum monetary compensation that can be required by the Public Administration to the private investor for the entire redevelopment initiative. Considering that the best enhancement projects for the parties involved will be identified by the implementation of the *branch and bound* algorithm and recalling Eq. (4), the financial conveniences for the Public Administration and the private investor can be respectively expressed through Eqs. (6) and (7).

$$N = \sum_{j=1}^{m} \sum_{i=1}^{n} \left[F_{t\_ij} \cdot \frac{(1 + r_{ij})^{T_{ij} - PbP_{ij}} - 1}{r_{ij} \cdot (1 + r_{ij})^{T_{ij}}} \right] \cdot x_{ij} \tag{6}$$

$$R = \sum_{j=1}^{m} \sum_{i=1}^{n} r_{ij} \cdot K_{ij} \cdot x_{ij} \tag{7}$$

The objective function to be pursued concerns the identification of the *m* enhancement projects able to define the best compromise solution, in terms of respective financial conveniences (*N* and *R*), for both the parties involved in the entire redevelopment initiative. As the two goals are conflicting, two multiplicative coefficients *a* and *b*, variable in the range [0, 1], are considered, to adequately weigh the importance of each goal and define a Pareto-optimal frontier of the enhancement solutions to be implemented. Therefore, the objective function of the optimization model can be reported in Eq. (8).

$$\max (a \cdot N + b \cdot R) \tag{8}$$

5.2. The algorithm of the optimization model

In Table 3 the algorithm of the optimization model has been reported, whereas in Table 4 the meaning of each term of the algorithm has been explained.

6. Application of the optimization model

In order to test the optimization model performance, the developed algorithm has been applied to five case studies, concerning five public properties located in the city of Rome (Italy), for which redevelopment initiatives have been planned to be implemented through the enhancement concession procedure. The five properties are represented by the following public buildings: the Arsenale Pontificio complex, the former warehouse "Vittoria", the former factory "Mira Lanza", the former police

Table 3
Algorithm of the optimization model.

variable	x_{ij}
objective function	$\max (a \cdot N + b \cdot R)$
constraints	$N = \sum_{j=1}^{m} \sum_{i=1}^{n} \left[F_{t\_ij} \cdot \frac{(1 + r_{ij})^{T_{ij} - PbP_{ij}} - 1}{r_{ij} \cdot (1 + r_{ij})^{T_{ij}}} \right] \cdot x_{ij}$
	$R = \sum_{j=1}^{m} \sum_{i=1}^{n} r_{ij} \cdot K_{ij} \cdot x_{ij}$
	$\sum_{i=1}^{n} x_{ij} = 1 \quad j = 1, \ldots m$

Table 4
Variable and exogenous parameters of the optimization model.

x_{ij}	binary variable associated to the i-th enhancement project for the j-th property
F_{t_ij}	cash flow (in the period t) determined by the i-th enhancement project for the j-th property
r_{ij}	expected return on investment (%) for the i-th enhancement project realized on the j-th property
T_{ij}	analysis period for the i-th enhancement project realized on the j-th property
PbP_{ij}	Discounted Payback Period for the i-th enhancement project realized on the j-th property
K_{ij}	investment costs of the i-th enhancement project for the j-th property
N	maximum monetary compensation that can be required by the Public Administration to the private investor for the entire redevelopment initiative
R	total return on investment (in currency) of the entire redevelopment initiative for the private investor
a	multiplicative coefficient [0,1] to weigh the importance of the public goal
b	multiplicative coefficient [0,1] to weigh the importance of the private goal

station "Porto Fluviale" and the former hospital "Santa Maria della Pietà". For each property, different enhancement solutions are provided. Given the size of the buildings, each alternative is characterized by the mixture of different intended uses. Particularly, each enhancement solution has been selected following the results of a survey carried out among different design studios and experts (architects, urban planners, sociologists), who have been asked to develop project proposals related to the five public properties. All the projects take into account the needs expressed by the local communities in terms of new uses of the specific public properties in the city of Rome, in order to ensure a participatory mechanism of urban planning.

