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The Effective Use of National Recovery and Resilience Plan Funding: A Methodological Approach for the Optimal Assessment of the Initiative Costs

Francesco Tajani [1,*], Felicia Di Liddo [2] and Rossana Ranieri [1]

[1] Department of Architecture and Design, Sapienza University of Rome, 00196 Rome, Italy
[2] Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari, 70126 Bari, Italy
* Correspondence: francesco.tajani@uniroma1.it

Abstract: With reference to the National Recovery and Resilience Plan (NRRP), the financial budget provided for a specific project constitutes a fundamental constraint to be taken into account in the selection phase of the initiatives to be carried out. In the present research, a methodological approach based on an optimization algorithm that allows one to minimize the differential between the assessed costs and the budget provided for the project, has been defined. The methodology is organized in three phases and, by borrowing the logic of the Operational Research, aims to minimize the gap between the costs assessed by the expert technician and the final costs, in order to fit the preliminary set budget. In this sense, the developed tool constitutes an effective support for Public Administrations and private investors for choosing the investments to be implemented, in order to identify the best initiatives in which to allocate the public funding, by preventing needless waste of limited financial resources that could be invested in alternative interventions, and to generate further benefits for the communities.

Keywords: construction costs; costs assessment; NRRP; methodological approach; budget of the project; optimization algorithm

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1. Introduction

Within the project life cycle, the assessment of the construction costs is included in several steps, from the first phase of project idea conception to the final phase of its disposal, with different purposes. In this sense, the ex ante evaluation of the intervention costs aims at determining the most likely expenses associated with the different operations of which the initiative is composed; the ongoing or in itinere evaluation intends both to determine the costs of the work variants during construction, and to verify the costs for ensuring the down payments at each step of the workings; the ex post evaluation aims to verify the adequacy of the costs incurred, and to assess the costs of the physical and functional adjustments.

With reference to the different subjects involved in the construction process, the goals for which the construction cost assessment is implemented are multiple: (i) for the client (contracting authority in the cases of public works), the determination of the expenditure order of magnitude, the definition of the financial plan of the works and the determination of the monetary amount to be considered for the awarding contracts; (ii) for the company, the quantification of the bidding in the tender, the determination of the payments plan and the organization of the building site and the succession of operations to be carried out; (iii) for the designer, the comparison between the project alternatives for the choice of the "best" project and the calibration of the best solution by balancing needs, requirements and performances in line with the budget constraint.

By taking into account the goals for which the assessment is developed, the subjects implement different tools for determining the construction costs, which are official price lists or price analysis for the client and their own price lists for the companies.

In this way, the contracting authority formulates a “generally valid” value judgment-based on the prices included in the lists normally used in the reference market, in which the amounts are derived considering the normal skills of an ordinary entrepreneur operating in the specific market. On the other hand, the company draws up a “specifically valid” judgment, strictly correlated to its own skills and specificities on the basis of its own price lists.

Within all phases of the project, the intervention costs valuation plays a central role and, simultaneously with the progressive increase in the detail of the different stages of the conception and subsequent design, the ex ante assessment is improved, becoming more precise and reliable.

In the Italian context, starting from a roughly broad summary estimation in which the overall cost order of magnitude and the amounts related to the main categories of the works to be carried out are determined, the three design levels admit a progressively decreasing error tolerance concurrently with the greatest project detail level and the improvement of the tools used to assess the costs. In fact, the art. 23 of the Public Works Procurement Code Legislative Decree No. 50/2016 [1] governs the articulation of the design according to three levels of subsequent technical in-depth analysis, in the *technical and economic feasibility project*, the *definitive project* and the *executive project*. Then, it clarifies the main goals that, in general terms, the design process intends to pursue in terms of: (a) meeting the needs of the community; (b) architectural and technical functional and relationship quality in the reference context; (c) compliance with environmental, urbanistic and protection for cultural and landscape asset standards, and with the provisions of the legislation on the protection of health and safety; (d) limited land use; (e) compliance with hydrogeological, seismic and forestry constraints as well as other existing constraints; (f) energy saving and efficiency in the construction and subsequent project activity as well as the assessment of the life cycle and maintainability; (g) compatibility with pre-existing archaeological sites; (h) rationalization of design activities and related checks through the progressive use of specific electronic methods and tools such as modeling for buildings and infrastructures; (i) geological, geomorphological, hydrogeological compatibility of the work; (j) accessibility and adaptability in accordance with the provisions in force on architectural barriers.

Therefore, the assessment of public project construction costs blindly follows the increase in technical detail that characterizes the different design levels. From a synthetic assessment, the analytical cost quantification is carried out by implementing the Metric Estimative Computation procedure, i.e., by associating the unit prices taken from the official regional price lists to the quantities of the different processing categories envisaged by the project.

In this sense, according to the Italian legislative reference, the definitive project is aimed at fully identifying the works to be carried out, in compliance with the needs, criteria, constraints, addresses and indications established by the contracting authority, for the required authorizations and approvals issue, the definitive quantification of the cost limit for the construction and the relative time schedule.

The executive project is intended for determining, in detail, the works to be carried out and the relative expected cost, in order to identify each intervention element in terms of form, typology, quality, size and price.

These two design steps provide for the analytical estimation of the construction costs to obtain a more precise ex ante evaluation of the costs to be incurred for the implementation of the initiative.

The first design level, instead, consistently with the limited in-depth analysis of the developed documents, includes the summary costs estimation, carried out starting from the costs of similar interventions performed in an adjacent spatial horizon (i.e., close to the intervention area) and in a recent period to that of evaluation. The contents of the technical and economic feasibility project have been defined by the guidelines of the Superior Council of Public Works approved on 29 July 2021 and, currently, referred to the elaboration of the technical and economic feasibility project for the award of contracts of National Recovery and Resilience Plan (NRRP) and National Plan of Complementary Investments (NPCI) works and interventions [2].

In the context of the Next Generation EU [3], aimed at promoting a "sustainable, uniform, inclusive and equitable recovery" following the crisis caused by the COVID-19 pandemic, in Italy, the NRRP definitively approved the Council's Implementation Decision on 13 July 2021 [4]; this provides a synthetic framework of reforms and measures to be implemented from 2021 to 2026 within the six pillars identified in the European Green Deal [5], i.e., green transition, digital transformation, social and territorial cohesion, health, policies for the next generation and sustainable, smart and inclusive growth.

The Italian NRRP foresees investments for a total of EUR 222.1 billion, of which EUR 191.5 billion are financed by the European Union through the Recovery and Resilience Facility (68.9 billion are non-repayable grants and 122.6 billion are loans), and a further 30.6 billion of national resources are part of a complementary fund, financed through the multiyear budget variance. In Figure 1, the summary of the structure of NRRP with the identification of the six investment sectors and the set monetary amount provided for the national plan, is reported.

