# Assessing Plans and Programs for Historic Centers Regeneration: An Interactive Multicriteria Approach

Salvatore Ercolano, Fabiana Monacciani, and Pietro Rostirolla

University "L'Orientale", Naples, Italy
{sercolano,fmonacciani,rostirol}@unior.it.

**Abstract.** The paper proposes a decision support system (DSS) for definition and implementation of complex policies for globally preserving and valorizing the cultural heritage, in a context of limited financing.

The proposed methodology is inspired by the fundamentals of Goal Programming. The multiobjective decision problem is articulated into two phases: the first, aimed at allocating the public financial resources among different kinds of homogeneous actions; the second, aimed at selecting the punctual investments to be financed with the optimal resources assigned to each action during the first stage.

In order to find the best compromise solutions, the original multiobjective problem is transformed into a monobjective constrained problem. For this purpose, phase 1 is supported by a linear programming model, while phase 2 by a binary one. The first and the latter are interactive DSS allowing to identify, through a series of iterative steps, the best compromise solution, if it exists.

The proposed methodology is applied to a decision problem derived from the "Great Program for the Historic Center of Naples", launched by the Municipality in year 2007 with the aim of triggering a requalification process involving the whole historic center, enrolled in the UNESCO World Heritage List since 1995.

**Keywords:** financial allocation, investments selection, mathematical programming, decision support system

## 1 Introduction

The task of preserving and valorizing towns' historic centers is implied by the wider duty of cultural heritage protection; such task is defined both by the Constitutions of modern Countries and in many international documents such as the Athens and Venice Charts, the UNESCO Agreement and the European Chart on Architectural Heritage.

In particular, the last two documents state the concept of cultural heritage "global" protection, and stress the need of not considering historic centers as a simple sum of buildings or assets, but as a whole, whose preservation must be integrated into city planning and economic programming.

A.G.S. Ventre et al. (Eds.): *Multicriteria & Multiagent Decision Making*, STUDFUZZ 305, pp. 151–162.
DOI: 10.1007/978-3-642-35635-3_13 

Following this, in the last years, various local communities have started devising new policies aimed at preserving and valorizing their cultural heritage, even in consideration that, in many different cases, such strategies have been proved to play a key role in inducing the start up of virtuous transformation processes of degraded areas, also thanks to the joint action of public and private efforts.

Unfortunately, though, the aim of "global" preservation has to face strict public budget constraints avoiding the implementation of wide restoration programs; therefore, accurate financial programming and coherent investments selection is strongly required in order to successfully preserve and valorize towns' historic centers.

The key questions to be faced, therefore, are the following: "how to define the best financial allocation to better contribute in restoration program's targets reaching?", "how to choose among the various possible restoration projects?", "how to verify the coherence between projects selection and program's targets attainment?"

Answering to such questions is very complex, and the current evaluative procedures, unfortunately, are still unable to effectively support decision making in this field: the first problem to be faced, in fact, is due to the difficulty in identifying the causal relations existing between the possible typologies of actions and their impacts on social relevant targets; the second problem, instead, is related to the fact that many of the available information are either fuzzy or qualitative, with the consequence that they often remain unused.

In other words, current evaluative procedures for supporting the design of restoration programs are undermined by the difficulty of obtaining reliable quantitative data and of using and synthesizing all the available "weak" information.

As a result, the design of complex restoration policies for historic centers is currently based only on technical and political judgment, while economic assessment is often limited to the evaluation of monetary impacts and confined at the end of the decision making process for a mere validation of the choices already set by the technical and political staff.

In order to overcome the current limits characterizing the evaluation procedures linked with programs design and implementation, therefore, a robust methodology for effectively supporting final decision making is strongly needed.

Next sections, therefore, describe one of the possible solutions to be adopted for this specific purpose, based on the use of the mathematical programming methods.

The usefulness of such methodology will be shown through its application to a specific case study related to the sector of cultural heritage and inspired to the real problems that bubbled up when designing "the Great Program for the Historic Center of Naples", an ambitious Program whose aim is that of triggering a huge requalification and development process involving the whole Naples historic center, enrolled in the UNESCO World Heritage List since 1995. Such Program, launched by the Municipality in year 2007, has been temporary stopped due to the new rules set by Stability Pact; anyway, the evaluative problems put in place by such an experience are still very updated and, for this reason, such case study will be further used as a mere exemplificative starting point for showing the features of the proposed DSS.

