Green Energy and Technology

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Values and Functions for Future Cities

Springer

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Preface

Towards Sustainable Cities and Communities

Several emerging issues are becoming more and more important in the context of the analysis of urban and territorial processes.

Firstly, mention has to be made to the urbanization phenomena that are currently taking place in the whole planet, leading to a situation in which the number of people living in cities has overcome the rural population.

Secondly, according to the United Nations estimations in the next future, large migrations will affect territories all around the world, especially from the sub-Saharan and Northern Africa regions which are also characterized by the presence of environmental refugees.

Thirdly, the population is going to increase and the number of world inhabitants is expected to be 9 billion by the year 2050.

In the front of the aforementioned data, it becomes urgent to understand if the environment and the ecosystems will be able to tolerate these increasing anthropic pressures. In this sense, we have to recognize that we are living in a new era that the geologists have called Anthropocene. According to the Nobel Prize Scientist Paul Crutzen, the Anthropocene defines the Earth's most recent geologic time period as being human-influenced, based on the global evidence that atmospheric, geologic, hydrologic, biospheric and other Earth system processes are now altered by the presence of humans.

The discourse on Anthropocene highlights the existence of specific environmental urgencies related to the availability of natural resources, such as soil, water, air, that are fundamental for the production of energy and food and for the conservation of the biodiversity.

In order to respond to these urgencies, specific policies are taken place, such as the Sustainable Development Goals (SDGs) defined in the Agenda 2030 issued by the United Nations in 2015. SDGs aim at achieving a better and more sustainable future for all; to this purpose, they address the global challenges focusing on poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. Of particular importance in the context of urban and territorial transformations is the Sustainable Development Goal 11 related to sustainable cities and communities whose target is to “make cities and human settlements inclusive, safe, resilient, and sustainable”. Here emerges the need for policies and strategies able to strengthen the resilience through concrete actions for the reduction of energy consumption, mitigation of pollution, social inclusion and creation of urban identity.

The proposed volume aims to contribute to the discussion, encouraging a reflection on the role of future cites in terms of sustainable development, with particular attention to the improvement of collective and individual well-being.

This volume comprises a selection of the best papers presented in two seminars of the Italian Real Estate Appraisal and Investment Decisions Society (SIEV) held in 2017 and 2018 in the context of the Urbanpromo Green events (Venezia, 21 September 2017; Venezia, 20 September 2018).

The contributions are here organized into three parts reflecting the main topics of the volume.

Part I, called “Sustainability Strategies and Human Well Being”, consists of seven contributions investigating innovative strategies and policies able to improve human comfort and well-being. Different integrated approaches are suggested providing reflections and proposals to tackle the vulnerability of both built environment and green areas. The relevance of the energy management also emerges in developing sustainable cities and communities.

Part II is composed by ten contributions under the subtitle “Environmental Improvement Benefits and Values Creation” and dealing with the current problem on how to properly measure the value generation and the benefits brought by efficient, sustainable and resilient spaces. The aforementioned contributions analyse the value creation question with a particular focus on private and collective benefits, energy efficiency and ecosystem services. Moreover, they propose interesting social and inclusive approaches basing on case studies.

Part III faces the topic of “Economics and Decision Making in Urban Regeneration” through nine contributions. They report case studies or methodological approaches to assess values and trade-offs within decision-making processes stressing the importance of the regeneration mechanisms supported by financial, social and multicriteria techniques.

The book is addressed to experts and scholars who work in the context of urban and territorial transformations and aims to encourage a multidisciplinary dialogue for shaping cities in the next future.

Turin, Italy Giulio Mondini

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Part I
Sustainability Strategies and Human Well Being

How to Revitalise a Historic District: A Stakeholders-Oriented Assessment Framework of Adaptive Reuse

Francesca Abastante, Isabella M. Lami and Beatrice Mecca

Abstract This research proposes an application of a MultiCriteria Decision Analysis (MCDA) in the adaptive reuse framework, which is able to structure the complex decision process required for the effective reuse of an historic district. Nowadays, many cities are facing an economic, financial, social and urban decline. This is particularly true when thinking about historic districts, which are usually characterized by high unique cultural values but, at the same time, show difficult characteristics in terms of comfort and security. Accordingly, the planning rules to be applied to the historic districts need to be re-written overcoming the traditional logics. The proposed adaptive reuse framework deals with the application of the Macbeth method. To properly test, develop and illustrate the framework we conducted an experimental validation through a case study: the urban regeneration of an historical district in Biella (Italy) starting from the adaptive reuse of an historic building.

Keywords Adaptive reuse · MCDA · Macbeth · Cohousing · Historic district

1 Introduction

"The days of easy growth in the world's cities are over": this was the title of McKinsey Global Institute Report in October 2016, showing that there is an expectation of a population decline (from 2015 to 2025) equal to 17% of large cities in developed regions and to 8% of all large cities. The main reasons of the phenomenon are two: (i) the aging and falling fertility rate; (ii) the waning rural to urban migration.

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In a more fragmented urban landscape, we are seeing not only stagnating towns, but also shrinking and abandoned cities. This phenomenon in Europe concerns some Countries more than others (i.e. Spain, Italy and Germany), as shown in Fig. 1. Those abandoned urban areas are often historic sites with an intrinsic and significant identity. According to ISTAT (2017) in Italy there are as many as 6000 abandoned villages.

Faced with this phenomenon, the reactions of Public Administrations (PA) range from simple resignation, to creative solutions as whole municipalities put up for sale for a symbolic price. Between these two extremes, the majority of municipalities are looking for sustainable solutions. The paper contributes to the latter, illustrating the application of a stakeholders-oriented assessment framework to tackle the problem of the reuse and valorisation of historic districts.

Address the problem in a perspective of adaptive reuse represents an increasing trend as strategy for existing buildings and is a form of sustainable urban regeneration (Young and Chan 2012).

In Italy, the protection and the conservation of the architectural heritage has been always considered a cultural imperative and, therefore, supported by institutional constraints. The consequent adaptation of this heritage makes the architecture a window to the past and the maximal present potential for social practices, improving the living standards within a community (Dyson et al. 2016).

While in the past the concept of adaptive reuse has been usually related to the industrial sites (Günçea and Mısırlısoya 2015), recently many interesting examples can be found in heritage districts, seeing them as opportunities rather than risks. The

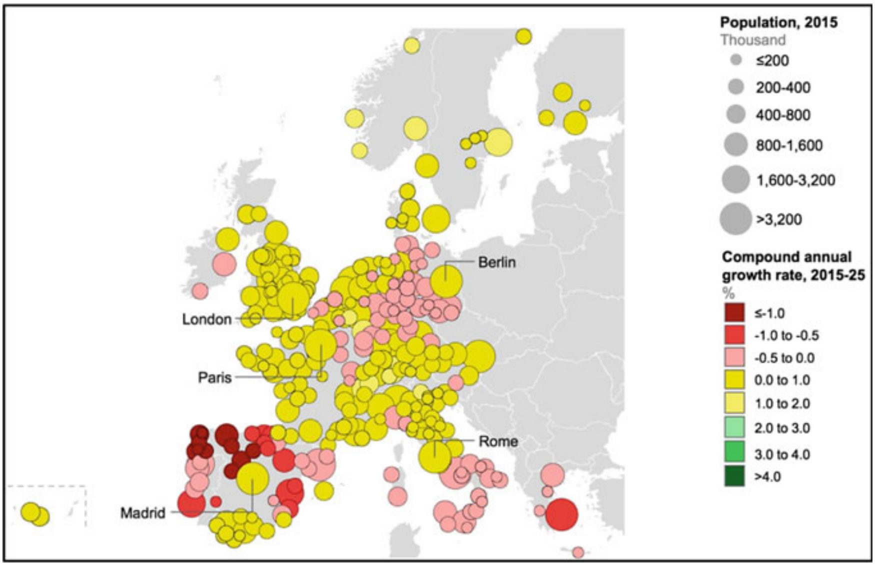

Fig. 1 Population 2015. *Source* The Guardian

adaptive reuse of heritage districts often proves better than demolition and reconstruction due to different reasons: it maintains the identity of the location (Geraedts et al. 2017) and strengthens the community feel by linking a city's past to its future (Robiglio 2016); it decreases the construction times affecting the overall construction costs (Douglas 2006) and it draws investments, as innovative activities are attracted by recovered historic buildings; Finally, it contributes to global climate protection and emission reduction (Elefante 2007).

However, an effective reuse of a district is a complex task. The multidimensional nature and the high complexity that characterises the definition of strategies for enhancing historic districts requires support for the structuring of problems (Abastante and Lami 2013; Abastante et al. 2018; Tavella and Lami 2018; Lami 2019), the development of alternative scenarios, the measurement of their impact and the identification of the most satisfactory solution.

Using an Italian case study, the paper shows the combination of different analyses on the territory and a MultiCriteria Decision Analysis (MCDA) (Figueira et al. 2005; Abastante and Lami 2012) to pick out crucial decisions related to the final destination of some spaces involving the community.

The paper is organised as follows. Section 2 provides a description of the theoretical aspects; Sect. 3 describes the case study while Sect. 4 illustrates the MCDA application discussing the valuation processes and the results obtained. Finally, conclusions and future developments are provided in Sect. 5.

2 Theoretical Framework

2.1 The Adaptive Reuse Concept

The first theoretical discussions on adaptive reuse began in the 19th century and allowed to define this practice in the late 20th century as a creative discipline with its own rights and theories in favour of the preservation of cultural heritage and to cope with the huge social, technological and environmental changes (Douglas 2006).

In general terms, it can be defined as the practice of introducing a new content in an existing container (i.e. building, infrastructure, area), paying particular attention to the needs of the society and following the principle of the maximum conservation and the minimum transformation (Robiglio 2016). Furthermore, the adaptive reuse stresses the need of avoiding the waste of energy and materials caused by new constructions and projects, preserving portion of urban landscape and offering new social and economic profits (Dewiyana et al. 2016). It is worth mentioning at least three reasons in favour of the adaptive reuse approach: (i) the adaptation of a building or an area is cheaper than proposing a brand-new project (Douglas 2006); (ii) it allows to preserve social, cultural and emotional values that the buildings or areas acquire through the years; (iii) the revitalization of a building or area in an urban abandoned district could encourage an upgrade of the whole urban section.

Operatively, for a valuable adaptive reuse able to meet the market demand and the lifestyle changes of the society, it is necessary to approach different analyses (Robiglio 2016). The first analysis suggested by the literature is related to the location of the building or area since it plays an important role: accessibility, connections, services of the area should be investigated in order to be aware of the opportunities and risks of the projects. The second analysis refers to the scale of intervention, which is usually defined according to the context and the goals of the project.

A third analysis is usually devoted to identify the potential of the building or area that need to be carefully maximized.

The final analysis provided by the adaptive reuse approach aims at investigate the local and global interests associated to the project in exam. Consequently, a stakeholders-oriented approach is required in order to understand the needs and expectations of the people affected by the transformation (Abastante et al. 2012; Lami and Abastante 2017; Abastante et al. 2019). With this regard, it is advisable to involve partners in the transformation project in order to make the abandoned and forgotten places known again by the communities (Németh and Langhorst 2013).

2.2 The Macbeth Method

The MCDA proposed in this research is called MACBETH (Bana e Costa and Vansnick 1997). The MACBETH is an interactive approach based on the Additive Value Model (Figueira et al. 2005) and the pairwise comparisons, which are easy to make, discuss, justify and agree on (Dyer and Forman 1992). According to Bana e Costa and Vansnick (1997) and Bana e Costa et al. (2010), the technical procedure supports the construction of numerical scales grounded on semantic judgements requested to the Decision Maker (DM), also used to determine the criteria weights. In this sense, the MACBETH method supports an interactive learning process about the problem and the elaboration of recommendations reducing the "cognitive discomfort" (Fasolo and Bana e Costa 2014) that could arise in the DM when he/she is asked to express his/her preferences in a numerical scale. Operatively, the MACBETH approach can be divided into three main phases: model structuring, model evaluating and analysis of the results.

