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Rethinking Feasibility Analysis for Urban Development: a Multidimensional Decision Support Tool

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Abstract. Large-scale urban development projects featured over the past thirty years have shown some critical issues related to the implementation phase. Consequently, the current practice seems oriented toward minimal and widespread interventions meant as urban catalyst. This planning practice might solve the problem of limited reliability of large developments' feasibility studies, but it rises an evaluation demand related to the selection of coalition of projects within a multidimensional and multi-stakeholders decision-making context.

This study aims to propose a framework for the generation of coalitions of elementary actions in the context of urban regeneration processes and for their evaluation using a Multi Criteria Decision Analysis approach. The proposed evaluation framework supports decision makers in exploring different combinations of actions in the context of urban interventions taking into account synergies, i.e. positive or negative effects on the overall performance of an alternative linked to the joint realization of specific pairs of actions.

The proposed evaluation framework has been tested on a pilot case study dealing with urban regeneration processes in the city of Milan (Italy).

Keywords: Feasibility analysis, Urban acupuncture, Urban catalyst, synergy, multi knapsack approach

1 Introduction

The concept of urban acupuncture refers to small-scale interventions that can be developed in a short time and have a “healing” effect on the surroundings or on the whole city.

On one side, this new idea of planning might solve the problem of large developments' feasibility evaluation, but on the other side it rises an evaluation demand related

to both the selection and feasibility analysis of coalition of actions within a multidimensional and multi-stakeholders decision context. This study aims to propose a framework for the generation of feasible coalitions of actions in the context of urban regeneration processes and for their evaluation using a Multi Criteria Decision Aiding (MCDA) approach. Given the decomposition of the concept of feasibility into three main criteria (environmental, economic and social), the proposed evaluation framework supports decision makers in exploring different combinations of actions in the context of urban interventions meant as catalysts. Two pillars underpin the proposed framework. The first pillar concerns the modeling and evaluation of synergies and temporal priorities among different combinations of projects. The second pillar concerns the inclusion of stakeholders' preferences and values in the evaluation process of the different combinations of projects. A first test of the evaluation framework on a pilot case study of urban regeneration in the city of Milan (Italy) is proposed. This paper will contribute to the debate on how to innovatively design policies and programs by exploring the use of MCDA and Operational Research in the field of urban development projects. More precisely, after the introduction, section 2 focuses on the notion of urban acupuncture; section 3 proposes an overview of the literature dealing with the design of alternative options for public policy making; section 4 focuses on the methodological approach aimed to define and evaluate synergic coalitions of elementary urban development interventions; section 5 shows the results of the first test of the evaluation model and, finally, section 6 discusses the results and future research perspectives.

2 Feasibility Analysis under the Urban Catalyst Paradigm

At the end of a long period of urban renewal processes focused on the development of large brownfields, many European cities are facing two interrelated issues (UNHABITAT, 2017). The first deals with the difficulty to fulfill the urban developments undertaken in the last decade, due to the real estate market crisis and the consequent reduction of demand, as well as the inability of local governments to select a set of sustainable interventions.

The second relates to the presence of disused spaces spread across the cities in addition to new constructions still unsold, that represents an opportunity for local governments to define reuse strategies and test innovative planning practices (Savoldi et al., 2012). Abandoned areas and buildings, besides reflecting the demographic, social and economic decline, highlight other signs of change, such as i) the geography of this phenomenon – nuclear and diffused – and dispersed in the tissue; ii) their relationship to a recent historical memory (Lynch, 1990; Augé, 2004); iii) the advanced state of decay with problems of public safety due to the presence of irregular settlements. Thus, the abandoned spaces consisting of punctual and discontinued areas, disused buildings, interrupted interventions scattered in the city can overcome their residual condition when they become part of a system. Under this perspective, the notion of urban acupuncture can be considered as one of the possible lines of action. Urban acupuncture has been firstly introduced by Manuel de Sola Morales (2004) with respect to urban planning practice. According to the idea of a city as a living organism, where change in one part

generates change in another, local actions placed in specific areas are able to address the overall cities development (De Sola Morales, 2009; Casagrande, 2007; Lerner, 2014). Large development projects, with their high investments, laborious bureaucratic-administrative processes and not always consensual results, are going to be replaced by widespread and small interventions, meant as urban catalysts (Attoe and Logan, 1989), capable of activating synergies with existing projects and trigger economic and social development processes.