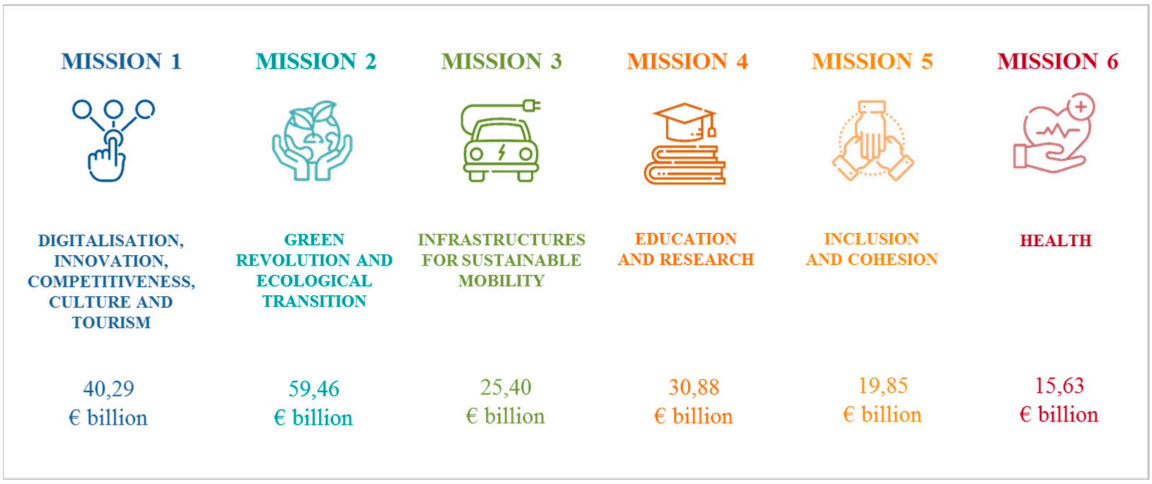

Figure 1. Summary of the NRRP structure.

In the context of the mentioned six main strategic missions upon which the national plan is developed, the construction sector plays a fundamental role in the success of the NRRP and the planning of effective investments is a fundamental aspect to be considered for an efficient use of the funds allocated. In this sense, relevant importance has been attributed to the technical and economic feasibility project which, according to the provisions of the Simplification Decree of 2021 (Law No. 108/2021 [6]), can constitute the document on the basis of which to entrust the executive design and execution of the works financed by the NRRP and the NPCI.

Currently, the guidelines for the drafting of the technical and economic feasibility project represent the only reference that defines the contents of this design level document: hence, its importance overcomes the NRRP projects context. Among the 19 documents in which this design level is divided, the project costs assessment has to be implemented through an estimative computation, in relation to the intervention size, typology and category. In particular, the reference guidelines specify that the analytic costs estimation replacement with an adequate synthetic one, able to justify the adequacy and appropriateness of the assessed costs, is allowed.

Within the phases of the project, an effective assessment of the intervention costs in all the stages assumes a significant role in avoiding, as much as possible, (i) the failure of initiatives to be implemented in the territory, deriving from the occurrence of unexpected events that cause the unforeseen increase in costs, and (ii) the transformation initiative start-up and subsequent interruption associated with incorrect ex ante costs assessments not validated during the construction.

In the framework outlined and focused on the development and the selection of initiatives to be financed through the NRRP funding, the ex ante, in itinere and ex post valuations of the construction costs allow one, respectively, to adequately estimate the project costs in relation to the fixed expenditure budget, to monitor the costs progressively incurred with those estimated and determine the variants monetary amounts and to verify the congruity of the costs paid with those assessed, in order to effectively use the available and limited resources.

In the context of the NRRP, the role played by the urban requalification is crucial: in fact, Mission 5 Component 2 (Investment 2.1), entitled "Investments in urban regeneration projects, aimed at reducing situations of marginalization and social degradation", concerns the projects regarding (i) the reuse and the refurbishment of existing public areas and buildings, including the demolition of structures illegally carried out by private individuals in the absence of, or total divergence from, the building permit, (ii) the improvement of the quality of the urban decor and of the social and environmental tissue, (iii) the development of social and cultural, educational and didactic services, (iv) the promotion of cultural and sporting activities. In this sense, the initiatives aimed at the rehabilitation of occupied/built up urban areas are included among the most relevant territorial management mechanisms: conscious land use involves the definition of urban planning strategies that promote the renovation of the exciting property asset (real estate enhancement) and the functional reconversion of degraded and underused areas (urban regeneration). Within the decision processes for the development of effective territorial policies, the assessment of intervention costs represents a key step for the successful initiatives implementation: in the mentioned topic, the "Monumental Budget Busters" represent a considerable phenomenon that concerns the overbudget construction projects, both in terms of duration and required amount of money, for which an "inadequate" or "unreliable" preliminary intervention cost assessment had been carried out. In the precious opportunity given by the PNRR, these situations should be avoided, in order to properly use the financial resources and to generate important benefits for the communities.

2. Research Objectives

The increasing need to define assessment tools and techniques able to support decision-making processes in the optimization of the allocation of foreseen financial resources and in the design and selection of projects highlights the role of the evaluation to orient Public Administrations in planning choices.

The compliance with the fixed financial constraint constitutes a fundamental issue in the preliminary intervention costs evaluation, connected to the cogence to carry out "high quality" projects. Thus, the variation between estimated costs and incurred costs, possibly due to in itinere variants, should not cause the lowering of performance level of the design solution (e.g., in terms of materials, constructive techniques and decrease in technological and qualitative standards). Within the scientific debate on the valid use of NRRP funding allocated for the urban requalification, the use of assessment tools for the "appropriate" compliance with the project budget determines the urgency to define effective methods for the optimal assessment of the initiative costs, able to provide a reliable reference in the ex ante evaluation phases.

In this perspective, the present research proposes a methodological approach that intends to facilitate the definition and the calculation of investment costs in the technical and economic feasibility projects level, as provided by the legislative references in force in the Italian context, in particular by the Procurement Code. The aim of the research is to highlight the key role played by the assessment discipline—during the first design phases—in the determination of the total costs, that have to be consistent with—and as close as possible to—the expenditure budget provided by the Public Administration. For this goal, an optimization algorithm that borrows the logic of the Operational Research is defined, that allows one to minimize the differential between the costs assessed by the expert technician and the a priori budget of the project. Given the set cost limit, for each category of work, the developed methodology allows one to reduce, as much as possible, the gap between the costs derived from official price lists taken as a reference for the assessment and the final costs.

The potentialities of the proposed assessment tool, firstly, concern the disaggregation of the project into single work categories, whose costs are optimized by implementing the developed methodological approach. This aspect represents an important innovation of the methodology: in fact, in the reference literature there are several applications of methods for the optimization of the cost assessment. The algorithm of Branch and Bound (B&B) [7–10] is an example of these methods: in particular, starting from a set budget to be divided among different projects to be carried out on the territory, the algorithm allows one to identify the initiatives for which the difference between the set budget and the sum of the respective total intervention costs is minimized. In this sense, the B&B algorithm allows one to determine only a priority list of the interventions, whereas the reliability of the costs assessed for each considered project is not verified.