The "model structuring" phase identifies all the options to be evaluated (understood as the alternative to solve the problem), their performances and the values of concerns of the problem in exam. The specific and clearly defined values of concerns are called "criteria nodes", while values with vague information, are called "non-criteria nodes". During the "model structuring" phase, all the aforementioned elements are visually represented in form of a tree, called "value-tree".

Lastly, the "model evaluating" phase involves a series of pairwise comparisons, where the DM is asked to specify the difference of attractiveness between the options with respect to the criteria nodes according to the following semantic categories of difference: extreme, very strong, strong, moderate, weak, very weak.

The options can be scored in two ways: directly comparing the options two at a time (direct comparison) or indirectly through the use of a value function built by comparing pre-defined performance levels rather than the options themselves (indirect comparison—for more details see Bana e Costa et al. 2010).

Once the model has been structured and filled in, the "analysis of the results" phase provided by the MACBETH method aims at reporting clear results in the form of ranking. During this phase, to provide a deep understanding of the problem, can be performed the sensitivity analysis in order to explore the extent to which conclusions can be drawn given varying amount of uncertain information (Bana e Costa et al. 2002).

The choice for applying the MACBETH method is due to a number of reasons. First it is a simple and understandable methodology even by those who are not experts in the decision process. This aspect is supported by numerous applications of the MACBETH method in different fields as: territorial planning projects and real estate market (Frenette et al. 2009; Abastante et al. 2017); education (Cuadrado and Gutiérrez Fernàndez 2013); waste management (Douhib 2014); energy consumption (Marques and Neves-Silva 2015).

Second, its technical parameters have a clear and easily explicable substantive interpretation allowing the processing of difficult problem of relative importance of the criteria in a precise way. Finally, it is a stakeholders-oriented and constructive method helping the DM ponder, communicate and discuss their values coming to robust and shared decisions.

In this sense, the MACBETH approach seems to be useful in assessing an urban regeneration problem on adaptive reuse concept, where the most variables under consideration are intrinsically qualitative.

3 Description of the Case Study

The "Piazzo" is a historic district of the city of Biella (Piedmont—Italy), which was founded in the XI century and in which the atmosphere is "frozen" to ancient times. The "Piazzo" district is well known in Italy for the highly valuable historic heritage, which comprises buildings of different centuries. Particularly, from the XVII century Nobles families modified the medieval lots into big palaces, today's public museum or cultural locations.

Despite the valuable characters of the historic area, the "Piazzo" district has faced a progressive depopulation starting from the XX century due to several reasons, not only connected to the general decline of Biella. Despite its panoramic location on the hill top of the city it has limited accessibility, that played an important role in the activation of the district isolation process.

The complicated road conformation is constituted by one main road longitudinally crossing the district and different small steep roads perpendicular to the main one and made of cobblestones (Fig. 2).

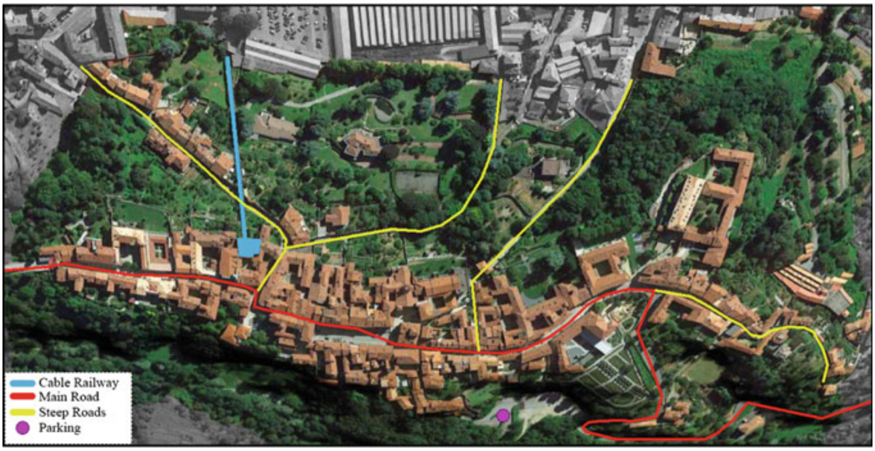

Fig. 2 Drivability scheme on the aerial view of the Piazzo district

It emerges that the road conformation is no more suitable for the current automotive traffic and private and public parking are almost absent in the district. Although the Administration of Biella tried to promote the “sustainable mobility” paradigm (Banister 2008) the only interesting and efficient alternative for the “Piazzo” district inhabitants is the still-working cable railway constructed in 1885, recently renewed in 2018.

A further element that has contributed to the depopulation of the district in exam is the current compact urban pattern, constituted by contiguous urban lots and which is almost unvaried from the XVII century.

Generally, the buildings are 4/5 floors characterised by facades of the XV and XVI centuries and the presence of basements and cellars. However, the rigid structure in bearing walls and the single wings make the distribution of the internal spaces very difficult to satisfy the current standards of comfort for the inhabitants. This contributed to hasten the state of abandonment of the district.

Finally, the abandonment of the “Piazzo” district increased further as a result of the financial crisis started in 2008, since which the economic and social de-growth involved the entire city of Biella.

In this panorama, it is important to notice that the interest in reactivate the “Piazzo” district has been showed in recent times by both, public entities as PA, private investors, real-estate companies, associations and freelancers. Those stakeholders are currently discussing about the best future for the “Piazzo” district.

3.1 Case Handling

After having framed the main intrinsic characters of the "Piazzo" district, we conducted different analyses devoted to understand the social dynamics of the territories, the lifestyle changes and the uses of the district. This constitutes a fundamental step to make a valuable adaptive reuse proposal for the relaunch of the district. In particular, those analyses are related to three main areas: demography, tourist flows, services and activities.

3.1.1 Demographic Analysis

Since the average age of the population strongly affects the decisions of new urban activities (Robiglio 2016), the first analysis conducted is the investigation of the demographic situation of the city of Biella (Fig. 3).

According to the data from ISTAT (2016), Biella reached the peak of population in the decade of greatest industrial fervor (1961–1971—54.076 inhabitants). From the following decades, a situation of progressive decreasing degeneration emerges up to attest to 44.733 inhabitants in 2016.

However, compared to the other two main cities in the Piedmont Region, Novara and Vercelli, Biella is the only one that is facing this general depopulation, due to the 2008 financial crisis and to the limited train's system connection with the main northern economic poles of Italy.

A further analysis conducted in terms of aging of the population (Fig. 3) highlights that more than half of the people living in Biella (28.475 inhabitants) is over 45 years old, indicating a non-favorable generational change due to a low birth rate together with the emigration of the younger groups. This perfectly reflects the current Italian trend in terms of average age: the Italian population is over 45 years (ISTAT 2017).

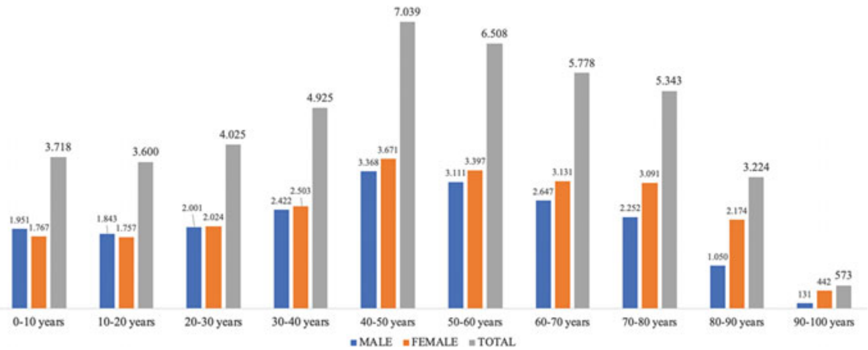

Fig. 3 Demographic analysis according to age and gender

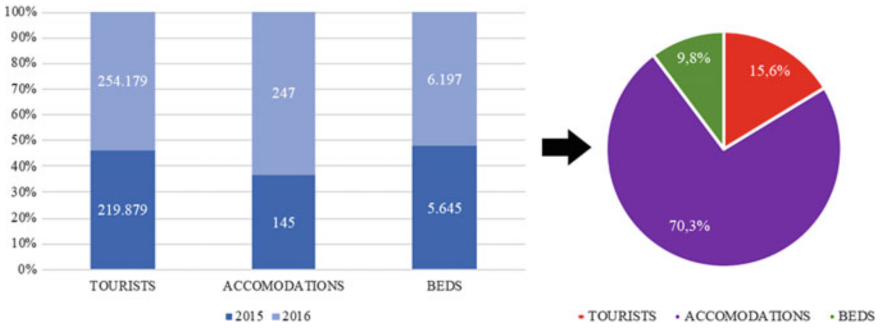

Fig. 4 Tourism flows

3.1.2 Tourist Flows Analysis

The second study reported is devoted to understand the tourist flows in the Piedmont region and, more specifically, in the city of Biella to identify new-possible functions for the historic district in exam.

According to the data reported by the ATL (Local Tourism Promotion Agencies 2018) in the decade 2006–2017, the tourists in the Piedmont region increased up to 23.3% thanks to foreign income. In particular, the number of tourists in Biella increased up to 15.6% in the 2016 being the second city of the Piedmont region in terms of tourism's raise (Fig. 4). This brought in turn to an increase terms of accommodation's offer (70.3%). However, the overall number of beds increased simply up to 9.8% (Fig. 4), suggesting the need for more beds in Biella.

Although a growing number of people prefer to stay overnight in extra hotels facilities, the number of beds that the city of Biella is able to offer in those kinds of accommodation is very low.

3.1.3 Services and Activities Analysis

The last analysis conducted aims at highlighting the current activities and services of the "Piazzo" district. This analysis has been fundamental to understand which kind of activities could contribute to enhance the interest of the possible inhabitants. Figure 5, it is possible to recognize the commercial activities as bars, a restaurant, a hairdresser and few small shops. The services for the population are scarce except for a nursery school, a kindergarten a cash machine.

As an attempt to regenerate the district, in the early 2000, the PA invested in the requalification of noble palaces to host permanent museums and temporary international exhibitions. This financial operation turned out to be successful since the number of visitors is increased.

Fig. 5 Map of the current activities

Two professional offices moved in the district contributing to the repopulation of the "Piazzo" district, thanks to the interesting policy of tax breaks and to the low rents promoted by PA.

A part from those weak but important incentives, the "Piazzo" district still appears as a desolate district in which there are no more activities and services for the population and the most residential buildings are currently empty and degraded.

3.2 The "Antoniani" Building—In the Piazzo District—As a Development Engine

After having conducted the analyses reported in Sect. 3.1, from an adaptive reuse perspective we were better situated to identify a pilot building that could act as an engine for the redevelopment of the district. The rationale of this point is directly related to the adaptive reuse perspective. According to the economic and social conditions, it is very unlikely to imagine the presence of a developer ready to invest on the whole district of Piazzo. It is more plausibile to hypothesise a series of small interesting interventions with a limited budget, but not "too unique" to allow a sort of replicability of the real estate operation. Clearly, this is a simplification because it does not consider the synergies arising from a valorisation of several buildings, but we think that is acceptable.

In this sense, among the numerous buildings currently unused in the district, we decided to analyze a specific one, the so-called "Antoniani" building for several reasons. First, it is located in a strategic position at the arrival of the cable railway, moreover it is near to the central square and five minutes' walk to the main services (Fig. 6).