Fig. 1 shows a map of the city of Rome with the location of the five public properties considered. For each case study, the current state and the different eligible project solutions have been described below; a summary Table is therefore presented, in which, for each enhancement solution, the economic items that are required for the implementation of the algorithm of the optimization model have been reported. These items have assessed through appropriate market surveys, by considering the demand, the supply and the risk components related to each intended use, based on the size and the specific location of each property, the behavior and the return expectations of the private investors that ordinarily operate in the area where the analyzed properties are located. It has been assumed that the analysis period (*T*) and the Discounted Payback Period (*PbP*) are the same for all the case studies and the related projectual solutions, equal respectively to thirty years ($T_{ij} = T = 30$) and ten years ($PbP_{ij} = PbP = 10$).

6.1. Description of the case studies

CASE STUDY 1: Arsenale Pontificio complex
Current state. The complex is located in a semi-central area of the city of Rome, from which the city centre is easily accessible by road and rail means of transport. The entire Arsenale Pontificio complex consists of three independent structures developed around a single open space and each one developed on a single level: the arsenal, the corderie and the salt deposit. Realized in the early eighteenth century, the buildings have been characterized by their original functions until the end of the 19th century. The Arsenal Pontificio complex is located in an extended area covering a surface of about 50 ha, currently in an advanced state of degradation, also due to the widespread phenomena of illegal constructions.

Enhancement projects. The main objective common to the three enhancement projects concerns the recovery of a part of the degraded urban fabric through a joint operation of building renovation, functional reconversion and environmental requalification. The three enhancement solutions are presented below. Solution A_1 involves the construction of a music school, a theater and a restaurant. Solution B_1 aims at redeveloping the Arsenale Pontificio complex through the functional
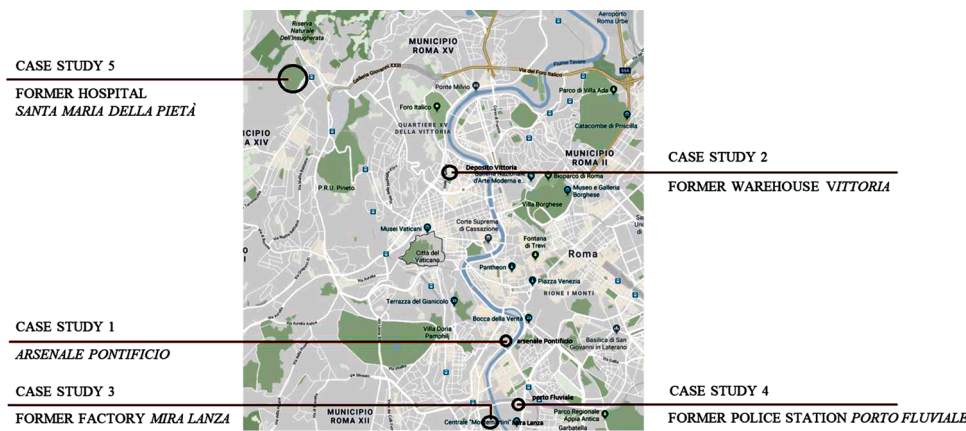
Figure 1. Location of the five case studies in the city of Rome

Fig. 1. Location of the five case studies in the city of Rome.

reconversion to museum, commercial space and bar/restaurant. Finally, solution C_1 involves the construction of a library and annexed commercial spaces and dining options. Table 5 shows the three enhancement solutions and the respective economic items necessary for the implementation of the optimization model, i.e. the cash flows, the realization costs and the expected annual returns. Fig. 2 shows the current state and a possible enhancement solution of the Arsenale Pontificio complex.

CASE STUDY 2: Former warehouse "Vittoria"

Current state. Built in the early '900 s, the former warehouse "Vittoria" is currently in disuse and in an advanced state of abandonment. The urban area in which the structure is located is central and well connected to the remaining parts of the city through the main public and private transport lines.

Enhancement projects. The two enhancement solutions considered in this research provides the total functional reconversion of the complex spaces. The two solutions, although different for the intended uses, aim at transforming the building and the area into neighborhood landmark, by promoting the regeneration of an area that is currently an empty urban space. Solution A_2 involves the construction of an interactive sports museum with indoor and outdoor play areas. Solution B_2 provides the reuse of the former warehouse "Vittoria" as a multifunctional sports centre, a nursing home and commercial spaces. Table 6 shows the two enhancement solutions and the relative economic items, i.e. the cash flows, the realization costs and the expected annual returns. Fig. 3 shows the current state and a possible enhancement solution of the former warehouse "Vittoria".