## 2 The Great Program for the Historic Center of Naples

The Great Program for the Historic Center of Naples" (from now on GP) has been conceived by the Municipality as a very ambitious Program implying both the restoration of historic monuments and buildings, and the implementation of various other "physical" and "un-material" interventions in the Historic Center enrolled in the UNESCO World Heritage List.

Such Program is articulated into two main documents: the Strategic Orientation Document (S.O.D.), and the Urban Integrated Program (U.I.P.). The S.O.D. is aimed at defining the general strategy (actors, synergies, instruments, roles) to be adopted in the entire UNESCO area; the U.I.P., instead, is the operating document, which relies, at least before the stop set by the Stability Pact, on a total financing of about 240 million Euros out of the POR-FESR 2007-2013 (objective 6.2), plus additional 110 Euros out of other funding specifically addressed to some sectors such as tourism, welfare, security, transports, entrepreneurship, for a total budget available of more than 350 million Euros.

The GP pursues 15 different targets, all of them converging toward the general aim of global requalification and development of the Historic Center of Naples. In particular, three groups of targets can be identified as relevant: a) targets directly related to the GP general strategies, declined by the S.O.D.; b) targets indirectly derived from considering the GP as an instrument for fostering local economic development; c) targets specifically traceable from the UNESCO directories regarding the sites enrolled in the World Heritage List.

To reach such targets, 9 different kinds of actions have been identified; the actions represent homogeneous expenditure categories and they are implemented by several punctual investments. We can split the actions into 4 groups:

a. *interventions on monumental heritage/buildings.* This group comprises all the actions regarding interventions on the external facades and for the internal requalification of public – private monumental heritage/buildings;
b. *interventions on ordinary goods/buildings*. This group comprises all the actions regarding interventions on buildings with no artistic value, whose requalification and refunctionalization contribute to valorize the historic center;
c. *Requalification of open spaces and urban areas*. This group comprises the actions regarding the re-making of urban furniture;
d. *Interventions of urban archeology*. This group comprises the actions regarding the archeological excavations and all the interventions for requalification, safeguard, and valorization of urban areas.

## 3 The Proposed Methodology for Supporting the Design of the Great Program for the Historic Center of Naples

As evident, the Great Program for the Historic Center of Naples is a very ambitious program, whose global and efficient implementation would require huge financing and high planning capacities by the decision maker.

Given the context of strict budget constraints, however, the only way to successfully succeed in pursuing the wide set of GP goals is to make an accurate programming for the scarce resources available, and a coherent selection of the investment projects to be included into the Plan.

Following this, the decisional process should be articulated into two consecutive steps: the first aimed at supporting the “Programming Phase” or, in other words, at defining the amount of resources to be devoted to each GP action in order to get the best compromise impacts on all the GP targets; the second, aimed at supporting the “Budgeting Phase” or, in other words, at defining, with respect to the budget constraints identified for each action, the investments set that better contributes to the targets pursued by the action they belong to.

In order to operatively fulfill the GP targets, a wide set of 247 investments projects has been proposed since the year 2007 by citizens, institutions, and economic operators to be included into the Program; starting from such wide and overlapping list of projects, then, the final decisional stage to operatively implement the GP should be the selection of the projects to be actually included in the plan, in order to reach, at best, the ultimate goals it has been conceived for.

Next sections will describe, more in detail, the features of the two evaluative steps, and the techniques to be used for supporting the related decisions implied by each.

### 3.1 Step 1 – Programming Phase

Aim of the first step of the model is to define the best budget structure of the Program in order to get the best compromise impacts on the GP most relevant objectives.

Step one could be run out by considering that the definition of the GP expenditure Program is a typical multi-objective problem: the preliminary S.O.D. and U.I.P., in fact, state that heterogeneous objectives should be pursued through the use of the public financing available.

Given the trade-offs among objectives and in consideration of the general budget constraint, however, no financial allocation (among the different GP actions) capable of maximizing all the GP objectives, exists.