The extensive literature on the subject of urban catalysts (Sideroff, 2003; Landry, 2005) mainly addresses issues related to the scale and form of urban development, disregarding the instance of how to i) define a system of catalytic projects/interventions; ii) evaluate how much they meet different objectives; iii) explore their feasibility with a multidimensional perspective.

The transition from a traditional concept of feasibility focused on an utilitarian vision to a broader notion which encompasses intangible aspects and uncertainty due to chains of effects that are not always predictable, requires to overcome the limitations of sectorial approaches and to introduce valuation approaches co-extensive to planning, programming and design processes (Patassini, 2006).

What deserves to be explored and represents a major challenge in the context of decision aiding models and practices is the modeling phase, when objectives are identified and alternative strategies and actions are defined (Sharifi and Rodriguez, 2002). Moreover, the definition of elementary projects and actions' coalitions requires to pay particular attention to the generation of alternatives (Tsoukias, 2014), which are not given but should be defined starting from a cognitive map of criticalities and potentials of urban contexts, in addition to expectations and values expressed by institutions and inhabitants (Crosta, 2010).

3 Literature Review

Creating quality alternatives plays a crucial role in many decision-making contexts, from those without an obviously complete set of alternatives to those without a set of desirable alternatives. One of the fields where the design of alternatives can have the most significant impact in terms of consequences on the local communities, quality of life and sustainability, to name a few, is that of public policy making. Yet, research on the potential usefulness of creating alternatives and how to effectively create alternatives for policy design is scarce (Ferretti et al., in progress).

Policy design is one of the eight major steps in the policy cycle, together with issue identification, defining policy objectives, policy testing, policy finalisation, policy implementation, policy monitoring and evaluation, policy readjustment and innovation (Lasswell, 1956). Being part of the policy cycle, policy design has been explored within the body of literature concerned with policy making but by few fields (Ferretti et al., in progress). The following paragraphs summarise the contribution of these fields.

Policy making has been mainly studied in policy analysis (e.g. Moran et al., 2006), with a large body of literature devoted to retrospective (ex post) analysis of policies (e.g. Considine, 2012).

Economists have been also concerned with policy making, focusing much of their research on rational theories of public decision making and formal methods for the ex-ante and ex-post evaluation of public policies (e.g. Dollery and Worthington 1996).

Operational Research and Decision Analysis too have developed methods which aim at supporting different phases of the policy cycle, such as problem structuring methods (e.g. Rosenhead, 2006), system dynamics (e.g. Sterman, 2001), and Urban Operational Research (e.g. Larson and Odoni, 1981), to name the most relevant ones. However, most emphasis in this stream has been on evaluation of alternatives, with limited consideration to support policy design (Ferretti et al., in progress).

Most decision problems discussed in the literature consider the set of alternatives on which they apply as “given”, although we know that in practice such a set frequently needs to be constructed. There is little in the literature addressing this problem (Belton and Stewart 2002), despite the awareness of it (e.g. Newstead et al., 2002). Few notable exceptions are summarised below.

Keller and Ho (1988) characterize five approaches for the creation of alternatives. Three approaches use attributes, states of nature, or both to generate alternatives, while the remaining approaches refer to general creativity techniques such as brainstorming (e.g. Ackoff 1978). Another approach to designing alternatives is the value focused thinking one (Keeney, 1992) which focuses on the values that should be guiding the decision situation, thus removing the anchor on narrowly defined alternatives and making the search for new alternatives a creative and productive exercise.