Conversely, the methodology proposed in the present research optimizes the costs of each work categories, in order to carry out a reliable assessment of the intervention costs in the preliminary phase and to allow their remodulation according to the fixed budget and the reference official price lists.

With reference to the city of Rome (Italy), two urban regeneration projects related to public housing (*Tor Bella Monaca*) and public community services (*Santa Maria della Pietà* monumental complex) are selected as case studies. Specifically, following the identification of the relevant consistencies of each intervention, the main categories of works are determined. Then, for each of these, the construction costs are assessed by consulting the official reference price lists ordinarily used by local market operators. The application of the optimization algorithm makes it possible to verify the consistency between the estimated construction costs and the preliminarily set budget, by aiming to the effective management of available financial resources.

In the context of the funding allocated by NRRP for urban redevelopment, the proposed methodological approach represents a valuable support for the decision-making processes of Public Administrations, as it is able to define optimal modalities of using the available monetary resources. Furthermore, the model could facilitate the selection phase of the projects most consistent with the objectives of the plan and capable of determining greater benefits for the community. With reference to private entities, the optimization tool can be used to verify the feasibility of the investment, given an initial expenditure budget, the different categories of planned work and project consistencies. In this sense, the analysis points out the valuer role in the successful transformation initiative since the early design phases within the project life cycle. The valuer is able to assess the intervention costs by consulting valid and consistent sources, in order to define feasible and profitable solutions and to avoid failures and waste of significant economic resources. Therefore, the strong relationship that should be established between the design and the evaluation phases clearly emerges with the purpose to adequately use public funding. In addition, it highlights the increasing need to reach the interdisciplinarity among the different issues involved in a planning process. Moreover, already in the technical and economic feasibility project, several feasibility aspects (technical, environmental, financial, economic, procedural) are considered and explored in order to provide an overall analysis of the project and to identify any critical issues that do not ensure the convenience of the initiative. It is evident that the intervention cost topic assumes a relevant importance for the development of the next design levels, as the set budget constitutes a limitation and an essential condition to be taken into account.

The structure of the paper is organized as follows: in Section 3, the background related on the cost assessment method is illustrated; in Section 4, the methodology proposed in the paper is explained; in Section 5, the case studies related to the two urban regeneration projects referring to the *Tor Bella Monaca* public housing compendium and the *Santa Maria della Pietà* monumental complex are reported, and a concise framework of the funding provided for the city of Rome aimed at describing the context in which the case studies are included is outlined, the application of the optimization algorithm is discussed and the outcomes are presented. In Section 6, the conclusions of the research are drawn, and potential future developments are listed.

3. Background

During the recent decades, the need to implement accurate and robust cost assessments has been growing and closely linked to the requirement to effectively use the scarce national economic resources available to public entities, to adequately invest European funding and the financial resources of private partners involved in initiatives aimed at the urban territory development.

The thorough project cost assessment has been known as a major challenge that could influence project performance and its ultimate success: in this sense, a valuer needs to have expertise in converting the early scope of the project into costs [11], especially with reference to the different levels of project progress.

The risks of exceeding the costs paid compared to the estimated costs are very frequent in the construction sector, and an effective cost control process should allow one to limit significant differentials between the two cost items (assessed costs and incurred costs). This is also associate to the need to minimize the uncertainty related to cost variations and/or the occurrence of new unforeseen operations, to which significant increases in costs may be connected. The analysis of the risks associated with an increase in the project costs is performed to identify likely mitigation measures of the risks [12]. It is clear that the cost overrun, i.e., the increase in project cost that causes high variation compared to the estimation results and to the fixed budget, can significantly reduce the feasibility of the entire initiative. In the framework pointed out, the intervention global cost analysis—often used interchangeably with the term project life cycle cost [13,14]—and the cost monitoring in all the project phases represent essential steps for financial planning and management and for the determination of the resource requirements and budgets.

Furthermore, the cost assessments can orient the intervention implementation modalities, allowing one to select those that are consistent with the established spending limits and to reject the design solutions that are not convenient as too expensive (the so-called "white elephant" investments) [15–17].

With reference to the NRRP resources, the cogency to increase the quality of cost estimates through improved consistency and transparency of methods, assumptions and reporting, is currently predominant, and is strongly linked to the need not to waste the allocated resources, but to use them in the best possible way.

In general terms, the cost represents a fundamental element for the development of all the chosen processes, starting from the first phases of the building cycle up to its conclusion, at different scales. An accurate cost analysis is based on information data quality and long-term forecasts, indicating that data uncertainty is very often associated with Life Cycle Cost (LCC) methods [18–21], due to the limited level of detail that concerns the first design steps in line with the still not in-depth technical project definition. In fact, the scarce availability and reliability of the input data that usually characterizes the early stages of a project cycle in which the technical study of the project is limited, increases the uncertainty of the output [22].

To the lack of reliable information, among the main reasons for the uncertainty of the estimated costs, Sesana and Salvalai [23] have added the difficulty of predicting temporal factors over a long period (future operating, maintenance and demolition costs and discount rates and inflation rates). In addition, the authors have identified the variability of construction costs of the same component or material (depending on the company, quantity and availability in the specific context, etc.) as a key factor to be taken into account. In this sense, the uncertainty is endemic to Whole life Cost (WLC), as, by definition, it deals with the future, which is unknown. This contingency is worsening by the difficulty in obtaining the appropriate level of information and data and, thus, various risk assessment techniques applicable to WLC (sensitivity analysis, probability-based techniques, fuzzy approaches, etc.) have been mostly implemented in order to assess the uncertainty in WLC modelling. In accordance with this goal, Ilg et al. have provided a comprehensive overview of the uncertainties in LCC [24], by systematizing the uncertainty types and concluding that their variety makes it difficult to provide a simple and meaningful categorization [25]. To overcome the problem of unreliable and inconsistent data, El-Haram et al. [26] have developed a framework for collecting WLC data in building projects, and Wu et al. [27] have analyzed the impact of reliability on the improvement of WLC performance.

In the situations with different project alternatives, the WLC represents a valid support tool in the decision-making processes, and, although the approach can be conducted at any stage of the project, the potential of its effective use is maximum during early design stages, mainly because most, if not all, options are open to consideration [28,29].

It should be outlined that, in the referenced literature, the WLC is described as a wider notion than LCC; therefore, vice versa, the LCC can be considered as part of WLC, as the LCC is defined as costs of an asset or its parts throughout its life cycle, whereas the whole life costs concern all significant and relevant initial and future costs and benefits of an asset throughout its life cycle [30]. In this sense, the LCC methodology focuses exclusively on costs, whereas the WLC approach covers both costs and benefits during the lifetime of a project, and includes other costs, such as non-construction cost. The RICS professional guidance [31] clarifies the difference between LCC and WLC, by pointing out that LCC focuses only on the construction, maintenance, operation and disposal of the asset, whereas WLC also includes client and user costs, such as project financing, land, income and external costs (those not born by parties to the construction contract–such as tenants). However, the guide highlights that the same rules and procedures can be applied equally to WLC and LCC.