As a result, the hypothesis of identifying an optimal solution to the problem should be rejected, while a solution of "best compromise" should be pursued; such solution is the one implying a financial allocation whose impacts are considered "acceptable" for all the decision makers involved in the process; the level of satisfaction attributed to a solution, therefore, is not an absolute concept, but it is linked to the structure of the decision maker preferences.

In consistence with the principles of Goal Programming, the research of the "best compromise" solution could be operated by transforming the "original" multi-objective problem into a "new" mono-objective constrained problem with continuous variables, where one of the GP targets is set as the objective function, and the remaining ones are treated as constraints, whose minimum (maximum) value must be respected.

In such a model, the control variable is the amount of financial resources devoted to the GP and the basic hypothesis is that each objective is linearly linked to the GP financing assigned to the various actions impacting on them. In particular, in consideration of the low level of knowledge regarding the relation existing between the action and the objectives, the impacts that the first have on the second can be quantified by using a Delphi approach, where experts may be asked either to use a scoring system (e.g., -5/ 5 scale) where negative/positive scores must be attributed in case of negative/positive impact on the target, or to give quantitative evaluations based on the activation coefficient linked to a unit of expense observed in other similar interventions.

The solution to such mono-objective constrained problem leads to the identification of the best budget allocation for a given structure of the model (according to the objective function chosen and the constraints set), and to the evaluation of the economic impacts related to such financial plan.

By modifying the model structure (by choosing a different objective function and/or modifying the constraints value), alternative budget allocations could be easily generated, and their relative impacts easily compared with those related to other scenarios previously found.

The approach used for the generation of the various scenarios is interactive, because it is based on a dialogue with the decision maker: at each step, the model provides a new solution to be proposed to the decision maker, described in terms of impacts on the GP targets; after the creation of each scenario, then, the decision maker is asked about its degree of approval with the impacts and, in case of low satisfaction, he is asked to provide additional information (e.g. specification of new constraints, changing of the objective function, etc.) for generating a new solution.

The process ends when the decision maker identifies the "best compromise" budget structure, that is the financial allocation bringing to an acceptable level of all the GP objectives.

In this way, therefore, the first step of the proposed approach allows both to generate the budget structure of the GP and to make an ex-ante evaluation of the impacts associated to it: the result is the identification of both *effective* (able to reach a solution, if it exist, where all the objectives are at an acceptable level) and *feasible* (in terms of capacity in respecting the financial and other existing constraints) expense Program to be adopted.

### 3.2 Step 2 – Budgeting Phase

Once defined the amount of resources to be devoted to each GP action, the second step of the approach consists in identifying, for each of them, the investments set to be realized with that resources.

Like in step one, the selection phase is a typical multi-objective problem. Each investments Plan, in fact, pursues a "best compromise" solution among a set of conflicting objectives among which: (a) some are related to the contribution that each investment project gives to the reaching of the GP targets; (b) others are related to projects' micro-economic performance, strictly due to their technical and economic specificities (e.g., minimize project investment cost, maximize project Financial Net Present Value, maximize project Economic Net Present Value, etc.).

Again, like in step 1, the research of the "best compromise" solution could be operated by transforming the original multi-objective problem into a "new" mono-objective constrained problem, where the decision variables are binary variables linked with the investments projects.

The solution to such new problem leads to the identification of the best investments set to be included into the Program, for a given structure of the model, and a prevision of the impacts associated to its implementation.

By interacting with the decision maker, it is possible to modify the model structure and, consequently, calculate a new solution, characterized by a different Plan configuration bringing to a different set of impacts.

The second step process ends when the decision maker is satisfied by all the impacts of a given Plan configuration.

In this way, therefore, the second step of the model allows, at the same time, to generate and evaluate the investments Plan to be adopted, by ensuring both its *effectiveness* and its *feasibility*.

## 4 Description and Formalization of the Model

This section describes more in detail the mathematical models to be used in order to implement the proposed evaluative approach.

In particular, paragraph 4.1 describes the model used for supporting the programming phase (step 1); paragraph 4.2, instead, is focused on the model supporting the budgeting phase (step 2).