CASE STUDY 3: Former factory "Mira Lanza"

Current state. The area of the factory "Mira Lanza" is a former industrial site located in the southern periphery of the city of Rome. The

complex is divided into six autonomous buildings. The factory was realized between 1918 and 1945 and used for the production facilities of the soap and as household cleaning factory until the definitive closing in the 1970s. Following its disposal, the entire area has remained in a complete degraded condition, being isolated from the surrounding urban context.

Enhancement projects. The redevelopment of the complex involves the transformation of "Mira Lanza" into a new urban centrality through the enhancement of a building complex that is part of industrial archeology. The two enhancement solutions aim at securing buildings, renewing them from a structural point of view and adapting them to the new provided functions. In particular, solution A_3 concerns the construction of a market for the selling and distribution of food products and a restaurant with adjacent service areas (kitchen, services and reception areas). Solution B_3 proposes the realization of a cinema, a restaurant, a bed & breakfast and, finally, the reconversion of the archaeological area in a museum. Table 7 shows the two enhancement solutions and the relative economic items, i.e. the cash flows, the realization costs and the expected annual returns. Fig. 4 shows the current state and a possible enhancement solution of the former factory "Mira Lanza".

CASE STUDY 4: Former police station "Porto Fluviale"

Current state. Built in 1918, the former police station "Porto Fluviale" is currently in a state of total abandonment and illegally occupied by immigrant families. The entire urban area in which the building is located is characterized by relevant critical issues: the presence of illegal structures, the lack of parking spaces and green areas, a high index of noise pollution generated by the proximity of the site to the railway and by the high and continuous flows of road transport means, being the property located at the intersection of two important road axes.

Enhancement projects. The three enhancement solutions considered aim at recovering an entire portion of the city that is currently in an advanced degraded state. In particular, solution A_4 provides the functional reconversion of the existing building and the realization of a new building, through the mixture of several functions: in the existing building, a restaurant, training classrooms, social housing with recreational spaces, a conference room and offices for the personnel management; in the new building, a hydroponic greenhouse with a space for crops produced retail and an underground car park spaces. Solution B_4 provides the recovery of the existing property through the transformation into a media library and related commercial spaces and the construction of residential units to be leased through subsidized rents with commercial spaces located on the ground floor and the top floor of the building. Solution C_4 provides the mixture of different intended uses: a library and related services, exhibition and commercial spaces, a restaurant, student and private residential units and underground car parking spaces. Table 8 shows the three enhancement solutions and the

Table 5
Enhancement projects for the Arsenale Pontificio complex (CASE STUDY 1).

	Intended uses	Cash flow $(F_{t,ij})$ [€]	Realization cost (K_{ij}) [€]	Expected return on investiment (r) [%]
A_1	· Music school · Theater · Restaurant · Museum	269,244	1,911,347	7.00
B_1	· Commercial space · Bar/ restaurant · Library	328,659	2,276,105	7.50
C_1	· Commercial spaces · Dining options	873,262	4,007,131	10.50

Fig. 2. Arsenale Pontificio complex: current state and a possible enhancement solution.

Table 6
Enhancement projects for the former warehouse "Vittoria" (CASE STUDY 2).

	Intended uses	Cash flow ($F_{t,ij}$) [€]	Realization cost (K_{ij}) [€]	Expected return on investiment (r) [%]
A$_2$	· Interactive sports museum · Indoor and outdoor play areas	945,000	9,282,341	11.50
B$_2$	· Multifunctional sports centre · Nursing home · Commercial spaces	630,000	4,619,540	8.50

relative economic items, i.e. the cash flows, the realization costs and the expected annual returns. Fig. 5 shows the current state and a possible enhancement solution of the former police station "Porto Fluviale".

CASE STUDY 5: Former hospital "Santa Maria della Pietà"

Current state. The use of the structure as a psychiatric hospital definitively ceased in 2000. The original complex included forty-one hospital buildings, surrounded by a large park and connected to each other by a road network of about seven kilometers. Through the funds allocated to the Great Jubilee of 2000, five buildings of the compendium were refurbished, to be used as tourist accommodation and cultural activities. Some other buildings are abandoned and in an advanced degraded state.