Zwicky (1967) proposed the use of the morphological box to identify a set of complex alternatives or comprehensive strategies, by decomposing a system into its functional subsystems, creating elements of an alternative that achieve the function of each subsystem, and creating an alternative by combining an element for each subsystem. Similarly, Howard (1988) proposed the strategy table to decompose a strategy decision into a set of strategy areas and create possible alternatives for each. These last two procedures systematically identify a comprehensive set of feasible alternatives, even though many of the combinations may be unappealing (Siebert and Keeney, 2015).

Other interesting techniques to support alternatives’ design for policy making and territorial planning are Spatial Multicriteria Analysis (e.g. Geneletti and Ferretti, 2015) and Choice Experiments (e.g. Oppio et al., 2015), as discussed in Ferretti (2016).

Once the set of alternatives has been designed, several decision analysis techniques are available to compare and evaluate such a set (e.g. Belton and Stewart, 2002). Within the context of urban and territorial planning, promising approaches able to take into account coalitions of decision elements are the NAIADE (e.g. Munda, 2009) and the Choquet Integral (Choquet, 1953). However, they consider coalitions of actors and criteria, respectively. The present study, by proposing the use of an operational research approach based on the knapsack model to take into account coalitions of alternatives, has thus an innovative value.

4 The Methodological Proposal

In order to apply an optimization model to a “partially qualitative” science such as urban planning (precisely urban ago-puncture), it is necessary to develop a conceptualization that strictly defines the elements of the problem and positions them in a global framework.

This framework must have precise rules that define the properties of each element and their mutual interactions. Moreover the elements of the problem have to be described by numerical values, so that they can be input of the mathematical model.

This chapter describes the elements of the framework designed to apply 1) optimization methods for the generation of feasible sets of actions in the context of urban regeneration processes and for their evaluation using a 2) Multi Criteria Decision Aiding (MCDA) approach. The interaction with stakeholders to estimate the parameters of both the optimization model and the MCDA is essential. This implies the design of a framework that is easily communicable to non-experts in mathematical models.

4.1 Actions and Plans

As previously described, the present work considers an approach to urban planning called ago-puncture, which means defining a large number of specific actions to be implemented in a certain urban area. The aim of the optimization is to find the best set of actions that maximizes benefits and minimizes costs, given some constraints to be respected. Each set of actions is defined as a plan. A group of “good” plans is the outcome of the optimization model and input of the MCDA.

4.2 Attributes and Criteria

A set number of attributes characterizes each action. Attributes have to be maximized (benefit-like attributes) or minimized (cost-like attributes).

Some attributes (e.g. the social benefits) are qualitative attributes. The transformation to numeric values (for quantitative analysis) has to be done involving experts. The attributes are the main inputs of the optimization algorithm: their definition plays thus a crucial role in determining the results.

Criteria are used to compare and evaluate potential alternative plans.

4.3 Constraints

The alternatives that will be generated might have to respect some constraints. For some attributes, alternatives might simply need to respect a given constraint value instead of targeting optimal values. Two typical examples refer to “costs” and “time”, which in some cases have not to be minimized but rather to be kept lower than a certain value, i.e. the available budget and the maximum available time.

4.4 Relations between Actions

Synergies between Actions

The framework considers the synergies between pairs of actions. A synergy happens when the joint development of two actions leads to a better performance (positive synergy) or to a weaker performance (negative synergy) (e.g. jointly developing a road and a cycle path can lead to a positive synergy from the point of view of the costs).

Synergies between actions (all the feasible pairs) are evaluated with the help of experts using ad hoc questionnaires.

Precedence between Actions

Precedence relations between actions are also considered in the model. Two kinds of precedence relations are included: a temporal precedence and a conditional precedence. Each pair of actions can have a temporal and/or a conditional precedence relation.

The *temporal precedence* implies that, for example, if two actions A and B are selected to form an alternative plan, B can be developed only after A has been completed.

The *conditional precedence* means that action B can be included in an alternative only if action A is present as well.