### 4.1 Step 1 – Defining the "Best Compromise" Budget Structure for the GP

Let's indicate with:

- $O_j$ = the set of J objectives ($j=1, ..., J$) pursued by the GP;
- $X_n$ = the decisional continuous variable, that is to say the amount of resources to be assigned to each $n$-action ($n= 1, ..., N$);
- $C_{nj}$ = the average unitary impact of the expense $X_n$ on the *j-th* objective.

The search of the "best compromise" solution must be operated by respecting a set of exogenous constraints, defined before starting the interaction phase and considered as un-modifiable; such constraints regard the minimum and maximum value within which the decisional variables may range:

$$X_n^{min} \leq X_n \leq X_n^{max} \qquad [1]$$

In addition to the above, the global budget constraint must be considered, as well: the total amount of resources assigned to the various actions, in fact, cannot exceed the total resources *(K)* assigned to the Program:

$$\sum_{n=1}^{N} X_n \leq K \qquad [2]$$

Assumed that the value drawn by the generic target j depends on how the financial resources are distributed among the actions, such general relation could be written as $f_j(X)$ (with $j = 1,\dots, J$); more in detail, the value of each j objective may be represented as a linear combination of the decisional variables according to the performance coefficients $C_{nj}$

$$\mathrm{f}_j(X) = \sum_{n=1}^{N} C_{nj} X_n \qquad [3]$$
$$\forall\, j = 1,\dots,J$$

As a result, the following multi-objective linear programming model is obtained:

$$\max f(X) = \left[f_1(X); \dots\ f_j(X)\right] \qquad [4]$$
$$\text{S.T.}$$
$$X_n^{min} \le X_n \le X_n^{max}$$
$$\sum_{n=1}^{N} X_n \le K$$

Given that the j-targets are different from each other, and often conflicting among them, no repartition of financial resources allowing to optimize all the targets actually exists.

As said before, in fact, in multi-criteria problems the concept of "optimality" is substituted by that of "acceptable compromise", which implies the research of "satisfactory" results.

In order to find the "best compromise" solution, the first step is a technical one and consists in identifying the "ideal solution" vector: for each target $f_j(X)$, the ideal value $f_j^*(X)$ is calculated within the model by hypothesizing to optimize only one target, without caring of the level of the remaining ones, and considering only the exogenous constraints.

This technical phase is developed before starting the interaction with the decision maker.

Obviously, the ideal solution is external to the region of the feasible solutions; in other words, no real solution could ever generate such optimal values, otherwise this would mean that the targets are not conflicting. In general, in fact, a generic solution $\boldsymbol{f}(X)$, at least in one of its $f_j(X)$ elements, will present a lower value then the corresponding $f_j^*(X)$ belonging to the "ideal" vector $\boldsymbol{f}^*(X)$.

Anyway, the identification of the ideal vector is very useful because it represents a benchmark allowing to compare the "real" results obtained by the elaboration of the various scenarios while searching for the "best compromise" solution.

Once identified the "ideal vector", next step consists in identifying the best compromise solution: to do this, the DSS model should start interacting with the decision maker, in order to identify (within the entire set of targets to be pursued) both the objective function to be maximized (or minimized) and the set of discretional constraints describing decision maker's preferences.

The DSS generates a Pareto-efficient solution, described both in terms of impacts on the several relevant targets and in terms of value associated to each decision variables; such solution, then, is proposed to the decision maker. Furthermore the DSS provides information about the distance between the selected solution and the ideal one (ideal vector); such distance represents the "regret" with reference to the value that the target achieves in the ideal solution. Starting from these information, the decision maker is able to identify the target on which he wants to intervene, in consideration of both its specific level of attainment (compared with the ideal value) and of that of the other targets.

The decision maker, then, may define on such target a new constraint on the minimum accepted level of satisfaction; the DSS, then, generates a new solution that respects the new discretional constraint, and describes the new result achieved. This procedure goes on until a "best compromise" solution is accepted by the decision maker. The new solution to be proposed to the decision maker may be generated by using different approaches. The simplest one is to transform the original multiobjective problem into a monobjective problem, where one of the *J* objective functions is optimized subject to the several constraints, both exogenous (the availability of resources, the technologies etc) both endogenous, set in by the decision maker as minimum acceptable level in achieving the objectives. If the decision maker does not change his previous choices, he will arrive at the best compromise solution, if any, in a number of steps equal to *J-1*.