Fig. 6 The “Antoniani” building

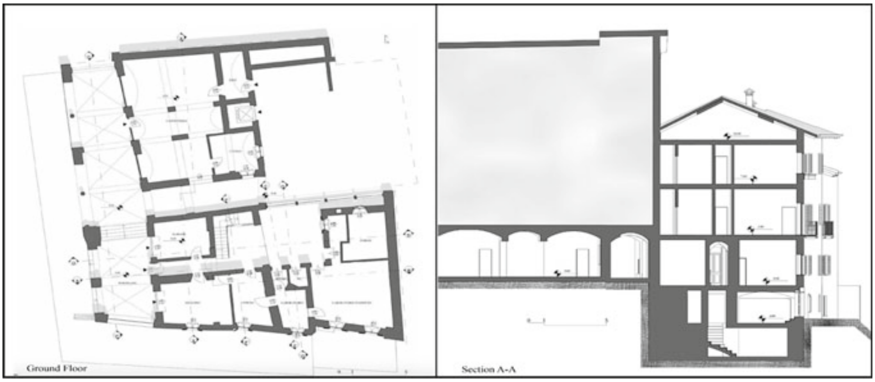

Fig. 7 Graphical documents of the “Antoniani” building

Second, the “Antoniani” building is a historic construction whose structural and distributive characteristics are similar to many other buildings in the district. This allows the possibility of replying in the district the idea of requalification proposed even if with different intended uses. In fact, it is composed by three floors above ground connected with a walkway distribution and structured in a regular mesh with beams and pillars, resulting in interior spaces of limited size (Fig. 7).

Third, the ground floor of the building directly communicates with the main road crossing the district. This aspect could constitute a high advantage in terms of possible activities and services for the population to be placed in (Fig. 8).

Finally, as suggested by Douglas (2006), it is possible to identify an adaptation scale in relation with the degree of transformation of the pre-existing building, namely: (a) small, that implies minimal interventions; (b) medium, which means changes in the internal schemes, structural alterations and important changes of use; (c) large, which sees strong spatial and structural changes.

In relation, we can place the “Antoniani” building transformation among the small/medium scale of impact. This aspect allows containing the financial and economic costs in a perspective of sustainable reuse.

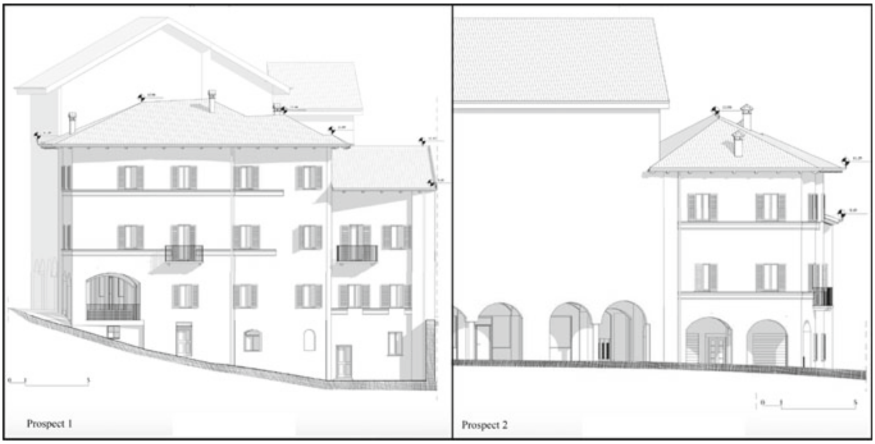

Fig. 8 The two main prospects of the “Antoniani” building

3.3 The Cohousing Vision

In order to properly requalify the “Antoniani” building we based on a design project of a cohousing, which represents a reaction to the contemporary social and environmental problems such as the changes of family structure, the hyper-isolation of individuals, the increasing stress level and the loss of face to face communication (Lietaert 2010). The choice of the cohousing is not casual but has been taken after a long discussion among the owners of the building, the PA and the designers. In fact, the cohousing is a peculiar form of living could be able to improve both residential and commercial attractiveness of the “Piazzo” district. Although in Italy is not regulated by dedicated institutional norms, in recent years, it contributed to the requalification of many abandoned buildings (Baratta et al. 2014) improving the sense of social cohesion. The cohousers are engaged to design the future community and to choose the services that satisfy their needs (Abastante and Lami 2012, 2014; Abastante 2016) in a collaborative process able to encourage the interdependence between residents.

One of the most interesting character of the cohousing is the coexistence of private units and collective (i.e. laundry, children’s room) and public spaces (Chiodelli and Baglione 2014). The latter are opened to the territory and managed by the cohousers in order to enhance the sense of community, involving also the district.

These public spaces are probably the most complex element during the design process since they have to be placed in functional zones, on the street side in order to be accessible from outside without overrun the private sphere.

For the requalification of the “Antoniani” building, we concentrated on the choice of the activities to be placed at the ground floor, using the MACBETH method as a stakeholders-oriented approach involving the community of the “Piazzo” and some possible future cohousers.

4 Macbeth Application

4.1 Definition of the Alternative Options

In order to properly apply the MACBETH method, it was first necessary to identify the possible alternative functions to be proposed as public activities managed by the future cohousers of the "Antoniani" building.

First, a literature review as well as different studies of the existing cohousing in Italy have been performed (Lietaert 2010; Housing Lab 2018) to identify the most widespread functions open to the territories.

These resulted in a number of possible functions as: swimming pool, kindergarten, bars, pubs, shops, gym, after-school activities, multipurpose big hall, spa services and library.

Second, we verified the compatibility of the identified functions in terms of size and availability of spaces in the "Antoniani" building. Accordingly, the swimming pool and the gym have been eliminated from the analysis. Moreover, it emerged that the ground floor of the "Antoniani" building is suitable for hosting a maximum of three different functions.

Finally, we crossed the possible alternative options with the empirical analysis of the territory reported in Sect. 3, in order to exclude the not useful functions, as the kindergarten that is already present in the district.

According to those observations, the alternative options considered in the MACBETH application are 13 (Tables 1)

4.2 Definition of the Criteria Nodes

After having identified the possible alternative options for the case study in exam, it was necessary to choose a coherent set of criteria nodes to properly describe and evaluate the 13 options.

The criteria nodes were defined with a series of interviews conducted with the PA and aimed at understanding the main desirable transformation drivers for the "Piazzo" district, considering also the point of view of the community.

After the discussions, the identified transformation drivers have been considered as the specific values of the evaluation defined as criteria nodes (Table 2).

4.3 Development of the Model

To apply the MACBETH method, we identified a heterogeneous interviewed sample. Accordingly, 45 subjects (representatives of users and bystanders of the "Piazzo" district) were selected paying particular attention to the balance in term of gender

(24 female and 21 male). The respondents were all among 23 and 70 years old. They were chosen in relation to the expertise on the four criteria nodes of the analysis (Table 3).

It is important to notice that the composition of the interviewed sample is aligned with the studies conducted and reported in Sect. 3. In fact, only a fifth of the people interviewed lives or works in the "Piazzo" district, while the others are bystanders.

After having identified the interviewed sample, we structured the decision problem through the M-MACBETH software (m-macbeth.com) obtaining 4 different questionnaires, one for each criterion node as well as 110 pairwise comparisons related both to the criteria nodes and to the alternative options. Each questionnaire was composed by two groups of questions. The first group of questions was devoted to acquire information about the ranking and weights of the criteria nodes. These questions were identical for all the questionnaires and were of the type:

(1/a) *Looking at the criteria node in exam, rank them from most preferred to least preferred.*

Table 1 Alternative functions as decision options

Alternative options	Description
Arts hall	Multifunctional room equipped for activities as painting and decoupage strictly linked to the identity of the territory
Theme bar	Bar and shop of local culinary products
Local textile shop	Small shop of local textile products
After-school activities	Activities for primary school children
Multimedia hall	Interactive room for different instruction uses
Small library	Small municipal library for primary school children
Meeting centre	Multifunctional room equipped with games for adolescents
Sport Pub	Pub in which it is possible to watch different sports games
Country club	Meeting room for sports clubs
Yoga/Pilates hall	Room equipped for yoga and Pilates activities
Photography club	Multifunctional room equipped for photography activities
Music Hall	Soundproof room for musical activities
Theatrical club	Multifunctional room equipped for theatrical activities

Table 2 Criteria nodes of the decision problem

Criteria nodes	Description
Tourism	Settlement of tourism attractions and activities and based on the local products
Didactic/Recreational	Settlement of functions related to the education and recreational fields for young people
Sport	Settlement of sport functions as fans clubs and spot associations
Socio/cultural	Settlement of flexible functions and activities, for cultural, social and entertainment enhancement

Table 3 Characters of the interviewed sample

	Gender		Why he/she knows the district			
Expertise	Female	Male	Live	Work	Leisure	Total
Tourism	5	5	1	1	8	10
Didactic/recreational	8	3	2	2	7	11
Sport	4	7	1	0	10	11
Socio/cultural	7	6	1	0	12	13
Total	24	21	5	3	37	45

(1/b) *According to the rank so far provided, to what extent do you prefer one criterion node to another? Please provide an answer using the semantic categories.*

The second group of questions was different in each questionnaire and was devoted to acquire information about the ranking and weights of the alternative options.

The questions related to a specific criterion node were of the type:

(1/a) *With respect to the criterion node "Tourism", which alternative option do you prefer? Rank the alternative options from most preferred to least preferred.*

(1/b) *According to the rank so far provided, to what extent do you prefer one alternative option to another? Please provide an answer using the semantic categories.*

All the answers provided by the interviewed sample, were then collected and aggregated in order to properly fill in the pairwise comparison's matrices required by the MACBETH model.

Among the numerous methods for the aggregation suggested by the literature, we decided to apply the Arithmetic Average on the basis of the majority (for more details we refer to Abastante et al. 2017). The answers were then inserted into the M-MACBETH software in order to provide a ranking in terms of most interesting criteria nodes to be considered for the design of the cohousing (Fig. 9).

According to the answers provided by the respondents, the most interesting criteria node turned out to be the "tourism" promotion (46.43%) followed by the "didactic/recreational" activities (32.14%). Those results are in line with the studies and analyses previously conducted in which emerges that the tourism activities could be

Table 4 Partial and overall rankings of the alternative options expressed in percentage

Alternative options	Partial rankings				Overall
	Tourism	Didactic/recreational	Socio/cultural	Sport	
Arts hall	80.95	85.95	0	0	67.7
Thematic bar	55	15.23	0	0	31.59
Photography club	0	72.72	0	0	24.26
Music hall	0	50	0	0	16.68
Multimedia hall	0	0	80.95	0	11.91
Theatrical club	0	35.47	0	0	11.83
Meeting center	0	0	60.95	0	9.72
Local textile shop	20.12	0	0	0	9.69
After-school activities	0	0	35.95	0	5.28
Sport pub	0	0	0	85.71	3.17
Country club	0	0	0	60.95	2.25
Small library	0	0	10.71	0	1.57
Yoga/Pilates hall	0	0	0	40.23	1.48

a huge economic opportunity for the district. On the contrary, the "socio/cultural" activities and the "sport" functions are not considered fundamental for the adaptive reuse of the district (18.86 and 3.57% respectively). In terms of most interesting activities for the territory of the "Piazzo" district, the results obtained thought the Macbeth method are reported in Table 4.

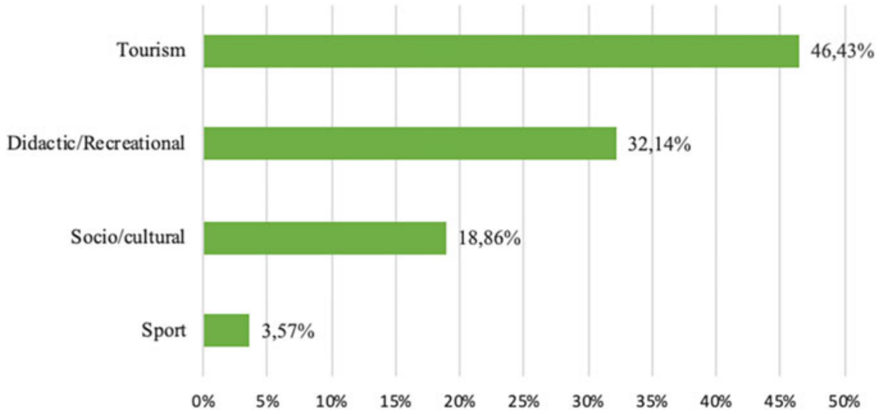

Fig. 9 Ranking of the criteria nodes

The partial ranking highlights the most interesting options for every criteria node, respectively: “arts hall” for tourism and didactical/recreational, “multimedia hall” for socio/cultural and “sport pub” for sport.