4.5 Solution of the Problem in 2 Steps

The problem is solved in two steps. Initially, a set of “good” alternative plans is generated through an operational research method, based on the Knapsack model (step 1). These alternative plans are then evaluated, ranked and selected through Multi Criteria Decision Aiding methods (step 2).

Step 1: Alternatives’ Generation

The solution to the problem would be a plan (a set of actions) that maximizes the benefit-like attributes, minimize the cost-like attributes and respects all the constraints.

In general, multi-objective problems don’t have a unique optimal solution, but rather a multi-dimensional Pareto frontier, which is the set of a large number of optimal solutions. This set of solutions can be difficult to show and to explain to the stakeholders involved in the evaluation step.

In order to limit the number of alternatives to be generated and to thus simplify the evaluation step, the optimizations are performed selecting two attributes at a time: each optimization process uses an attribute as a constraint and a second attribute as an objective function. This approach is known as the Knapsack algorithm (Feuerman and Harvey, 1973; Zhong and Young, 2010).

Within such a formalization, given an ordered pair of actions, a single solution can be found, i.e. the set of actions that respects the constraint and maximizes the objective function. That means that in a problem with n attributes, $n*(n-1)$ solutions can be found. This Knapsack approach requires a low computational effort and can thus be applied to problems characterized by a large set of actions. The drawback is that this algorithm finds only a “near-best” solution.

Benchmark with the full calculation approach

The full calculation approach would allow to investigate all the combinations of actions (plans) and so to find the optimal solution. This approach would allow to find the ranking of all the possible solutions instead of the “near-best” one only. The drawback is a high computational effort which limits the operability of the approach when actions are more than 20. In this application, the full calculation approach is used to produce a benchmark for the alternatives found by the Knapsack algorithm and test its ability to find the best solutions.

Step 2: Evaluation

To compare the options (plans) identified in the previous Section, we used multi-attribute value theory (MAVT) (Keeney and Raiffa, 1976; Belton, 1999; De Toro and Iodice, 2016). MAVT allows to rank the options by assigning to each one a global value based on its scores with respect to a selected set of criteria. The preferences of the decision-makers are expressed with criteria weights, which are scaling factors between the criteria, and value functions, which represent the level of satisfaction about the criteria scores.

The evaluation step is performed by considering all the available criteria, while the generation step considers only 2 attributes at a time.

5 The Methodological Proposal in Practice

The evaluation framework has been tested on a pilot case study of urban regeneration in the city of Milan (Italy). The area of Bovisa, located in the north west part of the city, has been selected among the areas currently under development since a recent competition has encouraged the definition of several requalification proposals, that can be considered as systems of elementary actions. Given the limited availability of economic resources', it is crucial to select a set of actions able to foster development over time. The proposal used to test the evaluation framework is the most consistent with the notion of urban catalyst, as it is aimed at the definition of coalitions of elementary actions selected with respect to their mutual synergies.

5.1 The Bovisa case study

Bovisa is a strategic area, both from the size point of view, as it covers approximately 87 hectares, and from the accessibility point of view, thanks to the presence of two regional and inter-regional railway stations (FNM Bovisa and Villapizzzone). Bovisa is located along the axis that connects the Expo area with the new district of Garibaldi and Porta Nuova (see Figure 1).

The site is a kind of enclave within the city, with several signs of its former industrial use. Thus, its environmental remediation and redevelopment is part of the larger development strategy of the entire city.