In brief, with reference to the life cycle of a project, the Life Cycle Costing Analysis (LCCA) represents an evaluation method. It allows one to determine the overall intervention costs, taking into account the investment costs (intervention preparation/promotion, site inspections, design, land acquisition and related legal, notary and administrative expenses, clean up and/or reclamation, construction, expenses related to the sale and/or lease, marketing, etc.) and all the costs that be incurred for its use (the operating costs of management and ordinary and extraordinary maintenance and of operation and replacement), including end-of-life costs, for example, those related to the disposal of the asset, or the residual value, positive or negative, that the asset has at the end of its useful life.

The main goal of LCCA implementation concerns the assessment of the project costs related to alternatives, in order to select the project solutions able to ensure the lowest overall cost consistent with its quality and function. Thus, during the last few decades, the WLC approach has considerably diverged from the traditional practice, according to which the construction investment and procurement decision were based on initial capital costs [32]. Currently the choices are addressed towards the design solutions characterized by higher initial costs and lower management costs. It is evident that an inverse functional correlation between the construction costs and the operating costs is established: the more accurate and detailed the design is, the higher construction costs and savings in the management phase will be.

An effective decision-making process that includes the life cycle costs among the "choice criteria" proposes that the LCCA should be performed early in the design phase, while there is still a chance to refine the design to ensure a reduction in costs [33].

The life cycle cost performance is regulated by Section 5—entitled "Buildings and constructed assets. Service life planning"—of the ISO 15686-5 standard [34], in which requirements and guidelines for the development of the economic evaluation technique of a new construction or an existing asset, by considering both immediate and long-term costs and benefits, are included. The relevance of the LCCA concerns the support provided by the analysis for design choices in various contexts, from individual products or components, to the entire building system, to an entire new construction project and to a renovation project of an existing property [35–37].

In theoretical terms, in fact, the LCC methodology aims at orienting the assessment of the economic benefits associated with the initiative, addressing the choice of the solution with higher initial cost and lower maintenance and management costs. Through this methodology, the single design solution is analyzed or the different project alternatives, in terms of materials and technological solutions, are assessed, in order to determine different costs in the building life cycle ant to guide the selection processes. Based on the goals of the parties involved in transformation operations (ex novo realization, property enhancement, energy retrofit, urban redevelopment, etc.), the LCCA should be implemented from the early stages of planning, to avoid costs for any future redesign [38]. The analysis should be adapted to the different steps of the project life cycle for the costs forecast, the alternative solutions analysis, the short-term costs estimation and the cycle cost management identification [39–42].

In 2007, The National Audit Office [43] published a guide for the implementation of a whole life costing analysis, identifying among the fundamental principles on which the success of a construction contract is based, the active participation of the client during all phases of project design, construction and management.

In the existing literature related to the concept of computation in decision-making mechanisms, the automation processes have been very often implemented for the determination of the market value (property valuation) [44–47]. However, the assessment of the cost value has been less studied in this way. The present research intends to fill the current gap, by defining a methodological approach for the optimal assessment of the initiative costs, given the fixed budget and the disaggregation of the projects into work categories.

4. Method

In order to define the methodological approach aimed at minimizing the differential between the estimated construction costs and the set project budget, the computational three-phase articulation is explained:

Phase (1) the analytic description of each single initiative into work categories, for which the quantities and relative units of measurement must be defined;

Phase (2) the assessment of the construction costs of each single work category, by consulting appropriate official price lists (named "official costs");

Phase (3) for each work category, the comparison between the official costs and those determined through the implementation of the optimization algorithm (named "optimal costs").

In Figure 2, a summary of the method operative logic is reported.

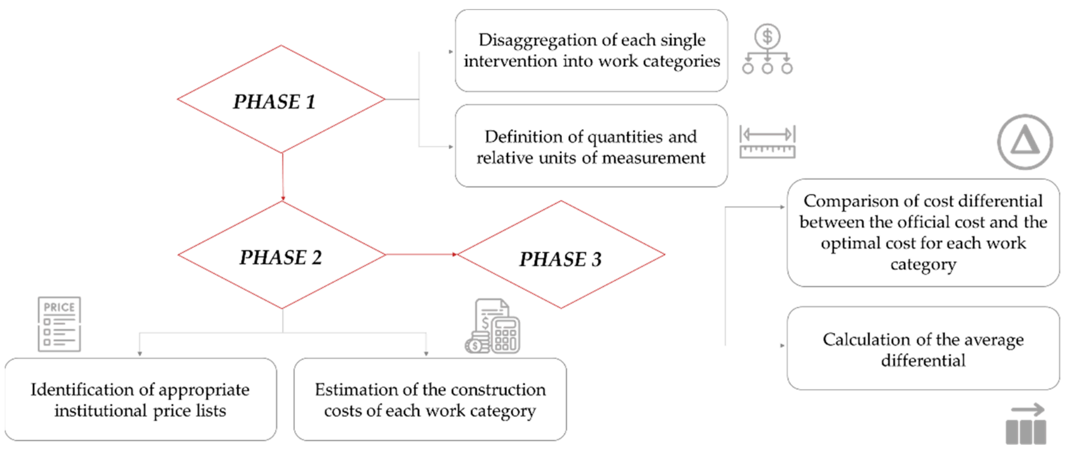

Figure 2. Computational phase articulation of the assessment method.

The proposed model borrows the operative logics of goal programming techniques, which support the definition of the optimal allocation of scarce resources that can be utilized for alternative uses. In this sense, a goal programming problem is characterized by the (i) resources available in limited quantities and for which different uses are provided (variable); (ii) constraints to the use of resources; (iii) objective functions, in order to assess the contribution that any possible use of resources contributes towards achieving a fixed objective [48].

In the case in which n available resources can be utilized for z possible uses, with f assumed to be the return function to minimize (min) or maximize (max) in line with the decision maker goal, and $a_1, a_2, a_3, \ldots, a_z$ allocated as the variables that represent the possible uses of the resources, the mathematical form can be defined as follows:

$$\min(\text{o} \max) f\ (a_1, a_2, a_3, \ldots, a_z) \tag{1}$$

The constraint system to achieve the objective can be summarized as shown in (2)

$$\begin{aligned} x_{11}a_1 + x_{12}a_2 + \ldots\ x_{1z}a_n &\le b_1 \\ x_{21}a_1 + x_{22}a_2 + \ldots\ x_{2z}a_n &\le b_2 \\ x_{n1}a_1 + x_{n2}a_2 + \ldots\ x_{nz}a_n &\le b_n \end{aligned} \tag{2}$$

In detail, by indicating with x_{ij}—whereby $i = 1, \ldots, n$ and $j = 1, \ldots, z$—the absorption rate of the i-th resource in the j-th use are considered unified, with b_i representing the amount of the i-th available resource, $\Sigma\ x_{ij}a_i \le b_i$.