Combining the partial rankings with the criteria nodes we obtain the over-all ranking and the three functions for the cohousing in the “Antoniani” building: the “arts hall” with 67.7%, the “thematic bar” with 31.6% and the “photography club” with 24.6%.

5 Conclusions

The paper proposes the use of a stakeholders-oriented assessment framework to help the PA and the private developers for developing strategies to revitalize historic districts.

The framework proposed aims to be adaptive and sustainable, in both ways: in the use of the buildings and in the preparation of the assessment itself. As for the latter, the hypothesis is to use as much as possible the data generally available to any European country on national, regional and local level. The next step is a carefully understanding of the potentialities of the district, to promote its maximum conservation, introducing a new content in an adaptive reuse perspective. The elements collected can be systemized and compared through the application of a MCDA. In the paper we showed the use of MACBETH, which is a simple and understandable methodology, whose technical parameters have a clear and easily interpretation, and helps the DM to reach robust and shared decisions.

To show the potential of the assessment framework, the method has been applied to an Italian case study, the “Piazzo” district in Biella. The analyses of the context were made on the entire district of the “Piazzo”, while the assessment of adaptive reuse opportunities was limited to a single building in the historical area. As has been said previously a series of small interventions with a limited budget are more plausible than an investment on the whole district of “Piazzo”.

The application of the method showed that it is possible to obtain precise indications about the transformation for a building and at the same time more general indications for supporting a decision process, such as a ranking of the criteria.

It is important to underline that the research so far conducted has limitations and there is considerable potential for further work. The main limitation is that the data illustrated is taken from one case study, which limits the generalizability of the findings. However, we carried out a detailed methodological path to approach the realm of the adaptive reuse of an historical district, aimed at exploring a phenomenon in depth and generating insights of operational importance. We would recommend to future researchers to explore the possibility of analyzing more case studies and of applying a sensitivity and robustness analysis to the results obtained in order to verify the validity of the model.

Finally, it would be appropriate to probe the technical feasibility of the alternative options proposed. This would imply a further decision process with different stakeholders apart from the community and the future cohousers.

References

Abastante F (2016) Multicriteria decision methodologies supporting decision processes: empirical examples. Geam-Geoingegneria Ambientale E Mineraria-Geam-Geoengineering Environment Mining 149:5–18

Abastante F, Lami IM (2012) Quality function deployment (QFD) and analytic network process (ANP): an application to analyse a cohousing intervention. J Appl Oper Res 4(1):14–27

Abastante F, Lami IM (2012) A complex Analytic Network Process (ANP) network for analyzing Corridor24 alternative development strategies, Communications, Computing and Control Applications (CCCA), 2012 2nd International Conference on; Marseille; France; 6/8 December 2012; Code 95662 pp. 17–24

Abastante F, Lami IM (2013) An analytical model to evaluate a large scale urban design competition. GEAM, Geoingegneria Ambientale e Mineraria 139(2):27–36

Abastante F, Lami IM (2014) Decision making for urban solid waste treatment in the context of territorial conflict: can the Analytic Network Process help? Land Use Policy 41:11–20

Abastante F, Bottero M, Greco S, Lami IM (2012) A Dominance-based rough set approach model for selecting the location for a municipal solid waste plant. Geoingegneria Ambientale e Mineraria 3(137):43–54

Abastante F, Lami IM, Lombardi P (2017) An integrated participative spatial decision support system for smart energy urban scenarios: a financial and economic approach. Buildings 7(4):103

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2018) Choice architecture for architecture choices: evaluating social housing initiatives putting together a parsimonious AHP methodology and the Choquet integral. Land Use Policy 78:748–762

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2019) A new parsimonious AHP methodology: assigning priorities to many objects by comparing pairwise few reference objects. Expert Syst Appl 127(2019):109–120

Agenzia Territorio Locale Biella, Available online at: www.atl.biella.it. Accessed on 13 Sept 2018

Bana e Costa CA, Vansnick JC (1997) The MACBETH approach: basic ideas. In: Proceedings of the international conference on methods and applications of multicriteria decision making, pp 86–88

Bana e Costa CA, Correa EC, De Corte JM, Vansnick JC (2002) Facilitating bid evaluation in public call for tenders: a socio-technical approach. Omega 30(3):227–242

Bana e Costa CA, De Corte JM, Vansnick JC (2010) Macbeth: measuring attractiveness by a categorical based evaluation technique. In: Cochran JJ (ed) Wiley encyclopedia of operations research and management science. Wiley Online Library, Hoboken

Banister D (2008) The sustainable mobility paradigm. Transp Policy 15(2):73–80

Baratta AFL, Fanucci F, Gabriele S, Metta A, Montuori L, Palmieri V (2014) Cohousing. Programmi per la riqualificazione del patrimonio esistente, Università degli Studi Roma tre, Dipartimento di Architettura, Edizioni ETS, Pisa

Chiodelli F, Baglione V (2014) Living together privately: for a cautious reading of cohousing. Urban Res Pract 7(1):20–34

Cuadrado MR, Gutiérrez Fernández M (2013) Methodology to select the best business game in higher education. Am J Ind Bus Manag 3(7):589–594

Dewiyana E, Ibrahim N, Hidayah HN (2016) The green aspects of adaptive reuse of hotel Penaga. Procedia—Soc Behav Sci 222:631–643

Douglas J (2006) Building adaptation, 2nd edn. Butterworth-Heinemann

Douhib D (2014) An extension of MACBETH method for fuzzy environment to analyse alternatives in reverse logistics for automobile tire wastes. Omega 42(1):25–32
Dyer R, Forman E (1992) Group decision support with the analytic hierarchy process. Decis Support Syst 8(2):99–124
Dyson K, Matthews J, Love PED (2016) Critical success factors of adapting heritage buildings: an exploratory study. Built Environ Project Asset Manag 6(1):44–57
Elefante C (2007) The greenest building is… one that is already built. Forum J. 21(4):26. National Trust for Historic Preservation
Fasolo B, Bana e Costa CA (2014) Tailoring value elicitation to decision makers' numeracy and fluency: expressing value judgments in numbers or words. Omega 44:83–90
Figueira J, Greco S, Ehrgott M (2005) Multiple criteria decision analysis: state of the art surveys. Springer, Boston
Frenette CD, Beauregard R, Abi-Zeid I, Derome D, Salenikovich A (2009) Multicriteria decision analysis applied to the design of light-frame wood wall assem-blies. J Build Perform Simul 3(1):33–52
Geraedts RP, van der Voordt T, Remøy H (2017) Conversion potential assessment tools. In: Remøy H, Wilkinson S (eds) Building resilience in urban settlements through sustainable change of use. Wiley-Blackwell
Günçea K, Mısırlısoya D (2015) Questioning the adaptive reuse of industrial heritage and its interventions in the context of sustainability. Sociology 5(9):718–727
Housing Lab (2018) Available online at: http://www.housinglab.it/hlab/. Accessed on 13 Sept 2018
ISTAT Annual Report (2016) 299. ISBN: 978-88-458-1901-8
ISTAT Annual Report (2017) 266. ISBN: 978-88-458-1927-8
Lami IM (2019) The context of urban renewals as a "super-wicked" problem. Smart Innov Syst Technol 100:249–255
Lami IM, Abastante F (2017) Social Housing evaluation procedures: literature review and steps forward. Geam-Geoingegneria Ambientale E Mineraria-Geam-Geoengineering Environment and Mining 150:15–28
Lietaert M (2010) Cohousing's relevance to degrowth theories. J Clean Prod 18:576–580
Marques M, Neves-Silva R (2015) Decision support for energy savings and emissions trading in industry. J Clean Prod 88:105–115
McKinsey Global Institute Report (2019) Available at www.mckinsey.com/featured-insights/urbanization/urban-world-meeting-the-demographic-challenge-in-cities. Accessed on Jan 2019
M-Macbeth (2018) Available online at: www.m-macbeth.com. Accessed on June 2018
Németh J, Langhorst J (2013) Rethinking urban transformation: temporary uses for vacant land. Cities 40:143–150
Robiglio M (2016) The adaptive reuse toolkit. how cities can turn their industrial legacy into infrastructure for innovation and growth. Urban and regional Policy Paper, p 38
Tavella E, Lami IM (2018) Negotiation perspectives and values through soft OR in the context of urban renewal. J Oper Res Soc 1–26 (in press)
The Guardian, Available at www.theguardian.com/cities/gallery/2016/nov/02/global-population-decline-cities-mapped. Accessed on Jan 2019
Young EHK, Chan EHW (2012) Implementation challenges to the adaptive reuse of heritage buildings: towards the goals of sustainable, low carbon cities. Habitat Int 36(3):352–361

Energy Management in Hospitals: Evolution of a Methodology

Giovanna Acampa, Daniele Liberanome, Georgios Kalogeras, Christos Koulamas and Athanasios Kalogeras

Abstract The impact of properly managing energy in hospitals is significant, due to the high bills and polluting emissions, and is complex, due to the wide range of energy consuming equipment to be kept always running. Energy efficiency plans in hospitals, which are pivotal in the European wide effort to redevelop existing buildings, have to be carried out as a part of a wider redesign process and must encompass complex data analysis and modeling. Based on the activity carried out within the European funded project H2020/MSCA/STEER, this work elaborates on the methodology, as tested on a building information model of a health center in Sicily, to identify positive and negative aspects of energy-related technology options to keep hospitals efficient. The main steps of the methodology carried out in the health center were: (1) collect data and input it in a digital model; (2) create and test a simplified quasi-steady state model of the building; (3) create a dynamic simulation model of the building; (4) run dynamic and simplified model simulations of the energy performance of the building; (5) compare results obtained from the two models in various scenarios, showing that the relevant differences after indicative interventions and parameter changes are equivalent.

Keywords Quality buildings · Energy consumption · Evaluation methodologies · Hospital energy efficiency

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1 Introduction

The quality of the buildings that structure the physical space of a settlement is strictly related to the design process through which it is generated (Fattinnanzi et al. 2018). This process is similar both for designing new buildings and for redeveloping or renovating existing buildings. It can never be separated from the evaluation methodologies that allow to optimize the choices to be made to obtain quality in architecture. Until very recently, in the design process this integration was very difficult and complex while nowadays, owing to the widespread use of the BIM (Building Information Modeling) methodology, now well established across the European Community, it can be achieved more easily. The purpose of a building information model is to create a sharable 3D model of a building referred to a database, so that whoever is involved in the design process can easily manage the available data (Garagnani et al. 2011; Acampa et al. 2018). Thus, given that in Italy as in most European countries, economic and environmental sustainability is one of the prerequisites considered essential for the achievement of quality in buildings, we believe that defining useful methodologies for the energy requalification of buildings is particularly relevant.

The aim of this article is to illustrate a methodology to evaluate in advance the impact of energy efficiency plans on a set of peculiar buildings—existing hospitals, and on their energy consumption. The methodology was developed as part of the STEER (Support Tool for Energy Efficiency in medical centers) project[1] funded by the European Commission under the Horizon 2020 Marie Sklodowska-Curie 2014 call. It was run by a consortium formed jointly by companies working in the energy efficiency sector and research centers, which thus coupled day-to-day knowledge with a more theoretically sound approach. This methodology, which takes into account the processes that lead to high variations in consumption—such as seasonality, adaptation of existing structures to changes in profile of users and technological evolution of the equipment—allows to evaluate a priori potential efficiency measures, in order to select the most suitable redevelopment choice by comparing different intervention scenarios.