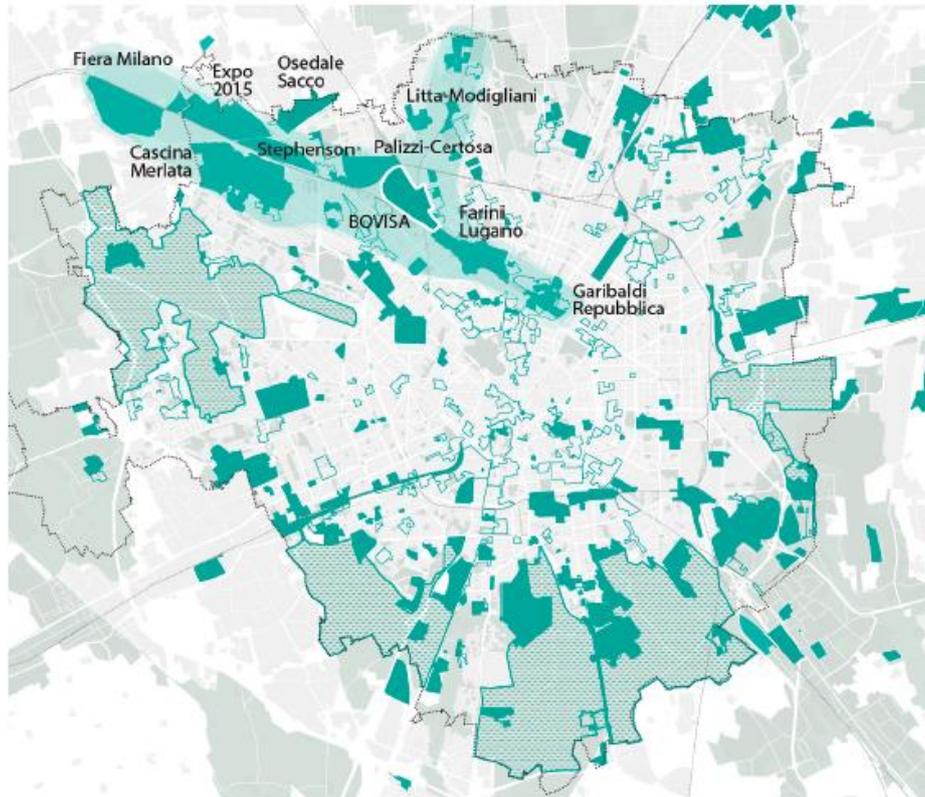


Figure 1. The area of Bovisa and the surrounding recent and on-going urban developments. Source: Verso le Nuove Municipalità un atlante, Comune di Milano, Politecnico di Milano DASTU, 2013.

In particular, Bovisa is characterized by the presence of the late nineteenth century urban structure made by small and medium-sized industrial and crafts buildings together with several residential buildings. Starting from the late '70s many industrial buildings have been abandoned or turned into smaller and fragmented workspaces with a progressive expansion of residential use.

The replacement process over the years has been carried out without an overall redesign of the districts. Actually, small industrial activities still coexist with multi-store residential buildings from the early Twenties. Over the last decades a key role has been played by the Politecnico di Milano and the Mario Negri research center with their support related activities. Figure 2 shows that, with the exception of these two large-scale functions, there is a shortage of quality services to the people, as well as of green areas.

The “drop” shaped Bovisa area, limited by the railway, represents a gap between the surrounding residential districts because of the lack of accesses, links and cycle-pedestrian lines. Even though Bovisa is one of the most easily accessible areas by the regional

rail network, the two existing railway stations should be connected to the urban public transport system.