Enhancement projects. The three enhancement solutions involve the buildings in total disuse. Solution A$_5$ provides the construction of a hostel with 51 total beds and 14 rooms, a restaurant, co-working spaces and a gym. Solution B$_5$ involves the realization of a digital arts museum, with adjoining a bar and a restaurant, a library and educational laboratories. Solution C$_5$ provides the realization of a hostel with 20 rooms, for a total of 70 beds, and related services such as a bar, a restaurant, a wellness center, a cinema arena with a capacity of 170 seats. Table 9 shows the three enhancement solutions and the relative economic items,

i.e. the cash flows, the realization costs and the expected annual returns. Fig. 6 shows the current state and a possible enhancement solution of the former hospital "Santa Maria della Pietà".

6.2. Results

The algorithm of the optimization model has been implemented to the five case studies by considering different weights for the two goals - maximization of the monetary compensation that can be required by the Public Administration and maximization of the total return on investment of the entire redevelopment initiative for the private investor - that define the objective function. In particular, the multiplicative coefficients *a* and *b* have been made to vary in order to obtain that the sum of them is always equal to the unit: these variations have generated a range of solutions that reflect the different importance given to each goal (public or private) of the objective function. In Table 10 the outputs obtained by the implementation of the optimization model have been reported, in terms of enhancement solution selected by the algorithm for each case study, maximum monetary compensation (N) for the Public Administration, total return on investment (R) for the private investor and total investment costs of the entire redevelopment initiative

Table 7
Enhancement projects for the former factory "Mira Lanza" (CASE STUDY 3).

	Intended uses	Cash flow ($F_{t,ij}$) [€]	Realization cost (K_{ij}) [€]	Expected return on investiment (r) [%]
A$_3$	· Food market · Restaurant · Cinema	420,000	2,598,760	10.50
B$_3$	· Restaurant · Bed & breakfast · Museum	375,000	2,004,532	8.50

Fig. 3. Former warehouse "Vittoria": current state and a possible enhancement solution.

Fig. 4. Former factory "Mira Lanza": current state and a possible enhancement solution.

Table 8

Enhancement projects for the former police station "Porto Fluviale" (CASE STUDY 4).

	Intended uses	Cash flow ($F_{t,ij}$) [€]	Realization cost (K_{ij}) [€]	Expected return on investment (r) [%]
A_4	· Restaurant · Training classrooms · Social housing · Conference room · Offices · Hydroponic greenhouse · Underground car park spaces · Media library · Commercial spaces	713,890	5,931,543	6.50
B_4	· Residential units to be leased through subsidized rents · Library · Exhibition spaces · Commercial spaces · Restaurant	1,062,000	9,062,248	8.00
C_4	· Student residential units · Private residential units · Underground car parking spaces	1,280,500	10,822,508	10.00

identified by the optimization model as the best combination of the enhancement projects.

The outputs of the application of the optimization model lend themselves to interesting considerations.

For a significant importance of the private goal compared to the public goal - $a = 0.1$ and $b = 0.9$ - the enhancement solutions that optimize the objective function are: C_1 for the complex of the Arsenale Pontificio, A_2 for the former warehouse "Vittoria", A_3 for the former factory "Mira Lanza", B_4 for the former police station "Porto Fluviale", C_5 for the former hospital "Santa Maria della Pietà". The maximum monetary compensation (N) that can be required by Public Administration and that is still financially sustainable for the private investor is equal to 12,186,500 €. The total return on investment (R) of the entire redevelopment initiative for the private investor is equal to 2,734,290 €, whereas the total investment cost of the enhancement solutions selected by the model is equal to 27,207,005 €.

For an increase of the importance of the public goal compared to the private goal, starting from $a = 0.3$ and $b = 0.7$, the optimization model identifies a new best compromise combination of the enhancement solutions for the five case studies: for the former factory "Mira Lanza", B_3 is the enhancement solution selected by the algorithm, whereas there are not variations for the enhancement projects assigned to the other properties. This change determines an increase of the maximum compensation N ($= 12,428,300$ €) and a reduction of the private return on investment R ($= 2,631,800$ €) and of the total investment cost of the redevelopment initiative ($= 26,612,777$ €). Furthermore, it should be noted that this combination is also preferred by the optimization model

if the two goals of the objective function are characterized by the same importance ($a = b = 0.5$).