With reference to the present analysis, for the model, the resources in limited quantity are the available monetary amounts, the alternative uses are identified by the different work categories in which the entire initiative can be analytically divided, and the constraint is represented by the preliminary set budget provided for the project. The objective concerns the simultaneous compliance with the budget and the fulfilment of the adequate quality standards of the final project, in order to ensure the high intervention level.

For the purpose of structuring the optimization algorithm, the main components to be considered in formalizing the mathematical expression of the developed methodological approach are defined and listed below:

C_i = the construction costs of the i-th initiative;

$D_i = a_i \cdot C_i$ = the indirect costs of the i-th initiative;

a_i = incidence of indirect costs (contingency, technical expenses, VAT), determined in percentage on the construction costs;

n = the number of initiatives to be financed;

$B_{TOT} = \sum_{i=1}^{n} (C_i + D_i)$ = the total provided budget;

q_{ij} = the quantity related to the j-th work category of the i-th initiative;

k_{ij} = the unitary official cost, i.e., the unitary construction cost of the j-th category of work of the i-th initiative, estimated from institutional price lists;

k^*_{ij} = the unitary optimal cost, i.e., the unitary construction cost of the j-th work category of the i-th initiative (variable of the model);

m = the number of work categories (different for each i-th initiative).

In Table 1 the summary of the variables, constraints and objective function of proposed algorithm is reported.

The optimization algorithm, which is able to define compromise solutions between architectural design and the expenditure budget, should be determined for each category of work, such as to preserve the aim of the planned quality of the initiatives.

It should be observed that, in the situation where for each i-th initiative a specific budget is planned, for each of them the algorithm will be implemented; otherwise, the indexation with "i" and the corresponding summation disappear, and only the indexation in "j" remains.

Table 1. The optimization algorithm.

Variables	k^*_{ij}
Constraints	$\sum_{i=1}^{n}\sum_{j=1}^{m}\left[(1+a_i)\cdot\left(k^*_{ij}\cdot q_{ij}\right)\right] \leq B_{TOT}$
	$0 < k^*_{ij} \leq k_{ij}$
Objective function	$\min \sum_{i=1}^{n}\sum_{j=1}^{m}\left(k_{ij} - k^*_{ij}\right)$

The main advantages of the developed methodological approach concern, firstly, the ease and flexibility of the tool application in any geographical national context and for different goals, due to the computational three-phase articulation. Moreover, the method can be used for the rapid verification of the intervention costs and their remodulation in order to fit the preliminary set budget, starting from the disaggregation of total investment into work categories and "acting" on each of them for the optimization of the initiative costs.

5. Case Studies

Within the NRRP goals, and with particular reference to the capital of Italy (the city of Rome), the need to activate processes for the recovery and the function reconversion of degraded and unused urban areas is central and strongly considered in the political and scientific debate for the definition of territorial planning policies and practices.

Furthermore, in recent years in the metropolitan area of Rome, numerous urban transformation initiatives have been planned, given the increased funding, amounting to about EUR 8.2 billion [49]. In addition to funds from the NRRP, the city of Rome will benefit from investments for the organization of the Jubilee 2025 [50] and the likely EXPO in 2030 [51]. The investments will affect all areas of the city and will concern several initiative typologies: e.g., road infrastructure, public transport, management of water resources, improvement of the maintenance conditions of existing property asset (both residential and non-residential) [52].

With reference to the NRRP, the plan is divided into 16 components, grouped into six missions. In fact, in the implementation of Mission 5 Component 2 (M5C2; social infrastructure, families, community and third sector) and of the "Integrated Plans" project strategies, the Decree Law No. 152 of 6 November 2021, converted into Law No. 233 of 29 December 2021 [53,54], allocates funds up to a total of EUR 2493.79 million for the period 2022–2026 and, in particular for the metropolitan city of Rome, assigns EUR 330,311,511 for the same years. The specific investment, M5C2, is aimed at improving the suburbs of the metropolitan cities and, in general, large urban areas characterized by a relevant state of decay and degradation, in order to introduce new services for communities and to upgrade logistics infrastructures, by transforming the most vulnerable territories into new sustainable areas of "smart cities". Furthermore, the initiatives provided for by Article 21 of Decree Law No. 152 of 2021, with amendments by Law No. 233 of 2021, pursue the following goals: i) to encourage better social inclusion by reducing marginalization and situations of social decay; ii) to promote urban regeneration through the eco-sustainable recovery of buildings and public areas, the energy and water efficiency of existing property asset and the reduction in soil consumption; iii) to support projects related to smart cities, with particular reference to transport and energy consumption. In order to strengthen the initiatives for the Integrated Plans, within the "Resilience Italy Fund", an additional EUR 272 million has been allocated for the implementation of the strategies referred to in the Integrated Plans for municipalities projects. This fund, which is to be managed in the context of the European Investment Bank, aims to attract private financing for urban regeneration projects. The main goal is to promote the development and implementation of long-term urban investments, by creating new and alternative lending channels and innovative models for urban transformation projects, combining public resources with private resources [55].

In the context outlined, the metropolitan city of Rome should identify, within the limits of the resources allocated, the projects that can be financed. In this sense, the projects should present an opportunity to regenerate the territories and, consistently with the international sustainability objectives, to improve the quality of life and the resilience level of the city ecosystems. In particular, the first criterion to be considered in the decision-making processes regards the compliance with the legal limit of the Index of Social and Material Vulnerability [56,57]. The Index is a summary measure of the level of social and material vulnerability calculated for the Italian municipalities, capable of expressing different aspects of multidimensional natural phenomena with a single value in order to facilitate territorial and temporal comparisons and the monitoring of socioeconomic issues. The second criterion concerns the existence of a widespread and integrated multiyear planning of public and private interventions where the realization of public works related to the implementation planning tools has not been completed, or is unimplemented for lack of public resources, or for the lack of private interventions activation.

The interventions to be selected must be fully consistent with the strategic axes of the NRRP and the goals of the 2030 Agenda [58], and they are aimed at the sustainable development of the city.

As mentioned before, in the present research, the application of the defined optimization algorithm to two different projects to be realized in the city of Rome is carried out. The two urban regeneration interventions were selected according to the criteria for the selection of the projects among those proposed, and they are consistent with those provided for the NRRP funds. The two initiatives considered are located in two different city of Rome portions: the *Santa Maria della Pietà* monumental compendium in the northwest of the city, and the public housing asset of *Tor Bella Monaca* in the east of the city of Rome. In Figure 3, the localization of the two urban transformation areas is shown. Currently, the redevelopment projects in the two areas have already been defined: through the allocated funds, they will be integrated, and the realization process will be implemented. The finalization of the considered projects will allow one to take significant benefits from the NRRP funding uses, by assigning them to two important and densely populated city areas that, currently, need to be totally restored.