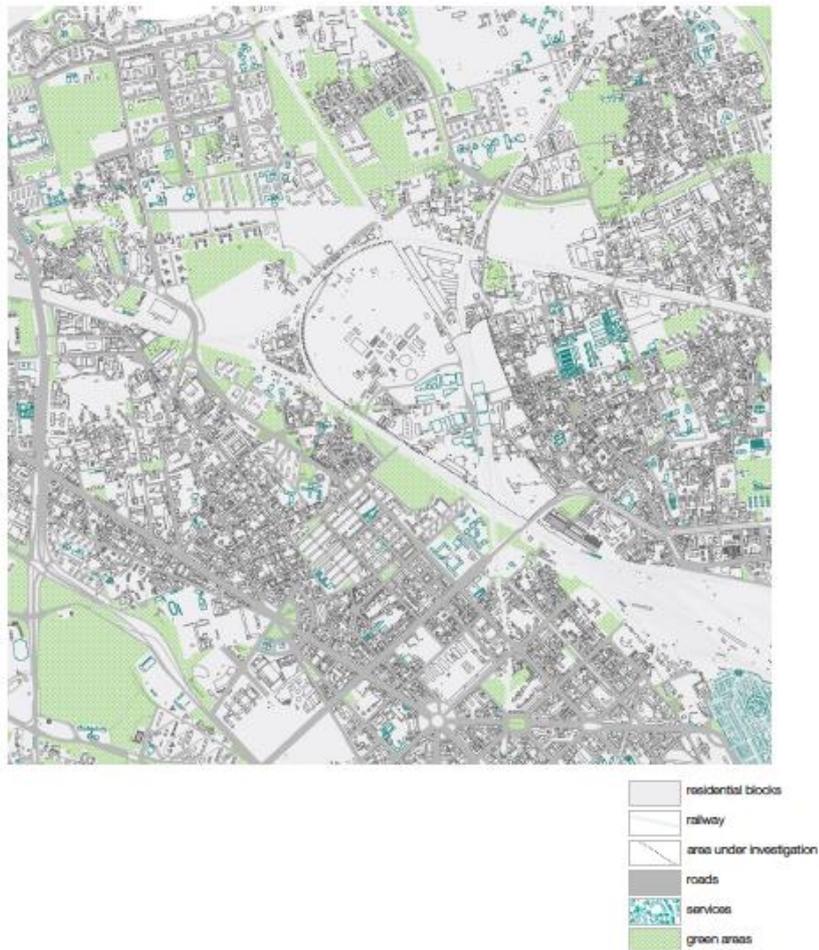


Figure 2. Territorial situation of the Bovisa area. Source: Carta tecnica comunale, 2006.

The territorial system under analysis thus represents an integrated and multifunctional urban area, able to create synergies among the strategic functions related to university and research and the residential blocks. Particular attention has been paid to the timeline of the development process and its feasibility. Different functional scenarios have been defined by combining flexibility and adaptive reuse (Figure 3). The basic idea of this proposal is that it is possible to manage urban transformations through the development of spatial elements, whose uses can change over time according to a principle of rotation.