A modification of the best combination is obtained for $a = 0.7$ and $b = 0.3$: in this case, A_5 is the enhancement solution selected for the former hospital "Santa Maria della Pietà", whereas there are not new variations for the other properties. The maximum monetary compensation obviously increases ($N = 12,562,400$ €), whereas the total private return on investment becomes lower ($R = 2,484,410$ €), with a total investment cost equal to 25,616,596 €.

Finally, for a high importance of the public goal compared to the private goal - starting from $a = 0.8$ and $b = 0.2$ - the new winner combination identified by the optimization model, that provides the selection of the enhancement solution B_2 for the former warehouse "Vittoria" without any variations for the other enhancement projects selected in the previous analysis, generates an increase of the maximum monetary compensation ($N = 12,746,100$ €) and a significant reduction of the total return on investment for the private subject ($R = 1,809,600$ €) and of the corresponding total investment costs ($= 20,954,095$ €).

The spider chart in Fig. 7 represents the Pareto-optimal frontier for the Public Administration and the private investor involved in the redevelopment initiative in analysis, by considering the different weights assigned to the two goals of the objective functions: in the graph, the variations of the maximum monetary compensation (N), the total return on investment (R) and the total investment costs of the entire redevelopment initiative have been normalized with respected to the maximum value obtained for each of them through the implementation of the model for the considered different weights of the two goals, and they have been reported for incremental values of the multiplicative coefficient a, to which decreasing values for the coefficient b are related. The consistent reductions of the values of the total return on investment R and of the total investment costs of the entire redevelopment initiative for the coefficient a higher than 0.7 - and the coefficient b respectively lower than 0.3 - are evident, while the corresponding increases in the maximum monetary compensation N are not very

Table 9

Enhancement projects for the former hospital "Santa Maria della Pietà" (CASE STUDY 5).

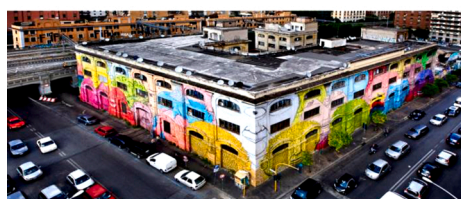|	Intended uses	Cash flow ($F_{t,ij}$) [€]	Realization cost (K_{ij}) [€]	Expected returnr on investiment (r) [%]
A_5	· Hostel · Restaurant · Co-working spaces · Gym · Digital arts museum · Bar	233,450	1,260,344	8.00
B_5	· Restaurant · Library · Educational laboratories · Hostel · Bar	182,450	1,537,110	7.50
C_5	· Restaurant · Wellness center · Cinema arena	350,000	2,256,525	11.00

Fig. 5. Former police station "Porto Fluviale": current state and a possible enhancement solution.

Fig. 6. Former hospital "Santa Maria della Pietà": current state and a possible enhancement solution.

Table 10
Outputs obtained by the implementation of the optimization model to the considered case studies.

| a	b	Arsenale Pontificio	Vittoria	Mira Lanza	Porto Fluviale	Santa Maria della Pietà	N [€]	R [€]	Total cost [€]
0.1	0.9	C_1	A_2	A_3	B_4	C_5	12,186,500	2,734,290	27,207,005
0.2	0.8	C_1	A_2	A_3	B_4	C_5	12,186,500	2,734,290	27,207,005
0.3	0.7	C_1	A_2	B_3	B_4	C_5	12,428,300	2,631,800	26,612,777
0.4	0.6	C_1	A_2	B_3	B_4	C_5	12,428,300	2,631,800	26,612,777
0.5	0.5	C_1	A_2	B_3	B_4	C_5	12,428,300	2,631,800	26,612,777
0.6	0.4	C_1	A_2	B_3	B_4	C_5	12,428,300	2,631,800	26,612,777
0.7	0.3	C_1	A_2	B_3	B_4	A_5	12,562,400	2,484,410	25,616,596
0.8	0.2	C_1	B_2	B_3	B_4	A_5	12,746,100	1,809,600	20,954,095
0.9	0.1	C_1	B_2	B_3	B_4	A_5	12,746,100	1,809,600	20,954,095
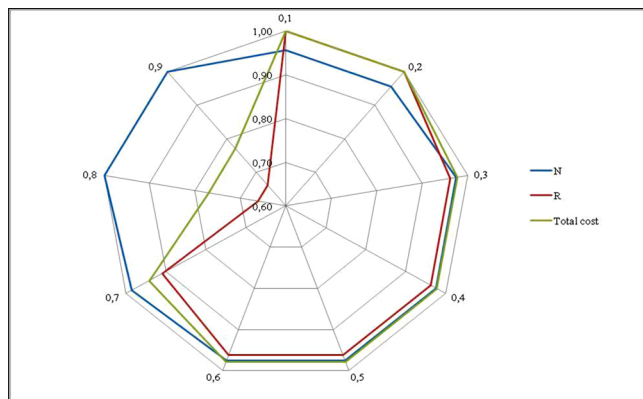
Fig. 7. Spider chart of the outputs obtained by the implementation of the optimization model.

relevant.