1.1 Quality in the Building Process

Quality in architecture (Forte 2012) is linked to a large number of factors and is a question that not only affects the relationship between the designer and the client but involves also the Authorities that in various ways intervene in the development of the building processes. An analysis carried out by studying the Regulations of the Member States of the European Union and a survey on the Calls for competitions held

[1] The project, that started on December 2014 and ended on November 2018, was run by a consortium formed by: Zephyro SpA (Italy), Politecnico di Milano (Italy), Afeka College University (Israel), Industrial System Institute (Greece), CTAdventure (Poland), Universitaet Bayreuth (Germany), Enertech Solutions (Italy), Meazon (Greece), Afeka Yssumim (Israel).

in recent years for the selection of architectural projects, showed that environmental and economic sustainability is one of the requirements held as most important.[2]

We should note that in Italy, as well as at European level, the increasing trend to reuse buildings and volumes already built is shifting the scope of design, from the construction of new buildings to the redevelopment of existing ones.[3] This coupled with the stringent regulations and goals set by various authorities in Europe aimed at reducing energy consumption and polluting emissions, means that energy efficiency projects on existing buildings are increasingly significant and popular.

Given that in the countries of the European Community some 15,000 buildings are used as hospitals or health facilities that operate 24/24 h 365 days a year, we understand that energy efficiency in hospitals is a pivotal issue in the overall redevelopment of the existing building stock, as it deals with a large sector.

Moreover, as 5% of the total emissions are thought to be generated by these structures, it is evident that they have a very significant impact on environmental quality and are strategically important to achieve the goal of reducing greenhouse gases and CO_2 emissions.[4] Nevertheless, the lack of economic and financial means to make the necessary investments in improving the hospitals' energy efficiency and the widespread belief that these actions are not part of the main activities of the "health system", brought to the consequence that rarely specific policies and programs for energy efficient hospitals are adopted.

Moreover, even when actions aimed specifically at health institutes are being implemented, too often they are carried out by professionals that do not interact as they should. The building envelope and the equipment are normally considered and treated by separated teams instead of being considered as a unique item in which the two aspects, architectural and technological are inextricably linked.

1.2 The Process of Redeveloping Buildings

The methodology presented in the present work becomes particularly significant if considered as part of a theoretical framework that seeks to organically insert the evaluation methodologies within the design process. Although dealing with a special case, namely hospitals, it is useful to put it into the context of a wider methodological approach that calls for the redevelopment of buildings with the aim of optimizing energy management.

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[2]This point was made by, Giovanna Acampa, in addressing an international conference on "Evaluation of quality in architectural design" held in Rome on October 22nd–23th _ To be published.

[3]In 2006, The European Parliament set the goal to reach zero soil consumption by 2050—Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions—Thematic Strategy for Soil Protection.

[4]https://noharm-europe.org/sites/default/files/documents-files/4746/HCWHEurope_Climate_Report_Dec2016.pdf.

1.3 Phases of the Design Process

The control mechanisms in the design process that allow to achieve quality in architecture have remained largely intuitive and therefore undefined and substantially unknown (Bentivegna 2015). Making the design process explicit, breaking it down into its fundamental phases, is a first useful step to understand the key points in which these mechanisms are put in place and in which it is possible or necessary to intervene by making choices (Fattinnanzi and Mondini 2015). For this reason, we outline the design process, where by design process we mean in our case the redevelopment of an old structure, by breaking it down into the following fundamental steps:

- Architectural survey or Building Information Model;
- Identification of the objectives and aims of the project;
- Verification of restrictions and constraints;
- Identification of resources needed to achieve the objectives;
- Analysis of the alternatives;
- Selection of the alternatives considered relevant (sufficiently good compared to the thresholds);
- Evaluation of alternatives using a system of predetermined criteria organized in an integrated system that will therefore assume a multi-criteria character;
- Choosing the solution considered to be the best in the specific situation.

When the objective is the energy requalification of a building, the team in charge of the process must necessarily be multidisciplinary even if coordinated by a figure with design skills. Once the whole set of constraints to be abided to and the amount of resources to be used are well known, this team will formulate various alternative ideas aimed at the technical/functional reorganizing of the activities. Any option deemed suitable to improve performance characteristics from the point of view of thermal comfort and energy savings must be compared with the other possible ones available and put in hierarchical order, according to a series of evaluation criteria. In this regard, the model developed makes it possible to run simulations and compare them, using the results to examine and put different solutions addressing the issue of consumption reduction in hierarchical order. It is therefore functional in the phase in which the evaluation must be carried out between alternative solutions.

2 The Methodology

STEER dealt with the issues related to energy efficiency processes in hospitals, providing the down-to-earth approach typical of companies involved in daily operations, with a sound theoretical expertise typical of research centers. Companies were mainly keen to investigate innovative solutions to run their pre-sales and sales process and to draw comprehensive energy efficiency plans in hospitals while reducing the risk related to the high investment required by those plans.

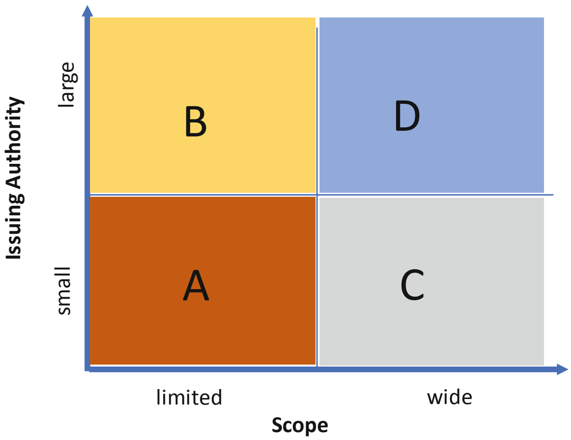
On the pre-sales and sales side, it should be considered that hospitals, being highly regulated entities, select through tenders the Energy Service Companies that support them in reducing polluting emissions and energy bills. The submission of offers in response to such tenders requires significant effort and cost. It is thus crucial to select appropriate tenders and targets before triggering the whole process of preparing a proposal.

We may categorize energy efficiency tenders in hospitals according to a two by two matrix (see Fig. 1). From one side of the matrix tenders are defined according to their Scope, on the other side according to the type of Issuing Authority.

As far as the Scope is concerned, contracts may include the supply of energy and/or maintenance and other services, which means that the company which is awarded the tender is then called to perform the energy efficiency project more freely, having to ensure that a certain reduction in energy bills and polluting emissions is achieved in ways which may also be loosely specified in the bid. Moreover, in this case, the projects' turnover is considerably higher, which means that companies are likely to get an easier access to credit and thus invest more heavily, but that they also have to submit guarantees that only large entities or group of entities can get from banks or insurance companies. On the other hand, companies may be asked to implement just a limited and well specified technical program and are rewarded according to the reduction in energy consumptions and emissions verified through well specified Measurement and Verification Plan[5] and the maintenance may continue to be carried out by the hospital's staff. In this case, the turnover and the guarantees required by tenders are of a smaller amount.

Looking at the matrix from the side of Issuing Authority, tenders may be issued by a large entity such as a Central Purchasing Unit (acting on behalf of a State or a Region or some other territorial entity which control the hospitals) and companies

Fig. 1 Matrix of the energy efficiency tenders



[5]Such Measurement & Verification Plans are increasingly prepared according to the so-called IPMVP protocol.

have to submit their offer to that Unit. Only at a second stage, the company that is awarded the tender applies to the hospitals to sign contracts with them, on the basis of the conditions set by the tender and according to the offer that the company submitted in response to it. This means that in the offer submitted to the Central Purchasing Unit, the energy efficiency program is loosely specified, because the object of the contract is not well defined. As the Central Purchasing Unit deals with a large number of hospitals, the turnover is again higher as the requested guarantees.

In other cases, it is a certain hospital or group of hospitals that issues the tender calling for companies to submit energy efficiency projects, which they are then called to implement by signing contracts with the hospitals that issued the tender. In these cases, the object of the tender tends to be better specified and the proposal to provide has to be better outlined and requires a higher level of technical analysis.

The wider the Scope (to include energy supply, maintenance and other services) and the larger the Issuing Authority (area D in Fig. 1), the larger the expected turnover and the higher the bank or insurance guarantees to submit. Such tenders are meant for large companies.

Tenders published by a large Issuing Authority having a limited Scope (area B in Fig. 1) are extremely rare, as it makes little sense that small tenders will be prepared by a large entity that is not aware of the specific hospital needs.

When a small Issuing Authority publishes a wide Scope tender (area C in Fig. 1), the companies' investment in time and resources in pre-tender phase to prepare the offer is quite significant, while the required insurance or bank guarantees are of a lower amount than in previous cases. These tenders may attract either large entities or smaller ones that have a good knowledge of the specific hospitals where services have to be supplied.

The pre-tender phase becomes even more cumbersome when a small Issuing Authority publishes a tender with wide Scope (area A Fig. 1), while the expected turnover and the required guaranties are low. Such tenders may often become unattractive especially for companies of any size which are not locally based.

The matrix above shows that companies that are neither very local, and thus not perfectly informed on the specific hospital structure, nor very large and financially sound to meet significant pre-tender expenses and submit high guarantees find it quite difficult to participate in most of the tenders. Small companies may easily participate to some, but will not be able to enlarge their activity beyond their local market.

Ultimately this means that the energy efficiency for hospitals sector is quite close and the competition there tends to be weak.

The STEER project aimed at giving some basic tools that can be easily used also by medium sized companies with little access to scientifically based analytic tools, supporting them in the decision to invest into an offer to submit a proposal under an energy efficiency tender, with special reference to those falling in areas A and C of the matrix at Fig. 1.

The goal was to quickly provide information on a hospital's ideal energy consumption in different scenarios and on the most appropriate energy reduction plan for the medium-long term. To that end, it was crucial to identify the main variables responsible for the energy consumption in hospitals and give to each of them a weight.

A novel mathematical model was created to reproduce energy consumption in given scenarios. On the basis of the above model, the consortium built a scenario-based assessment and prediction tool. The acquired knowledge and expertise were then embedded in a software prototype (E3s) to be used as a decision support tool.

The STEER project was thus divided into 5 main steps:

1. Collect and insert the required data in a digital model, focusing on the operational difficulties met in the specific case and on identifying both practical and theoretical methods to overcome possible lack of information.
2. Create a dynamic simulation model of the building, based on the collected data and using a popular energy simulation toolchain (OpenStudio and EnergyPlus).
3. Outline the results of the dynamic simulations, showing the effects of important variables and scenarios affecting the total energy consumption of the building.
4. Outline the static mathematical model by adapting it to the specific situation, through a "sterilization" of the effects of diversifying elements i.e. adopting standard/default values for parameters with no actual data or excluding extreme parameter values that drive the system outside the boundaries of realistic values.
5. Use the model to test possible interventions and obtain results that help identify positive and negative aspects of energy-related technology choices that will keep the hospital's efficiency up to date—including theoretical and practical issues.

2.1 Data Collection

The step (1) above, proved to be cumbersome, because of the amount of data that the consortium defined as necessary to collect—as listed in the "Hospital Energy Audit Form" that it published. The "Hospital Energy Audit Form" was prepared by the consortium using as reference forms from various European countries (namely Greece, Spain, Germany, Italy). It was prepared taking into account the "Guidelines on Data Management in Horizon 2020" to address ethical issues and European Parliament and Council Directive 95/46/EC of 24 October 1995 on the protection of individuals with regard to the processing of personal data and to the free movement of such data. The result was a quite extensive tool, divided into the following 8 macro categories:

1. Building General Data
2. Building Area, Use and Occupancy
   - Building use, Building area, Building Occupancy (Employees, Visitors, Patients).
3. Heating Ventilation Air Conditioning (HVAC) Systems
   - Heating systems, Cooling systems, Ventilation and air infiltration, HVAC distribution system, Hot Water production.

4. Building Envelope
   – External Walls, Beating Structure, Ceiling-Roof, Floor, Openings, Thermal Bridges, Zone Thermal Inertia.
5. Lighting System
   – Lighting System, Artificial Lighting System, On-Off control, Automation system.
6. Equipment
   – Medical Equipment, Laboratory Equipment, Office Equipment, Lifts, Other Equipment.
7. Energy consumption and costs
8. Data sources (mainly energy bills)
   – Electricity, Natural Gas, Diesel.