In the GP specific application, the target chosen for maximization is the - "*Recovery of monumental heritage*" (from now on *target 1*), given the high stress toward this objective highlighted in all the GP strategic documentation; therefore the objective function of model [4] could be substituted with the following:

MAX

$$\sum_{n=1}^{N} X_n C_{n1} \qquad [5]$$

ST

$$X_n^{min} \le X_n \le X_n^{max}$$

$$\sum_{n=1}^{N} X_n \le K$$

$$\sum_{n=1}^{N} C_{nj} X_n \ge B_j$$

$$\forall\ j = 2,\dots,J$$

where $B_j$ is the minimum acceptable level of *j-th* objective, discretionally set by the decision maker.

In this way, the problem of finding the best financial allocation of GP funds is represented through a simple linear programming model, to be solved by the iterative use of the interactive DSS.

In particular, the “best compromise” solution found for our case study (the one considered as the most "satisfactory" according to the DM preferences) has been identified after 7 iterations of the model, and resulted in the following funding distribution:

- interventions on monumental heritage/buildings, 51,8 %;
- interventions on ordinary goods/buildings, 13,3%;
- requalification of open spaces and urban areas, 27,9%;
- Interventions on urban archeology, 7%.

### 4.2 Step 2 - Selecting the Best Investments Set to Be Included in the GP

Once defined the optimal allocation of GP financial resources among the *N* actions, next task consist in identifying, within each action, the investments set to finance with those $X_n$ resources.

In order to better understand features of the proposed model to be used during step 2, this paragraph shows an exemplification of the selection phase, limited to a subset of 27 investment projects, proposed by different stakeholders, and belonging to the action "*restoration and reconstruction for social purposes"* (from now on *action a*), which has been assigned ( $X^*_a$ in the application described in previous paragraph) of the 15,4% of the GP total resources.

Let's indicate with:

- $aO_s$ = the set of *S* objectives *(s=1, ..., S)* considered as relevant for *action a* (*S = 16* in our simulation);
- $Y_i$ = the binary variable associated to the generic investment project i-th *(i=1, ..., I)* belonging to *action a* (I = 27 in our simulation); $Y_i$ is binary because its value will be 1/0 if the related project is selected/not selected in the optimum;
- $Z_{is}$ = the impact generated by the generic project *i* on the generic objective *s*.

The search of the "best compromise" solution must be operated by respecting the constraint regarding the maximum amount of resources available for projects implementation. In other words, the costs of the selected investments to be financed by the GP resources, therefore, must be lower or equal than the financial constraint defined for *action a*:

$$\sum_{i=1}^{I} K_i^* Y_i \leq X_a^* \qquad [6]$$

where:

- $X^*_{a.2}$ is the optimal amount of resources attributed to *action a* in Step 1;
- $K^*_i$ is the investment cost of project i belonging to *action a*.

In addition to constraint [6], the model must also take into consideration the relations of "mutual exclusion" and "complementarity" among the investment projects.

Given that the *S* objectives are different from each other, and conflicting among them, no projects selection allowing to optimize all the targets actually exists, therefore an "acceptable compromise" should be searched for.

To do this, the first step consists, again, in identifying the "ideal solution" vector.

Once identified it, we need to identify both the objective function to be maximized (or minimized) and the set of discretional constraints describing decision maker's preferences.

In our specific application, the maximization of ENPV has been chosen as the objective function, given that such index summarizes, in itself, many information regarding the whole economic performance of the projects.

In the new model, therefore, the objective function becomes the following:

MAX

$$\sum_{i=1}^{I} ENPV_i^* Y_i \qquad [7]$$

ST

$$\sum_{i=1}^{I} Z_{is}^* Y_i \geq D_s$$

where:

$ENPV_i$ is the value of the Economic Net Present Value associated to project *i*;

$D_s$ is the minimum level to be reached by objective s, discretionally set by the decision maker.

In this way, the problem of finding the best investment set to be included in *action a* of the GP, to be financed with the resources $X_a^*$ devoted to *action a,* is represented by a binary programming model: by defining new $D_s$ values, the decision maker may easily determine different solutions to be compared, in order to find the "best compromise" one. The process goes on until a "satisfactory" solution is achieved.