7. Discussion

The outputs obtained allow to point out the potential value and the limitations of the proposed model.

The five property assets considered - Arsenale Pontificio complex, former warehouse "Vittoria", former factory "Mira Lanza", former police station "Porto Fluviale", former hospital "Santa Maria della Pietà" - constitute cultural heritage of strategic interest for the urban, economic and social renewal of the central contexts of the metropolitan city of Rome. In the past, this issue has been dealt with in a dispersive and fragmented way. Using the proposed model, the local Public Administration will be able to plan the interventions in an integrated manner on a priority and gradual basis, and to avoid failures that could be caused by the inability of conventional methods to identify and accurately measure the repercussions and the private conveniences of the various initiatives.

This advantage is consistent with the objectives of numerous current international initiatives – e.g. the "Reinventing Cities" call, activated by the C40 Cities Climate Leadership Group -, aimed at regenerating the urban territory starting from the redevelopment of abandoned properties, in order to harmonize them with the existing building stock and to avoid further soil sealing.

The application to the context of the city of Rome has led to the selection of new functions for the properties considered, capable of constituting compromise solutions between the need to guarantee the convenience of the initiatives - that is the indispensable condition for their feasibility according to the private investor - and their riskiness. On the other hand, the Public Administration has the possibility of elaborating a clear framework of the private benefits of the initiatives, and therefore can suitably weigh the maximum burden - in monetary terms or through specific public works - that can be required to the private investor, without affecting the financial sustainability of the initiative. In this sense, the proposed model can constitute an essential tool in the negotiating phases that define the feasibility of the initiative. The model will allow *i)* to develop long-term strategies for the renewal of the city, *ii)* to represent a permanent tool of the local Public Administration, so as the public technicians can appropriately assess the consequences of the various renewal programs. It should be highlighted that, following the spread of the current pandemic (Covid-19), in the urban planning decisions the use of evaluation models able to support the identification of sustainable solutions and capable of enhancing their ability to adapt to "anomalous" changes of the scenarios initially assumed has become relevant, in order to assess and monitor the adaptability of the various projectual solutions to sudden socio-environmental shocks, even in consolidated economic contexts.

However, in the developed mathematical structure, the model does not properly evaluate the possible - positive or negative - correlations that could occur between the selected projectual solutions in the different property assets: for example, in the case of commercial spaces provided in properties very close to each other. Not by chance, in this work the model has been applied to the context of the city of Rome, characterized by a high demand - both from the community and the private investors - of new functions, and specifically to properties located in particularly "attractive" positions, where the considered intended uses for each projectual solution are all of particular interest. Applied to other contexts, the model may be suitably improved, through the inclusion of appropriate constraints which allow to avoid the selection of solutions that provide the proximity of very similar functions in the property assets to be enhanced. In fact, the simple structure defined has allowed to develop a flexible model and to avoid a "black box" tool: the model cannot replace experience and judgment of professional valuers, but it is a means of allowing these qualities to be more effectively focused on sectors that require the highest attention. The usefulness of the model can therefore be elevated by making appropriate

changes to the entry and exit data, and adding new constraints to the internal structure of the model itself.

Finally, further insights may concern the inclusion in the cash-flows, through a cost-benefit analysis, of the *social* value that the different functions have for the community (e.g. the value of a nursing home is not the same of a library for the community). In this case, the various interests of the parties involved must be appropriately weighed too, so as to guarantee the convenience of the initiative for the private investor, that represents the essential condition for the actual realization of the enhancement initiative in a PPP procedure: therefore, the flexibility of the proposed model will allow to adapt the Pareto-optimal frontiers function to the different points of view of the subjects considered (government, private investors, banks, communities, specific stakeholders, etc.).