By filling the form duly and completely, it is possible to get an extensive picture of the energy consumption performance of a building.

Unfortunately, it proved quite complicated to do so in various hospitals, either because the required data was lacking or because it was considered confidential: very often data was available but not as complete, reliable and dense as necessary to duly fill the form. This was especially true for data from which one might infer the amount and quality of activity taking place in that hospital, such as the average number of in-patients and out-patients, or the number of MRIs (Magnetic Resonance Imaging) and high energy consuming analysis carried out. It would have been possible to collect the data first hand, but the required time and effort would have been significant and economically not viable within the framework of the project.

The strategy that the STEER consortium adopted to overcome these obstacles was multilevel.

First of all, the consortium tried to ease the procedure of data collection, by automatically gathering data from Internet—both from web sites and social networks. A significant part of Sects. 1, 2 and 3 could be filled this way.

Secondly, raw data collected was post-processed to normalize it and to reduce the empty information, using standard methods of cleaning such as linear interpolation. By using this methodology, another significant part of the information gap was bridged.

Thirdly, the consortium strove to get the support of other hospitals, as the test-health center located in Sicily, that was ready to fully cooperate and disclose all its available data, which was quite vast. This proved to be a crucial step, as the data thus collected was used to test the model once implemented.

2.2 Modelling Techniques

To estimate the energy profiles of hospitals by interpreting the data collected, a large variety of modelling techniques and methodologies can be adopted. We opted first for class of models derived through the physical approach (equations from conservation laws), that allow to start from some physical parameters and quantities of the building and of the technological plants and thus arrive to an estimation of energy consumption. More specifically, we decided to exploit two well-known models and software.

The first is an implementation of the standard ISO 13790:2008 (ISO 13790: International Standard 2008) which provides methods for the assessment of the annual energy needed for space heating and cooling in residential and non-residential buildings. It provides a simplified calculation-based approach, dividing the buildings into thermal zones according to specific criteria, relying on a set of algebraic models. The calculation of the energy includes:

1. Calculation of the heat transfer by transmission and ventilation of the building zone when heated or cooled to constant internal temperature.
2. Contribution of internal and solar heat gains to the building heat balance.
3. Yearly energy needs for heating and cooling to maintain the specified set-point temperatures in the building.
4. Yearly energy needs for heating and cooling of the building, using input from the relevant system standards referred to in ISO 13790 and more specifically in Annex A.

An extra effort and care had to be given in order to use the ISO International Standard in the context of the national or even regional rules and regulations. The gathering of all of the inputs required for the calculations, in case of existing buildings, may be too labor-intensive for the purpose. Therefore, a more simplified method based on default values can be adopted at national level.

We created a quasi-steady model in accordance with the ISO procedures, selecting the monthly method. For implementation purposes, the calculation process was broken down into separate procedures for heating and cooling. All the calculations have been implemented in Matrix Laboratory (MATLAB).[6] User input and other necessary data for calculations were imported in the form of MS Excel files.

The goal of the process is to calculate the energy need for heating and cooling per month for each building zone.

The calculation process was divided into 5 calculation blocks:

1. Total Heat Transfer by Transmission (Qtr(H/C),z,m) in MJ (H.1 or C.1)
2. Total Heat Transfer by Ventilation (Qve(H/C),z,m) in MJ (H.2 or C.2)
3. Total Internal Heat Gains (Qint(H/C),z,m) in MJ (H.3 or C.3)

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[6]More precisely, the model code was developed using the Matlab-code compatible GNU Octave (https://www.gnu.org/software/octave/).

4. Total Solar Heat Gains (Qsol(H/C),z,m) in MJ (H.4 or C.4)
5. Energy Need for Heating or Cooling (Qnd(H/C),z,m) in MJ (H.5 or C.5).

The first 4 blocks are the same for both heating and cooling mode calculations. The final block incorporates all the previous calculations into the total energy needed to heat or cool a specific building zone.

The implementation of ISO13790 model in MATLAB was verified against all 12 test cases presented in EN15265. A great number of simulations were run, in order to tune the algorithm as accurately as possible and the model generated satisfactory results, well within the acceptable boundaries set in EN15265 (CSN EN 15265 2007).

The second well-known software and model used is the EnergyPlus dynamic simulator. This wide-spread simulation environment was developed in USA as a joint effort of different entities (the National Renewable Energy Laboratory, the U.S. Department of Energy National Laboratories, academic institutions, and private companies). It is an open-source and free simulation software that engineers and researchers use to simulate the buildings electrical and gas energy consumption in the context of both technical equipment for heating, cooling, ventilation, lighting (including external and internal lighting), and plug and process loads and physical aspects such as the materials and dimension according to the weather condition (Bonnema et al. 2013; «Energy Plus» 2015).

The tool allows to emulate a hospital energy behavior with high-level details, in different climatic zones and with different structures. We used the tool to perform some basic sensitivity analysis, evaluate the main breakdown of costs, and generate data to derive simpler, more focused models (Moronis et al. 2017).

Both approaches have advantages and disadvantages over each other. The simplified calculation approach is simpler and has less number of inputs, is based on unambiguous and transparent calculation rules, while it provides an easy identification of correlation between inputs and outputs. On the other hand, the dynamic simulation approach may be used for transient simulations, is of high modeling capability, provides integrated performance assessment, and evaluates innovative design solutions.

A major outcome of the concurrent modelling and validation efforts was the conclusion that there is not any unique and simple close analytic form that can describe, at the same time, multiple buildings, in multiple conditions covering all possible interventions in its envelope, HVAC (Heating, Ventilation, Air Conditioning) system/plant structures and usage schedules and patterns. Furthermore, there is no approach, forward or reversed, that can suite all purposes during the planning and execution phases of an energy efficiency project.

Consequently, the results of the first phases of the STEER project include a wider approach, based on generic and interconnected models, with the implementation of the ISO-13790 model set at its core. Still, certain use cases such as HVAC sub-system interventions, either minor (e.g. tuning of the SAT set-point) or major (e.g. changing the structure and technology of the HVAC system or plant), need to be initiated from more complex approaches. These refer mainly to the usage of dynamic simulators, which may allow then the derivation of simpler and faster, building-specific, reversed, or hybrid models, for each particular case.

3 Application to a Real Case Study

The models were tested against data from a real health center, and for this purpose the consortium that developed STEER was joined by the Kore University. The facility selected is a health center accredited by the Regional Health System, located in Sicily, Italy. The main facility consists of one building that can be divided into 3 blocks, Left, Middle and Right. The building spans a total of 10,833.9 m^2 over 5 floors (including the basement and ground floor), yet data was collected regarding only a total of 4551 m^2.

The process carried out in the hospital and which are presented in this work, can be divided in the following steps:

1. Collect the data using the "Hospital Energy Audit Form" and insert the required data in a digital model.
2. Test the static ISO based model on the basis of the data collected.
3. Create a dynamic simulation model of the hospitals' building, based on the collected data and using a popular energy simulation toolchain (OpenStudio and EnergyPlus).
4. Run dynamic simulations of the energy performance of the virtual building showing the effects of important variables and scenarios affecting the total energy consumption of the building.
5. Compare results obtained with the ISO based and the Energy Plus models.

As for step (1), the health center administration was extremely helpful in providing all the necessary data and more specifically:

6. Areas with different usage ranging from operating rooms and medical facilities to kitchens and office spaces. We could collect figures of the total area of each type of room according to its use and the floor it is situated on, as well as the volume of every room.
7. Detailed description of the building envelope elements and the corresponding areas; for each floor and for each hospital's block, the area covered by each type of element divided into wall, concrete, doors, opening (glazing), floor, roof.
8. Heating, cooling and ventilation systems, for which the hospital technical department provided the list of setpoints according to the different sage of spaces (offices, operating rooms, wards, out-patients facilities etc.), days in the week (holidays, working days).[7]
9. Occupancy parameters, i.e. expected number of persons per area unit (m^2).

The only actual consumption measurement that could be collected is the total building electrical consumption, as it appears in the utility bills; a common case for the majority of hospital buildings that the project team had access to.

[7]It should be mentioned that the modelling work was based on data derived from the building audit and that there is some missing information in it, for instance related to rooms with IT servers and paper archives. This is one of the reasons that led the consortium to also develop a detailed dynamic model, in order to exploit comparisons based on the credibility of the EnergyPlus tool, even if certain modeling decisions may slightly depart from actual conditions.

The data was input in a BIM model of the hospital, as result of a study carried out by the Kore BIM Research Group focusing on existing structures having complex features. Modeling the energy system proved to be the most problematic phase, as it was hard to find the information useful for studying the energetic state of the structure. Specific data collection campaigns were organized for each electromechanical equipment of the HVAC system, creating an information database for the AHUs (Air Handling Units), chillers, heat pumps, fan coils. The information obtained is a combination of data obtained both from the design process in digital format and from site inspections. They are complementary: not being able to access in some areas, reserved only to authorized personnel, reference was made to the design data, and vice versa, the lack of design data forced a visual inspection of the machinery.

The creation of a dynamic model of a real building structure, involves multiple steps and can be at any level of detail, depending on requirements and trading off accuracy for execution time and complexity of the input parameter set. Having enough set of data for a mid-size real hospital allowed the creation of a model that could be cross-checked with the behavior of the building, calibrated against it and used to generate datasets or test other models, projecting the building operation in freely varying conditions.

It has been decided to create the most detailed model that was allowed by the available data, thus the starting point was the 3D model of the building's structure, spaces and envelope elements. This process was based on importing the AutoCAD 2D drawings of each floor into the Google SketchUp editor loaded with the NREL OpenStudio plugin, through which, the communication with the OpenStudio application (EnergyPlus GUI & front-end) was made possible (Koulamas et al. 2017)—see Fig. 2.

In parallel, the necessary input data was fed to the quasi steady state model, leading to the calibrated output presented in Fig. 3.