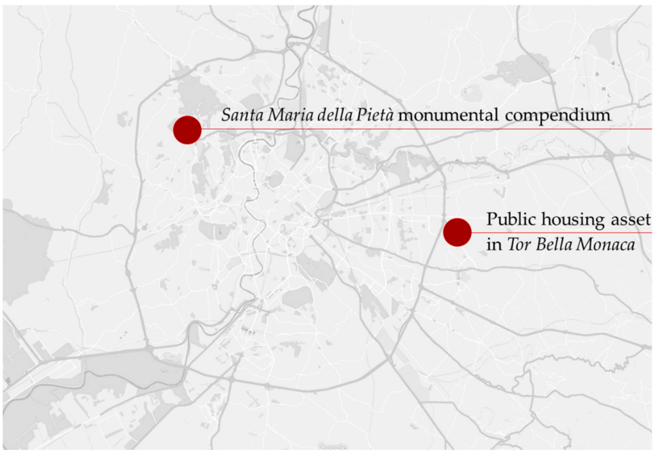

Figure 3. Localization of the two urban transformation areas considered in the analysis within the city of Rome.

5.1. Santa Maria Della Pietà

The *Santa Maria della Pietà* area is located in the northwest of the city of Rome. The area of intervention is surrounded by the *Agro Romano*, with parks and reserves of natural, historical and artistic interest, as well as by the agricultural areas, interspersed with numerous orographic incisions. The adjacent urban areas were developed in the 1950s, and have suffered a process of uncontrolled expansion. In fact, since their foundation, numerous urban transformations have been carried out, resulting in the construction of multiple building typologies, including public housing built in the 1980s and 1990s, alternating with private residential properties, which are often spontaneous and/or illegal.

In Figure 4, the monumental compendium of *Santa Maria della Pietà*, the main transport systems and the surrounding residential neighborhoods are shown.

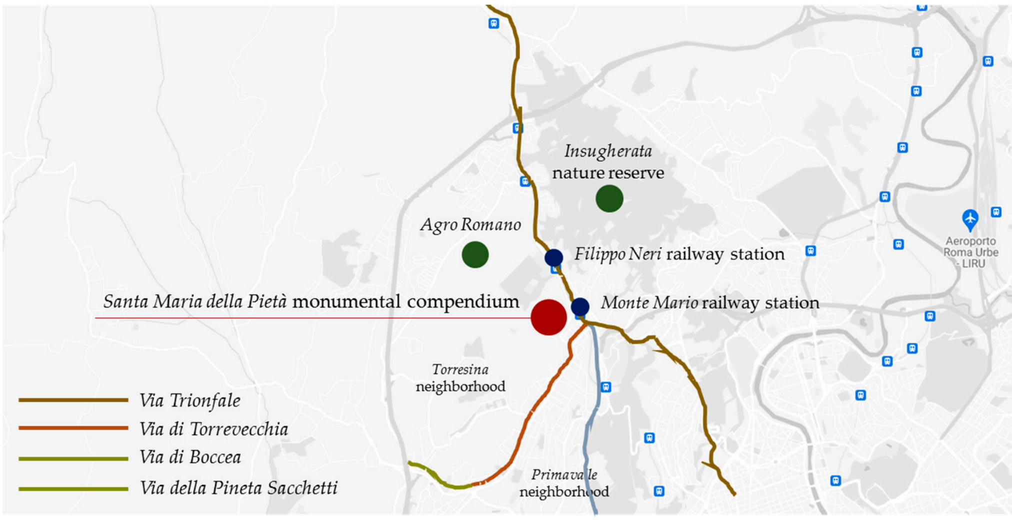

Figure 4. *Santa Maria della Pietà* monumental compendium, surrounding residential neighborhoods and main road axes.

The initiative provided for the monumental compendium of *Santa Maria della Pietà* is included in a program of interventions related to the health and well-being of the communities, intended as a state of physical, mental and psychological well-being, aimed at improving and spreading the culture of social inclusion, assistance and collective, community and generational integration.

As shown in Figure 5, the monumental compendium is organized in pavilions spread throughout the external park area in which different functions will be included, consistent with the structure of the pavilions and with the overall project solution.

For the pavilions to be transformed (Nos. 5, 6, 7, 16, 18, 23, 24, 25, 28, 31 and 41 in Figure 5), significant redevelopment works are planned in accordance with the original conformation of the building and the monumental constraints on the whole complex.

The project provides for refurbishment interventions, which involve a complete structural and systems renovation of the buildings and their functional reconversion, in compliance with the existing monumental constraint on the complex in which they are located. For the determination of the construction costs related to each pavilion, appropriate official price lists [59–63] have been considered. In particular, by analyzing the index items of the price list, the most appropriate one, i.e., the most similar intervention, has been selected and the unitary construction cost has been identified. These official costs have been validated and adjusted by analyzing the maintenance state of each pavilion and the functions envisaged by the project and, firstly, updated on the basis of the ISTAT revaluation coefficients for construction costs.

The summary calculation of construction cost was performed by considering the main work categories that contribute to defining the project, and attributing to each of them an appropriate value, which includes the sum of the expenses to be incurred for the category of work considered.

Figure 5. Pavilions of the *Santa Maria della Pietà* monumental compendium to be transformed.

5.2. Tor Bella Monaca

The *Tor Bella Monaca* neighborhood extends in the eastern quadrant of the city of Rome. It was built since the 1970s as numerous economic and social housing plans have been settled. In the neighborhood, the total number of inhabitants is approximately equal to 27,947: in particular, the urban built-up area is characterized by 2,012,293 m^3 of total volume and 77.7 hectares.

Residential buildings are mostly publicly owned: 4004 housing units belong to the city of Rome and about 1500 to the "Aziende Territoriali per l'Edilizia Residenziale Pubblica" (ATER Roma).

By considering the large consistence of the neighborhood, social gathering places are lacking, and widespread degradation of public spaces and housing can be observed. Furthermore, the urban area is poorly connected by local public transportation (there are only few bus lines), whereas there are different schools. In Figure 6 the localization of the *Tor Bella Monaca* neighborhood and the main existing infrastructure is reported.

The buildings considered in the redevelopment project are bordered on one side by a middle traffic road (on the west side) and to the east by the *Agro Romano*. In addition to the physical transformation of the buildings, the initiative aims to social objectives aimed at improving the entire surrounding area through the desirable cultural and economic revitalization with the promotion of shared initiatives for local development and the encouragement of new job creation. To this end, the transformation initiative provides for different interventions related to the building rehabilitation, the seismic adaptation, the energy efficiency, the removal of architectural barriers, the enhancement and regeneration of public space and the creation of park areas.