8. Conclusions

In the last decades, due to public budget constraints and higher expertise skills of private companies in the investments' realization and management, the adoption of procedures carried out through the public-private cooperation has been finding wide application in many countries. In this research, we propose a model that helps to define the optimal combination of novel uses in public properties to be enhance through the involvement of the private subjects. This model represents an answer to the need for effective strategies to find new functions for disused buildings or abandoned areas.

The model has been applied to five case studies located in the city of Rome (Italy), constituted by public properties to be improved and exploited through an enhancement concession procedure. The solutions defined by the optimization model, that implements an algorithm based on the goal programming logics, allow to maximize the financial conveniences of the subjects (Public Administration and private investor) involved in a redevelopment initiative that includes several property assets and different eligible enhancement projects for each of them. Furthermore, the simplification of some phases of a traditional DCFA provided by the proposed model reduces the possibility of manipulating the parameters of the valuation that could be aimed at demonstrating the validity of the project and ensuring its approval.

The Pareto-optimal frontiers obtained by the introduction of different weights for the goals that define the objective function of the algorithm allow to explore the strengths and the weaknesses of the possible combinations of the enhancement solutions: among them, the Public Administration and the private investors can identify the macrosolutions that better satisfy the public requests to advance, the importance and the urgency attributed to specific interventions, the risk appetite of the private operator. The spider chart of the redevelopment initiative has pointed out that the range of the macro-solutions for different weights of the subjects involved goals is characterized by a limited variation of the maximum monetary compensation for the Public Administration, and by a significant reduction of the total return on investment for the private operator and of the total cost of the redevelopment initiative, if the importance of the public goal is predominant respect to the private one. In this case, in the negotiation phase, the Public Administration could also accept a macro-solution that is more favorable for the private investor in terms of the total return on investment, guaranteeing anyway a substantial public convenience of the redevelopment initiative.

The outputs generated by the optimization model constitute a valid support for Public Administrations in all the phases that define an enhancement concession procedure. In fact, in the preliminary phase of the project assessments, the model allows to elaborate a priority list of combinations of the new functions, sorted by the maximum compensation that can be required to the private investor. In the negotiation phase for the contractual agreements, the model provides a transparent quantification of the financial convenience of the private investor for each macro-solution, establishing the maximum public request for the additional and financially sustainable burden that could be used for the local community. Then, in the monitoring phase, the flexibility that characterizes the optimization model allows to be adapted to the market changes that may arise over time, then the occurred market conditions can be considered in the model, in order to adequately adapt the enhancement concession agreements to the new economic situations. On the other hand, the private investor can implement the optimization model to assess the conveniences for different combinations of the enhancement solutions, outlining the investment risks and the best macro-solutions in relation to the current market conditions. Therefore, the proposed optimization model can constitute an important driving force for the effective networks of territorial investments, considering the difficulties of long-term duration of single interventions on the public property assets (especially the cultural ones), that often represent investment decisions totally disconnected from the territorial economic context in which they were realized.

Finally, the optimization model can be also used in the tendering processes, when the enhancement solutions are proposed by different bidders for each property asset: in this case, the model allows to define a double financial criterion that simultaneously takes into account the conveniences of both the Public Administration and the private investor. This result, integrated by further environmental and social criteria introduced by the Public Administration, can help to reduce the complexity and the costs that generally characterize the conventional bidding procurements in which the public subject and the private one are involved (Birnie, 1997; Dudkin and Välilä, 2006).

The policies for the urban regeneration of abandoned areas and the enhancement of the property assets represent a current and relevant issue. The scarce financial resources of Public Administrations require a careful and adequate selection of the territorial initiatives to be implemented, for which effective valuation tools are mandatory. Therefore, appropriate assessment tools as the model developed in the present research can direct the planning processes towards informed, effective and profitable choices in the medium-long term for the local communities. In this context, the role of a competent valuer is cogent from the earliest stages of the design, in order to verify its economic feasibility, to highlight the strenghts and the weaknesses and to exclude the projects characterized by potential threats.

Author statement

The paper is to be attributed in equal parts to the Authors. F. Tajani, P. Morano and F. Di Liddo have conceived, structured and written the paper in equal parts, as well as they have deepened the review and the editing of the paper.

Note

The paper is to be attributed in equal parts to the authors.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.105050.

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