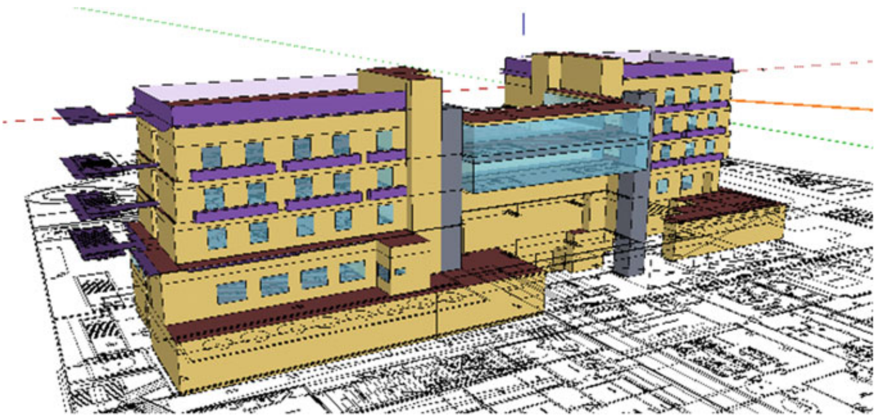

Fig. 2 OpenStudio/EnergyPlus model of the health center

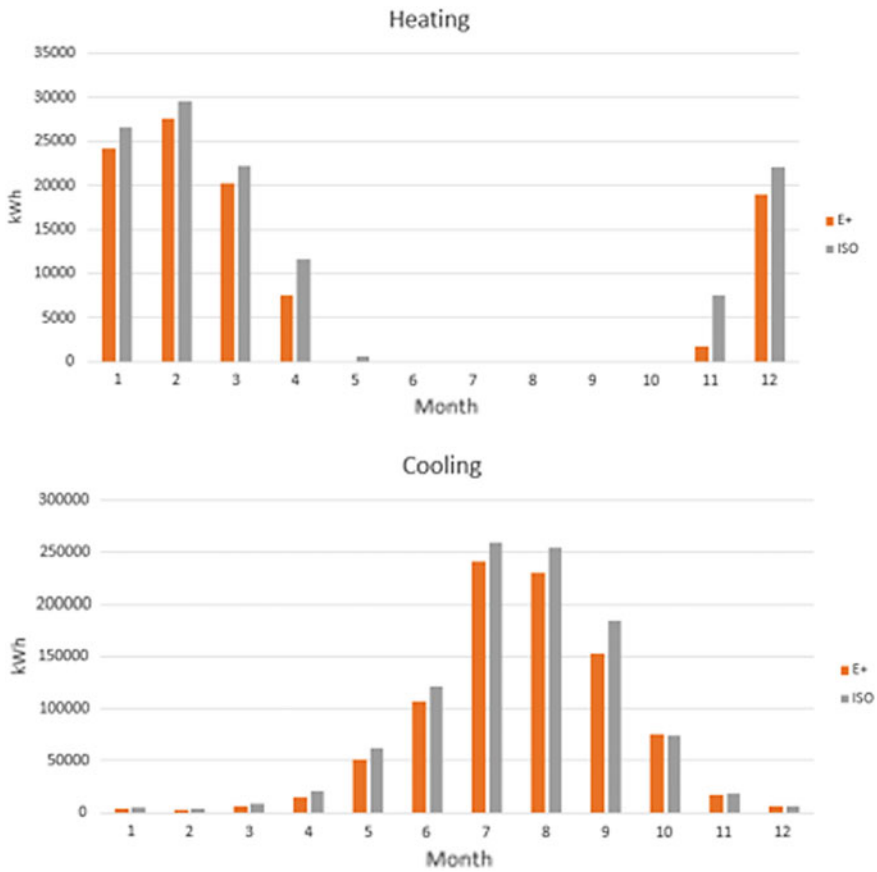

Fig. 3 Static versus dynamic model outputs

Apparently, the EnergyPlus model output compares fairly well with the static model implementation, however, there are certain cases (e.g. the heating energy in November) that show rather significant absolute differences.

Nevertheless, the context of the models' purpose in our case is not to predict the next month's consumption but to calculate amortization costs in a time depth of multiple years after specific interventions, and under the error metrics and guidelines of the standard itself.

Thus, by focusing on the annual differences after a test intervention, as percentages of the initial energy consumption, the two models become nearly equivalent in comparison, within a 5% error.

4 Conclusion

In conclusion, the models developed within the project STEER were validated also owing to the activity carried out in the health center in Sicily. Modelling an actual building and applying its real data and working conditions to the model made it possible to better understand the difficulties of the procedure and adjust the model to provide solutions to common problems, such us the lack of data in the early stages of proposing energy efficiency measures. The models can be considered a valuable tool for calculating the energy needs of heating and cooling at hospital buildings. The approach followed during the project can easily be generalized and used to model other building types in general, provided that building data about the specific building operation is available. The different simulations performed by the Energy-Plus dynamic simulator and the ISO based implementation make it possible to better understand relationships of variables and the influence of their change in the overall energy needs of the selected building. The proposed methodology and the created tool can therefore be used as a preliminary assessment mechanism to evaluate the energy saving potential of planned interventions, facilitating the work of professionals in the field of energy efficiency. The project outcome presents added value through the comparison of the two models. Cross-checking the extensive dynamic model against the static implementation allowed the researchers to narrow down the list of variables to a smaller and more easily manageable set, thus refining the static model and reducing the cost of performing a complete building simulation while achieving results that are well compared against well-known dynamic models.

References

Acampa G, Bona N, Grasso M, Ticali D (2018) 'BIM: building information modeling for infrstructures.' https://doi.org/10.1063/1.5079197

Bentivegna D (2015) 'Qui Si Parla Di Progetti, Valutazioni e Valutatori', Editoriale. In Valori e Valutazioni, Teorie Ed Esperienze, vol 6. DEI, Roma

Bonnema E, Leach M, Pless S (2013) Technical support document: development of the advanced energy design guide for large hospitals-50% energy savings. Natl Renew Energy Lab (NREL), Golden, CO (United States)

CSN EN 15265 (2007) Energy performance of buildings—calculation of energy needs for space heating and cooling using dynamic methods—general criteria and validation procedures

«Energy Plus» (2015) U.S. Department of Energy's (DOE) Building Technologies Office (BTO) and National Renewable Energy Laboratory (NREL), 2015. https://energyplus.net/

Fattinnanzi E, Acampa G, Forte F, Rocca F (2018) 'La Valutazione Complessiva Della Qualità Nel Progetto Di Architettura.' In: Valori e Valutazioni, Teorie Ed Esperienze, vol 21. DEI, Roma

Fattinnanzi E, Mondini G (2015) Analisi Multicriteri Tra Valutazione e Decisione. Dei, Roma

Forte F (2012) Il Valore Architettonico Di Un Immobile: Criterio e/o Obiettivo? VALORI E VALUTAZIONI 8:105–117

Garagnani S, Luciani SC, Mingucci R (2011) Building information modeling: La Tecnologia Digitale Al Servizio Del Progetto Di Architettura. DISEGNARECON 4(7):5–19

ISO 13790: International Standard (2008) 'Energy performance of buildings—calculation of energy use for space heating and cooling.' https://www.iso.org/standard/41974.html

Koulamas C, Moronis A, Kalogeras A, Liberanome D (2017) Choosing measures for energy efficient hospital buildings. In: 2017 22nd IEEE international conference on emerging technologies and factory automation (ETFA). IEEE, pp 1–7

Moronis A, Koulamas C, Kalogeras A (2017) Validation of a monthly Quasi-steady-state simulation model for the energy use in buildings. In: 2017 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA). IEEE, pp 1–6

Ecosystem Services: From Bio-physical to Economic Values

Marta Bottero, Marina Bravi, Carolina Giaimo and Carlo Alberto Barbieri

Abstract When speaking about sustainability in urban and territorial transformations, many dimensions have to be taken into account, thus asking for integrated approaches able to support complex decision-making processes. As it is well known, economic development has an ecological cost; for this reason, it is relevant to investigate the link existing between ecology and economics when addressing territorial planning and environmental policies. A very promising theory in this context is provided by the notion of Ecosystem Services (ESs) that have been defined as the benefits that humans derive, directly or indirectly, from ecosystem functions. More specifically, the article explores the perspectives offered by the application of the Life Satisfaction Approach (LSA) in the estimation of the economic benefits delivered by ESs, proposing an innovative methodological path linking biophysical and economic values.

Keywords Ecosystem services valuation · Life Satisfaction Approach · Subjective Well-Being · Ecosystem services quality · Sustainable development

1 Introduction

It is well known that when we deal with urban and territorial transformations we have to consider the paradigm of sustainability, according to which we should pass to future generations the same amount of natural capital that we had at disposal. Two are the most important approaches to the sustainability: the weak sustainability, supposing a certain level of substitution between natural capital and man-made capital, and the strong sustainability, where the losses of natural capital cannot be compensated with human man-made capital. In this direction, the link between ecology and economics

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is fundamental and the notion of Ecosystem Services (ESs) can be defined as the benefits that humans derive, directly or indirectly, from natural capital and ecosystem functions.

The reference to the concept of ESs allows also to consider the links between different dimensions: ecological, socio-cultural and economic (Mondini 2016). In fact, the current changes in contemporary territories involve many processes, thus requiring several levels of innovation for achieving complex goals such as the redefinition of public space in planning actions, with particular attention to green areas and recreational infrastructures, or the introduction of new parameters and indicators able to assess the sustainability of plans and programs with respect to regeneration and resilience issues (Arcidiacono et al. 2018).

The assumption of the cognitive perspective provided by the theory of ESs is a fundamental step in territorial governance for urban regeneration, as it allows to understand the relationship between environment and human well-being.

It has been generally agreed that in order to improve the ecological performance of public spaces, it is necessary to measure and assess the availability of green areas and natural amenities, not only from the quantitative point of view in terms of square meters per inhabitant, but also from the qualitative one, considering the bio-physical value of the soils that characterize these habitat. As recalled in the Millenium Ecosystem Assessment (MEA 2005), the complex relationship linking ESs and societal well-being requires to focus both on the aspects related to a correct management of the natural environment, and on the social and economic implications. In this sense, it has been generally agreed that ESs classification, mapping and estimation allow to include the value of the natural environment in planning processes, thus supporting the creation of innovative strategies for territorial governance (Brunetta et al. 2018; Giannelli et al. 2018).

The present work is part of a research carried out by a multidisciplinary group from Politecnico di Torino that is devoted to investigating the role of ESs in territorial regeneration, considering also the issues related to the economic valuation. In particular, the work explores the perspectives offered by the application of the Life Satisfaction Approach (LSA) for the Ecosystem Services Valuation (ESV). LSA is based on the concept of Subjective Well-Being (SWB) and on the factors that influence it, among which environmental conditions are particularly relevant (Welsch 2009).

2 The Ecosystem Services Theory

ESs have been defined as the benefits that humans derive from nature (MEA 2005). Some of these can be easily recognized, such as food, fibre and fuel provision or the recreation benefits, whereas other are less known, such as climate regulation, air and water purification, flood protection, soil formation and nutrient cycling. The Millennium Ecosystem Assessment (MEA) identifies four broad categories of ESs that can be described as follows:

- provisioning services, that correspond to products obtained from ecosystems;
- regulating services, that represent the benefits obtained from the regulation of ecosystem processes;
- cultural services, that are the intangible benefits that people obtain through spiritual enrichment, cognitive development, recreation etc.;
- supporting services, that are necessary for the production of all other ecosystem services.

Table 1 provides an overview of the ecosystem services categories, illustrating some examples.

Figure 1 disentangles the process from ecosystems and biodiversity to human well-being, clearly distinguishing between ecological phenomena (functions), their

Table 1 Categories of ecosystem services and examples

Category	Examples of ecosystem services provided
Provisioning services	• Food e.g. crops, fruit, fish • Fibre and fuel e.g. timber, wool • Biochemicals, natural medicines and pharmaceuticals • Genetic resources: genes and genetic information used for animal/plant breeding and biotechnology • Ornamental resources e.g. shells, flowers
Regulating services	• Air-quality maintenance: ecosystems contribute to extract chemicals from the atmosphere • Climate regulation e.g. land cover can affect local temperature and precipitation; globally ecosystems affect greenhouse gas sequestration and emissions • Water regulation: ecosystems affect e.g. the timing and magnitude of runoff, flooding etc. • Erosion control: vegetative cover plays an important role in soil retention/prevention of land/asset erosion • Water purification/detoxification: ecosystems can be a source of water impurities but can also help to filter out/decompose organic waste • Natural hazard protection e.g. storms, floods, landslides • Bioremediation of waste i.e. removal of pollutants through storage, dilution, transformation and burial
Cultural services	• Spiritual and religious value: many religions attach spiritual and religious values to ecosystems • Inspiration for art, folklore, architecture etc. • Social relations: ecosystems affect the types of social relations that are established, e.g. fishing societies • Aesthetic values: many people find beauty in various aspects of ecosystems • Cultural heritage values: many societies place high value on the maintenance of important landscapes or species • Recreation and ecotourism

(continued)

Table 1 (continued)

Category	Examples of ecosystem services provided
Supporting services	• Soil formation and retention • Nutrient cycling • Primary production • Water cycling • Production of atmospheric oxygen • Provision of habitat

Source Elaboration from MEA (2005)

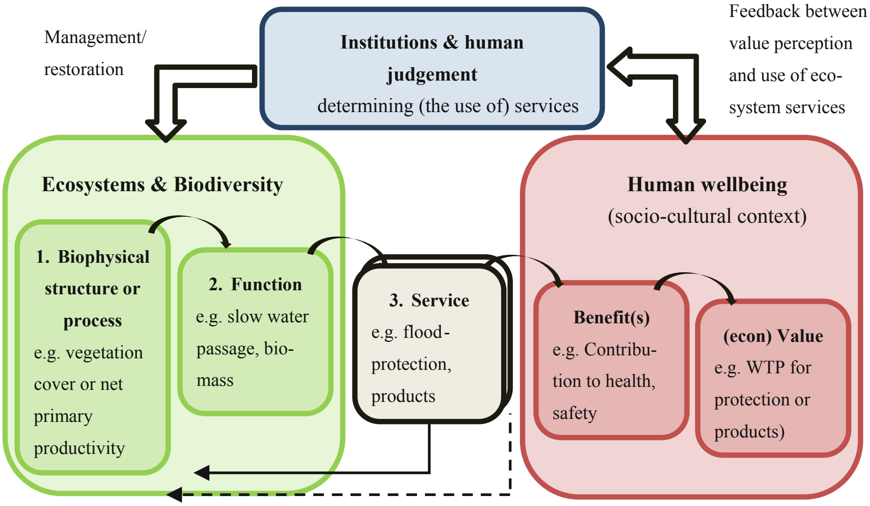

Fig. 1 The pathway from ecosystem structure and processes to human well-being. Adapted from TEEB (2010)

direct and indirect contribution to human welfare (services), and the welfare gains they generate (benefits).