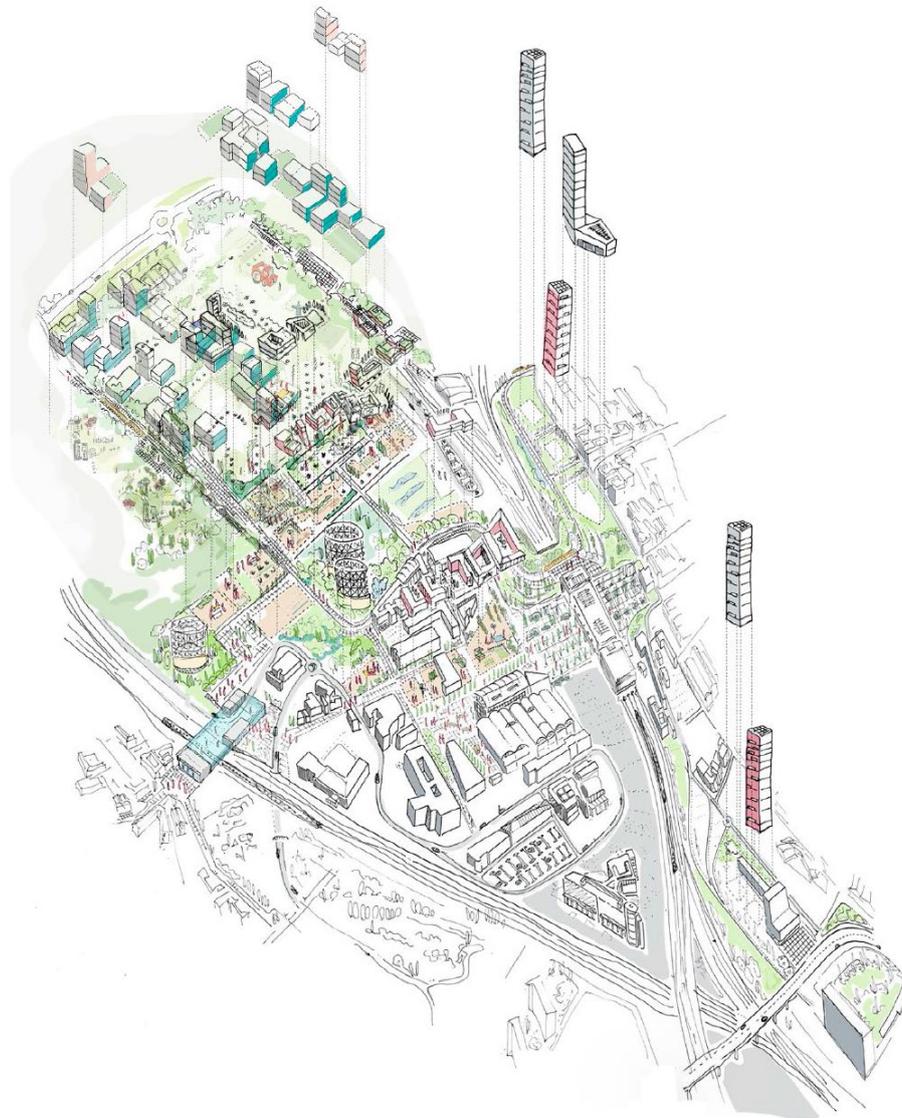


Figure 3. The proposal for the development of Bovisa selected to test the evaluation framework. Bovisa Call for Ideas, Politecnico of Milano, 2016, Proposal: “Bovisa Connection. Tasselli urbani per scenari resilienti”, Team leader: Andrea Arcidiacono.

5.1 Results

The set of actions proposed for the Bovisa case study are listed in the following tables. The actions are 18 and are grouped according to 3 main themes:

- A) Infrastructures
- B) Built environment
- C) Green space

Four attributes (n=4) are defined for the generation of alternatives: Economic feasibility (eco), Technical feasibility (tec), Social-Environmental feasibility (soc-env) and Costs (cost).

As described above, in order to limit the number of alternatives generated and to facilitate the evaluation step, the optimizations are performed selecting two attributes at a time: each optimization process uses an attribute as a constraint and a second attribute as an objective function. Given an ordered pair, a single solution exists, i.e. the set of actions that respects the constraint and maximizes the objective function.

Thus, ($n*(n-1) = 12$) alternatives (Alt_1, ... , Alt_12) have been generated for the Bovisa case study through the proposed approach (Table 1). The actions contributing to the creation of optimal alternatives taking into account a pair of attributes at a time (one as a constraint and one as an objective function) are highlighted in green.

Table 1. Alternatives generated for the Bovisa development

		Constrain	eco	tec	eco	soc-env	eco	cost	tec	soc-env	tec	cost	soc-env	cost
			tec	eco	soc-env	eco	cost	eco	soc-env	tec	cost	tec	cost	soc-env
A-Infrastructures	A2	railway station												
	A3	existing railway station dev												
	A4	bicycle path												
	A5	road												
	A6.1	parking_a												
	A6.2	parking_b												
	A6.3	parking_c												
A7	viaduct													
B-Built environment	B4.1	old buildings rehabilitation												
	B4.2	old buildings rehabilitation												
	B4.3	old buildings rehabilitation												
	B4.4	old buildings rehabilitation												
	B4.5	old buildings rehabilitation												
C-Green	C1	green_a												
	C2	green_b												
	C3	public space												
	C4	park												
	C5	green_c												
Generated alternative			Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6	Alt_7	Alt_8	Alt_9	Alt_10	Alt_11	Alt_12

The generated alternatives are composed of a minimum number of 4 actions (Alt_4) to a maximum of 13 actions (Alt_6, Alt_10, Alt_12).

The results of the generation step are inputs for the evaluation step. Synergies (expressed by experts, as significant interplays between pairs of actions in relation to individual attributes) contribute to increase/decrease the performance of the actions in relation to the attributes. In the generation step, when the algorithm considers elementary actions, it also considers pairs of actions and their positive/negative synergies, increasing/decreasing their performances. For the evaluation step the criteria are the same as the attributes selected for the generation step.