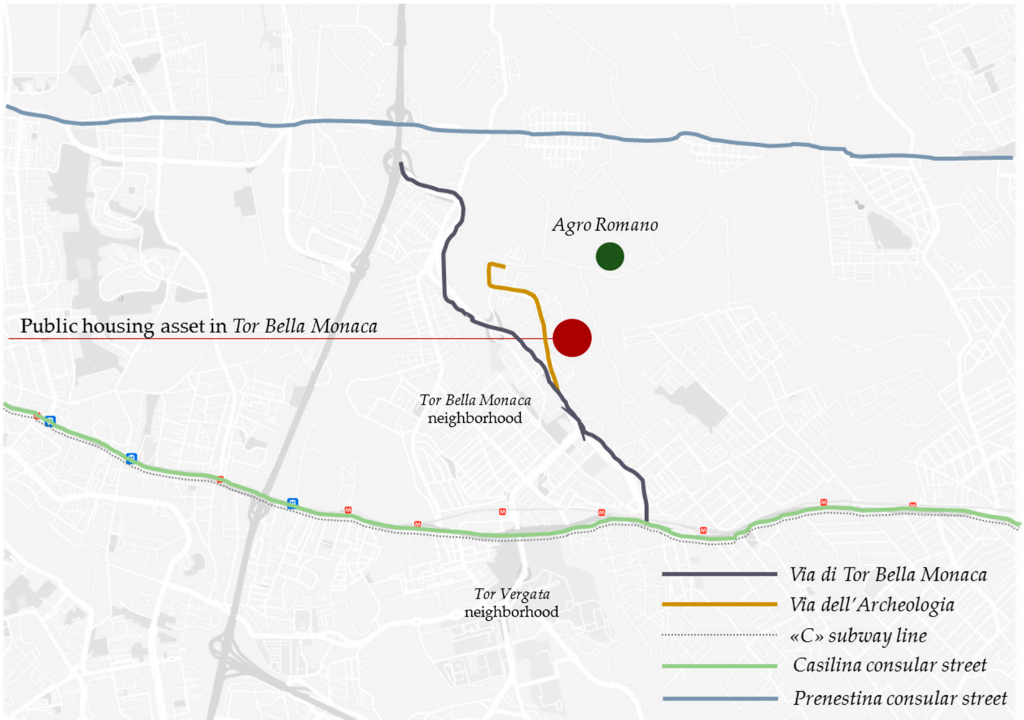

Figure 6. *Tor Bella Monaca* neighborhood and main road axes.

With reference to the buildings–named "North" and "South" in Figure 7 -, the most relevant interventions concern the first three levels: in particular, for the basement floor (Floor −1), the rehabilitation of the parking area with the expansion of covered parking spaces and the closure of internal crossing roads for safety reasons, are planned; for the ground and first floors (Floors 0 and 1) recovery operations aimed at diversifying the intended uses (currently only residential one is included) by introducing commercial activities and artist workshops are provided. For these two floors, a new organization of housing types and the insertion of collective spaces and services for the neighborhood are also defined. Finally, from the second floor to the seventh (Floors 2–7), "light" renovations are assumed, and they will concern the recovery of technological systems and on the envelope for energy efficiency (replacement of windows and doors and new envelope with insulation). In addition, the redevelopment of the courtyards of the buildings is also planned, with the inclusion of new functions such as a suburban museum and coworking spaces, as well as the complete renovation of green public spaces.

The construction costs for public residences, also established by the regional regulations No. 27/2006 [64] and implemented in the present analysis, can be attributed to three types of interventions. The first type is *primary recovery*, which tends to the renewal of the functionality and seismic safety of the building and concerns the common parts and includes the static consolidation of the load-bearing structures, by considering the foundations, the rehabilitation of masonry, stairs, roofs and the common parts of the installations and connections. The second type is *secondary recovery*, which tends to the habitability of individual dwellings rehabilitation and concerns a systematic set of works including functional reorganization, introduction of accessory elements, equipment and adaptation of facilities as well as restoration of the parts affected by the primary rehabilitation. The last type is *extraordinary maintenance*, as defined by Article 3(b) of the Italian DPR No. 380/2001 [65], which concerns the works and the modifications necessary to renovate and replace building parts, including structural parts, as well as to create and integrate the sanitation and technological systems, without varying the overall building volume and not involving significant urban changes in the intended use that would determine an increase in the urban planning load.

Figure 7. *Tor Bella Monaca* North and South Buildings.

Furthermore, the Regional Law No. 27/2006 indicates the parametric starting values, which have been appropriately updated and remodulated.

Therefore, the costs used for the three categories of intervention are as follows: EUR 580.28/m^2 for primary recovery, EUR 322.40/m^2 for secondary recovery, EUR 359.21/m^2 for extraordinary maintenance.

5.3. Application of the Optimization Algorithm

Borrowing the principles of the Operational Research, the proposed model has been applied in the analysis by implementing the simplex algorithm through the Linear Interactive Discrete Optimizer software (LINDO). For the case studies selected, the total budget provided by the Public Administration is EUR 82,538,000. By considering an incidence of the indirect costs (a_i) equal to 25%, the optimization algorithm defined in Table 1 has been applied. In this situation $n = 2$, whereas $m = 103$ (11 work categories for *Santa Maria della Pietà* monumental compendium and 92 for *Tor Bella Monaca* public housing compendium). It should be highlighted that in the model q_{ij} is the GFA for j-th work category of the i-th initiative. Therefore, the official costs are equal to ($k_{ij} \cdot q_{ij}$), with the unitary cost of each category of work estimated through institutional price lists and the optimal costs are assessed by applying the developed algorithm, equal to ($k_{ij}{}^* \cdot q_{ij}$), in which $k_{ij}{}^*$—which is the variable of the model—represents the unitary optimal cost for j-th work category of the i-th initiative.

Table S1 in Supplementary File reports, for each of the two initiatives, the intervention typologies, the GFA, the optimal costs estimated by the model and the official costs determined through appropriate price lists, the percentage differential (Δ) between the official costs and the optimal costs for each intervention, the total construction costs and the total initiative costs. As evidenced by Table S1, if the optimization model were not applied and the assessed costs (i.e., official costs) were considered, the preliminary set budget would not be respected: in fact, the total costs for the two initiatives would be equal to EUR 85,871,770, higher than the set budget for the two initiatives.

The implementation of the proposed model, on the other hand, allows one to verify the financial constraint imposed: in fact, the total costs of the two initiatives are equal to EUR 82,538,000. Furthermore, as it can be observed from the fifth column of Table S1, a very limited differential value between the official costs and the optimal costs for each category of work is ensured, with an average value equal to 4.7%: only for four work categories does the Δ reach up to 8%, whereas for 40 work categories it is lower than 4%.

In Table 2, the most relevant results are reported: in particular, for the two analyzed initiatives, the total construction costs, the indirect costs and the total initiative costs, calculated by consulting appropriate official price lists and through the implementation of the optimization algorithm, are shown in aggregate form. The disaggregation of the costs is specifically carried out in Table S1.

Table 2. Brief framework of the main findings obtained.