With reference to our simulation, the "best compromise" solution for the budgeting phase (the one allowing to obtain an acceptable deviation from the ideal solution for all the targets) has been identified after 6 iterations of the model. Such solution implies the inclusion in the GP of 18 projects from *action a* (of which 13 "material" and 5 "un-material"), for a total costs of € 35.737.500 (of which the 43% co-financed by the GP and the remaining 57% by private resources).

## 5 Conclusions

In conclusion, beyond the specific results obtained with reference to the GP case study, the main strengths of the proposed approach are the following:

- It allows to implement a relation map to understand the links between the instruments and the objectives;
- It allows to make the decision maker's choices more "explicit", by reducing the "hidden" space that could be seldom found in many DSS;
- It offers a coherent and flexible analytical framework for quickly representing the effects of different alternative choices;
- It helps determining efficient, effective, and feasible solutions, given the existing constraints and the decision maker's preferences, therefore allowing to easily exclude all the dominated solutions.

In addition to the above, another important feature of the approach is that the same methodology is used, with little changes, to support both the programming and budgeting phases, thus allowing to simplify model understanding and results reading by the decision maker.

Finally, the structure of the model allows a very simplified interaction between the Analyst and the decision maker: the latter's task, in fact, is not that of determining plausible trade-off values among the impacts, but only that of being oriented towards the determination of acceptable solution in terms of impacts obtainable; in other words, the decision maker should only express its judgment on the attainable impacts; if he is satisfied with them, this implicitly means that he is accepting the underlying budget structure, on the contrary, he must simply communicate where his dissatisfaction comes from, and a new scenario will be generated by taking into consideration new constraints.

## References


Barichard, V., Ehrgott, M., Grandibleux, X., T'Kindt, V.: Multiobjective Programming and Goal Programming. Theoretical Results and Practical Applications. Springer (2009)

Brancati, R., Rostirolla, P.: Un approccio metodologico per la valutazione intermedia: il caso del programma operativo della Campania 2000-2006, in Scienze Regionali. Italian Journal of Regional Science 3, 29–55 (2003)

Cefarelli, P., Rossi, F., Rostirolla, M., Rostirolla, P.: Analisi degli impatti e programmazione della spesa pubblica nel P.O.R. della Campania. In: Di Maio, A., Gallo, M., Simonetti, B. (eds.) Metodi, Modelli e Tecnologie dell'Informazione a Supporto delle Decisioni. Parte seconda: applicazioni, Milano, Franco Angeli, Italy (2008) ISBN: 978-88-464-8381-2

Comune di Napoli, Grande programma per il centro storico Patrimonio UNESCO, Documento di Orientamento strategico (2009), http://www.centrostorico.na.it (downloadable)

Comune di Napoli, Preliminare Programma Integrato Urbano PIU Europa per il recupero, il restauro e la valorizzazione del Centro storico di Napoli (2009), http://www.centrostorico.na.it (downloadable)

Monacciani, F.: Metodi, modelli e tecniche a supporto delle decisioni: riflessioni teoriche e aspetti operativi, tesi di dottorato, Il Torcoliere, Napoli (2007)

Monacciani, F., Rostirolla, P.: Un modello di ottimizzazione multiobiettivo per la selezione degli interventi in un Piano Regionale dei Trasporti. In: D'Ambra, L., Rostirolla, P., Squillante, M. (eds.) Metodi, Modelli e Tecnologie dell'Informazione a supporto delle Decisioni. Parte prima: metodologie, Franco Angeli, Milano (2008)

Regione Campania, Programma operativo regionale Campania FESR 2007-2013 (2007), http://www.regione.campania.it (downloadable)

Regione Campania, Linee Guida dei Piani Integrati Urbani (2008), http://www.regione.campania.it (downloadable)

Rostirolla, M., Rostirolla, P.: A multivariate and multicriterial approach for the SWOT analysis. Journal of Applied Sciences 11, 719–724 (2011) ISSN: 1812-5654

Steuer, R.E.: Multiple Criteria Optimization. Theory, Computations and Applications. John Wiley and Sons, New York (1986)