The evaluation is performed as follows: the performance of an alternative is calculated as the sum of the attributes of the actions that compose each alternative, taking in account existing synergies. The values of the criteria are then transformed through value functions. These functions assign the value 1 to the best performance of an action, if the attribute is a benefit-like one, or to the worst performance of an action, if the attribute is a cost-like one. The four value functions (i.e. one for each attribute) are then aggregated using the relative weights to obtain an overall score for each single alternative. For this pilot case study, weights are considered homogeneous across the attributes for providing a neutral scenario. The sensitivity analysis on weights should be introduced according to the stakeholders' involvement in order to explore the effects on ranking of their preferences.

The final result of the evaluation is a ranking of the 12 alternatives, as shown in Figure 4.

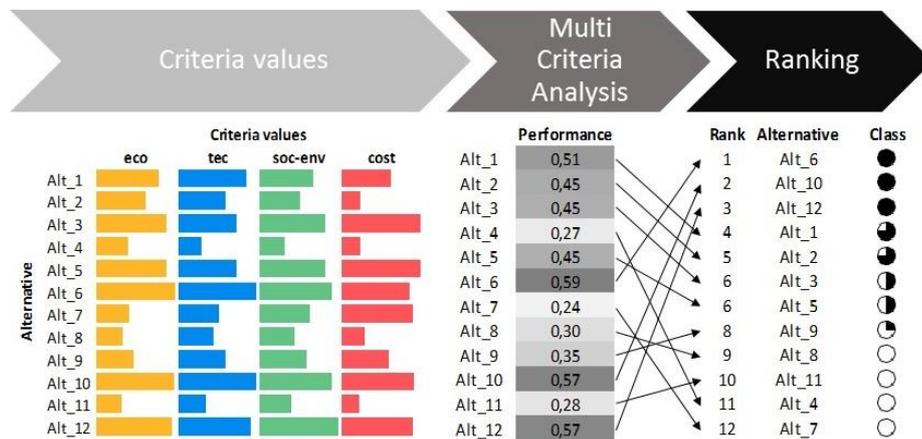


Figure 4. Ranking of the 12 alternatives.

A crucial aspect of the above described procedure consists in the elicitation of both value functions and weights. For the Bovisa case study this elicitation was performed by interviewing experts.

6 Discussion and Conclusions

The results of the first practical test of the evaluation framework seem to support the generation and the ranking of coalitions of elementary actions whose synergies have been evaluated with respect to a set of both qualitative and quantitative criteria. The decision about which coalitions of actions should be developed in order to maximize benefits, given limited economic resources, is supported by an evaluation process based on value judgments. Despite the approximations due to the limited involvement of real stakeholders and to the limited availability of data on the actions, the notions of urban

acupuncture and urban catalyst have been modeled and the complexity given by the coexistence of several interventions to be combined has been reduced by the use of the multi knapsack approach.

This approximations reflect the usual characteristics of urban development projects, i.e. limited time availability, presence of multiple and conflicting interests, need for tools able to support decision makers' understanding and development of arguments for the decision. Further developments of the model refer to: (i) implementation of a dynamic sensitivity analysis, to investigate the robustness of the results, (ii) refinement of actions' performances evaluation, (iii) deeper investigation of synergies (among functions, stakeholders, resources, thematic issues) and value functions. Synergies, in particular, require to be mapped and to be monitored over time as they are considered key drivers for successful urban development. To this end, the introduction of Geographic Information Systems could support a multilayer analysis of synergies and provide a sound basis for evaluation over time (for example in the implementation of monitoring systems and/or as a tool for performance evaluation of both the choices related to different time horizons and the deviations from predictions).

Finally, the application of the model on the Bovisa area represents a preliminary test to investigate the operability of the model. Further applications of the model are envisaged by the authors in decision-making contexts where elementary actions can be identified and be jointly developed.

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