Santa Maria della Pietà **Monumental Compendium**			
	Optimal Cost (EUR, €)	**Official Cost (EUR, €)**	**Δ (%)**
TOTAL CONSTRUCTION COSTS (EUR, €)	**26,318,869**	**26,994,980**	**−2.50**
INDIRECT COSTS (EUR, €)	**6,579,717**	**6,748,745**	**−2.50**
TOTAL INITIATIVE COSTS (EUR, €)	**32,898,586**	**33,743,725**	**−2.50**
Tor Bella Monaca **public housing compendium**			
TOTAL INITIATIVE COSTS (EUR, €)	**39,711,474.68**	**41,702,435.73**	**−4.77**
INDIRECT COSTS (EUR, €)	**9,927,868.67**	**10,425,608.93**	**−4.77**
TOTAL INITIATIVE COSTS (EUR, €)	**49,639,343.35**	**52,128,044.66**	**−4.77**
TOTAL COSTS OF THE TWO INITIATIVES	**82,537,929.6**	**85,871,769.7**	**−3.88**

In order to test the proposed model potentialities, the first attempts in terms of modifications of work category costs, that could be carried out for compliance with the set budget are shown in Table 3 for *Santa Maria della Pietà* monumental compendium initiative. In Table 3, the monetary amounts in correspondence of the highest work category costs or for the largest quantity to be realized are changed to fit the preliminary expenditure limit. Regarding the situation in which the developed model had not been implemented, and the empirical procedure was applied, the decrease in construction costs would have determined a reduction in quality standard of the final project. Thus, the validity of the proposed model is represented by the design solutions optimization, for which a reduction in intervention costs does not correspond with a decline in the qualitative standards of the overall project. In this sense, the constraint of the simultaneous compliance with the budget and the fulfilment of the adequate quality standards of the final project is guaranteed.

It should be observed that for the compliance with the budget, the work category costs have to be reduced, up to 35% for the items characterized by the highest total costs, due to the largest GFA or to the highest unitary costs, by determining a reduction in quality standards of the final project.

Table 3. Costs obtained by implementing an empirical procedure for the intervention of *Santa Maria della Pietà* monumental compendium.

Pavilion (No.)	GFA (m^2)	Official Cost (EUR, €)	Empirical Cost (EUR, €)	Δ (%)
5	1688	2,236,146	2,000,000	−12%
6	1629	738,263	650,000	−14%
7	1350	2,744,754	2,400,000	−14%
16	2140	3,220,400	2,750,000	−17%
18	2370	3,733,540	3,150,000	−19%
23	1500	2,398,174	2,050,000	−17%
24	396	869,360	840,000	−3%
25	740	1,649,528	1,550,000	−6%
28	3790	4,873,469	3,610,000	−35%
31	1900	2,855,072	2,450,000	−17%
41	750	1,676,274	1,550,000	−8%
TOTAL CONSTRUCTION COSTS (EUR, €)		**26,994,980**	**23,000,000**	
INDIRECT COSTS (EUR, €)		**6,748,745**	**5,750,000**	
TOTAL INITIATIVE COSTS (EUR, €)		**33,743,725**	**28,750,000**	

Another possible and empirical solution to satisfy the defined constraints using a non-optimizing procedure, may involve the only one reduction in the work category highest construction costs, leaving unchanged the other items costs. However, this would determine an even more significant decrease in costs for this work category, i.e., a relevant decreasing of the qualitative level of this component of the project and, in general terms, of the entire initiative.

6. Conclusions

During recent years, several construction, promotion and development operations have contributed towards the definition and spread of process control systems capable of identifying the main variables that influence the success of a territorial initiative. In particular, feasibility analyses play a key role for the correct planning of cash flows and for a clear determination of project management techniques throughout the entire project life cycle [66,67].

The growing attention for methodological approaches able to virtuously relate the decision-making phase before the project [68], the construction one and the management step demonstrates the current cogency of integration among the different stages of the project in order to support the choices processes of Public Administrations and to effectively manage funding. In this sense, the compliance with the project budget constitutes a fundamental aspect to be taken into account in each life cycle cost assessment phase to prevent needless waste of financial resources, which are limited, and whose use is subtracted from alternative investment resources that could generate benefits for the communities. In this regard, effective project evaluations developed by expert and competent technicians associated with a valid system for monitoring the results obtained in the different steps of the project cycle ensure, as much as possible, the success of the initiative with respect to the realistic goals set. The assessments should neglect overly optimistic forecasts, and the project, consistent with the technical analysis, should be complete and clear and consistent with urban planning and legal requirements. Furthermore, a correct evaluation of the total costs of the project must explain the exposure to risk, identifying the main "critical" variables that could affect the conditions of intervention feasibility, both in the construction and management phases and, possibly, by identifying appropriate mitigation and control measures. The assessment of the project costs allows one to rationally direct the use of public resources and, in the case of Public Private Partnership procedures, including private procedures, to legitimize the choices and to make the decision-making processes transparent and reliable [69].

In the framework related to the selection of interventions to be financed through the NRRP funding, the need to develop valid assessment tools to support decision-making processes for optimizing the allocation of foreseen financial resources is relevant. In the present research a methodological approach based on an optimization algorithm that allows one to minimize the differential between the construction cost assessed by the expert technicians and the a priori budget of the project, has been defined. Starting from the organization of the entire initiative in categories of work, the methodology logic allows one to identify the compromise solution in terms of costs, able to ensure the compliance with the set project budget.

The proposed methodology has been implemented to two urban regeneration initiatives related to public housings (*Tor Bella Monaca*) and public community services (*Santa Maria della Pietà* monumental complex) located in the city of Rome (Italy). The application has highlighted the potential of the developed model, which is able to minimize the differential between the initial assessed costs and the final costs that effectively satisfy the budget constraint.

In order to appropriately manage and use the available financial resources, e.g., the funding allocated by NRRP for urban regeneration or, generally, the public funds aimed at the territorial development, the methodological approach could support the Public Administrations decision-making processes related to the selection phase of the projects most consistent with the planned goals, also according to the cost terms. On the other hand, the methodology could guide private investors in choices mechanisms, to verify the feasibility of the initiative, by considering the initial expenditure limit.

Thus, the developed model could be used in itinere for the costs assessment, in order to monitor the variation of the differential between the official costs and the optimal costs for each intervention, and to highlight the influence of the possible construction variants on the costs. In this sense, this practical implication of the model could allow one to manage any excessive cost increase that can occur during the executive phases, such as those that exceed the preliminary set budget.

Further insight provided by the present research concerns the implementation of the proposed methodological approach to several initiatives, in order to test its effectiveness in other contexts. In addition, the results obtained should be validated and updated through analytic cost assessments in correspondence of the following design steps, for which more detailed investigations must be carried out.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11101812/s1. Table S1: Summary of the *Santa Maria della Pietà* monumental compendium and *Tor Bella Monaca* public housing compendium initiatives: identification of the GFA, of the optimal costs and the official costs, and the percentage differential (Δ) between the official costs and the optimal costs for each intervention.

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