3 Economic Valuation of Ecosystem Services

As already mentioned, the functioning of ecosystems and their services affect many aspects of human well-being and a broad set of indicators and attributes can be used for measuring the magnitude of their impact or value. Different metrics are available considering various disciplines: ecology, sociology, psychology, geography, economics. As far as economics is concerned, the term "value" is always associated with a trade-off and consequently, something has an economic value if we are willing to give up something to get it.

Economic valuation of ecosystem services and biodiversity can make explicit to society, in general, and policy making, in particular, that biodiversity and ESs are scarce and that their depreciation or degradation bring associated costs to society. If these costs are not imputed, then policy would be misguided and society would be worse off due to resources misallocation.

In making decisions on land policy, decision makers are normally faced with the dilemma of how to balance ecological, environmental, socio-cultural and economic values. However, as far as the economic values are concerned, only a small portion of the benefits delivered by ESs can be priced and included in cost-benefit analysis. All other values cannot be assessed by means of market-based valuation tools, even if they are fundamental in addressing decision processes in the context of territorial transformations. From this perspective, the logic behind the Ecosystem Services Valuation (ESV) is to unveil the complexity of environmental and socio-economic relationships in order to include them in public decision-making process.

The fundamental paradigm for the economic valuation of environmental goods and services is the Total Economic Value (TEV). According to it, the value of an ecosystem can be split in different components related, on one hand, to present or potential uses (direct and indirect) and, on the other, to the only existence of environmental resources involving inter-generational benefits/costs (Fig. 2). Different methods are available to estimate the monetary value of environmental services. According to the literature (Freeman et al. 2003), they can be divided in two main groups:

1. Revealed preferences: these methods derive the value of an environmental resource from the observation of individuals' decisions in real markets assuming

Fig. 2 Estimation methods for the TEV. Adapted from TEEB (2010)

that the preferences are revealed from the demand of private complementary or substitute good somehow linked to the environmental one. This group includes the Travel Cost Method (Voke et al. 2013) and the Hedonic Pricing Method (Rosen 1974; Ma 2010).

2. Stated preferences: these methods are based on data collected through a simulated market by asking individuals for their opinions or views. In particular, this approach lies on individuals' willingness to pay for using a certain good or service, or willingness to accept for renouncing or abandoning it. Among these, it is possible to recall the Contingent Valuation Method (Alberini & Kahn 2006), Conjoint Analysis, and Choice Experiments (Boxall et al. 1996; Louviere et al. 2010).

Economic valuation has been extensively applied in policy decision involving ESs and related benefits/costs. In 1997, a first attempt was made to put a monetary value on the various goods and services provided by the world's ecosystems (Costanza et al. 1997, 2014). This study had a big impact on the scientific community even its practical application was limited. The main goal of this kind of research was to give a monetary value to biodiversity and natural capital for different types of biomes by creating accessible information, based on the example of the Ecosystem Service Valuation Database (ESVD) released for the first time by the TEEB initiative (TEEB Foundation 2010). It included a large number of ecosystems, types of habitat, different definitions of services, areas, geographical scale, metrics and currencies, point of time, and different valuation methods (de Groot et al. 2012). Among the latter it is useful, first of all, to distinguish between those that directly estimate the benefits and those that compute costs as proxies of environmental services flow. In the first case, both revealed and stated preference methods were applied all over the world for the estimation of ESs, including recreational benefits (Mayer and Woltering 2018) and ESs provided by specific types of habitat: forests, wetlands, coral reef, coastal and marine areas, etc. (Newell and Swallow 2013; Laurans et al. 2013; Czajkowski et al. 2014; Jobstvogt et al. 2014). In the second case, the basic hypothesis, which may not always be valid, was that the benefits were at least as wide as the costs related to the restoration of environmental damage, to its prevention or compensation.

Moreover, the global approach to ESV has been criticized due to the specificities of different terrestrial habitats and the dynamics of change in land cover and its uses. The creation of these databases of values was supported by the conviction that, in spite of the differences between ecosystems, the transfer of an estimate from one to another would have been acceptable. Another reason of this effort has been related to the need to verify a certain convergence between estimates in a random domain such as the environmental valuation. For this purpose, a big number of meta-analysis (Nelson and Kennedy 2009) were implemented and the benefit-transfer method became popular. The latter has been also criticized because, for a number of reasons, its application may result in significant errors, i.e. a transferred value—or a mean/median—that may highly differ from the actual value of the ecosystem under consideration.

The other important ESV purpose has been to compare estimates produced in changing scenarios of land uses relevant to public policies: agriculture, landscape protection, culture and recreation, damage mitigation, etc. In this regard, methods able to map the land cover and its uses, to describe changes and derive their values have been conveniently experimented (Gascoigne et al. 2011; Bateman et al. 2013, 2014).

Furthermore, methods based on revealed and stated preferences suffer from well-known problems and limits. In order to overcome these difficulties, the technique based on the Life Satisfaction Approach (LSA) is proposed as described in the remaining part of the work.

4 Life Satisfaction Approach for Ecosystem Services Valuation (ESV)

As already mentioned, benefits provided by the ecosystem are innumerable and a wide literature has explored the relationships between ESs and individual well-being. Usually, people enjoy natural areas for recreational purposes, like walking, hiking, play outdoor sports, relaxing, experiencing and learning about nature and biodiversity. All these actions contribute to individual well-being and mindfulness improving environmental awareness. Whereas psychological effects of nature on humans are well known, only recently it has been discovered that Subjective Well-Being (SWB) can be profitably used to assess environmental benefits/costs (Welsch 2002, 2007).

The so-called Life Satisfaction Approach (LSA) is based on the SWB rating employed for environmental valuation purposes (Welsch and Kuhling 2009; Frey et al. 2010). The measurement of individual welfare and happiness, using data on reported SWB, has made great progress and has led to a new field in economics (Kahneman and Sugden 2005). A fundamental step in the debate on SWB was the analysis of the relationship between happiness and wealth. Easterlin (1974) was the first author to highlight the existence of a non-linear relationship between population's income and well-being level. Later on, Clark et al. (2008) clarified how, in the utility function, relative income can affect economic behavioral models in different domains.

More specifically, SWB represents an empirical approximation of the individual utility and it can be used for estimating the value of environmental goods (Welsch 2009). In other words, environmental conditions can be considered in a simple linear function along with income and other variables as follows:

$$\mathrm{SWB}_{ijt} = \alpha \mathrm{E}_{ujt} + \beta \mathrm{R}_{ijt} + \gamma \mathrm{X}_{jt} + \delta \mathrm{D}_{ijt} + \eta_j + \eta_t + \varepsilon_{ijt}$$

where:

SWB_{ijt} is the subjective well-being self-reported by the respondent i in a geographical position j on date t;
E_{ujt} describes the environmental conditions;
R_{ijt} is the income of i;
X_{jt} is a series of determinants observed on individual level (socio-demographic and household's characteristics);
$\eta_j + \eta_t + \varepsilon_{ijt}$ are unobserved terms, where the first two represent the effects of fixed location and time, respectively. These express the invariant characteristics that are common to all people in a place j and on date t, while ε_{ijt} is the disturbance term covering non-observable characteristics joined in the measurement error.

Once these parameters have been estimated, the SWB function can be used to obtain a monetary valuation of E variation by differentiating for the income and resolving for the marginal value (MV) relative to the environmental conditions, such that:

$$MV = \Delta EC_{ujt}/\Delta R_{ijt} = (\Delta SWB_{ijt}/\Delta R_{ijt})/(\Delta SWB_{ijt}/\Delta EC_{ujt})$$

In other words, in the case of environmental damages, it is possible to compute the increase in income that would be necessary to compensate an individual for a decrease in environmental quality. MV can be interpreted as the willingness to pay or to accept for environmental changes. A crucial requirement for obtaining reliable valuation results from LSA function is that the marginal value is estimated correctly taking into account that the relationship between consumption and SWB is rather complex, involving inter-personal and inter-temporal relativity (Welsch 2009). The specification of the arguments of the function, or, in other words, the introduction of explanatory variables and the use of a correct functional form, is fundamental in this regard.

This approach has been applied many times with different purposes. The relative literature can be clustered in four domains as follows:

1. Environmental damages: e.g. air pollution, climate change and extreme weather events; natural disasters (Luechinger 2011; Menz 2011; Sekulova et al. 2013; Li et al. 2014; Rehdanz et al. 2015; von Möllendorff and Hirschfeld 2016; Yuan et al. 2018).
2. Environmental benefits: e.g. natural environment, pro-environmental behavior, scenic amenities, greenery (Welsch and Kühling 2010, 2011; Ambrey and Fleming 2011; Doherty et al. 2014; Tsurumi et al. 2018).
3. Land uses: e.g. natural lands, urban green spaces, urban land uses (Kopmann and Rehdanz 2015; Bertram and Rehdanz 2015).
4. Energy supply and infrastructures: e.g. nuclear power, wind turbines, electricity supply (Welsch and Biermann, 2014a, b; Krekel and Zerrahn 2017).

The second and the third domains are very close to the ESV but some methodological issues have emerged from the empirical application. The intent of the present contribution is to highlight them with the aim to go further with the research project.

4.1 Data Sources and Geographical Scale

Data on SWB are usually collected in large-scale surveys led to the national or international level. Some of these refer to single countries, such as the General Social Surveys in the U.S. or the Multi-Purpose Survey on Italian Families in Italy. Others, like the European Quality of Life Surveys (EQLS) or the World Values Surveys, cover several countries. SWB is usually elicited through a question like this: «*All things considered, over the last few days, how would you rate your overall satisfaction with your life?*» in a Likert-scale from 1 to 10 points, but also with other rating, as 1–3, or 1–4 points. In Italy, SWB is measured through a 11-point scale ranging from 0 (very dissatisfied) to 10 (very satisfied).

These surveys bring with them the problem of the statistical representativeness of the sample. To stay with the Italian case, the Multi-Purpose Survey is the result of a stratified sample designed to be significant to a regional scale (ISTAT 2017). For the ESV purposes it would instead make sense to go down to a smaller scale, but this is not allowable, if not by building an ad hoc survey. For example, Bertram and Rehdanz (2015) employ a local survey for estimating the value of the urban green space in Berlin linking the respondents' location and spatial information with GIS data. Obviously, on one hand, the advantage of employing national surveys data is that it requires little resources; on the other hand, an ad hoc survey could be calibrated to a smaller geographical scale, and could be able to capture the qualitative and quantitative variations of ESs, which could be correctly measured in an appropriate scale and with suitable geographical representation tools.

Moreover, and following the LSA, the variation between regions or countries allows only the valuation of the marginal change in income, but it is not able to foresee any simulation on the future state of the environmental good or service. For example, Kopmann and Rehdanz (2015) consider changes in the natural land cover, estimating the willingness to pay for different types of habitat (agricultural, forestry, grasslands, wetlands, etc.). They gather information on land cover of the total area of the European regions NUTS 2 (in percentage) through the CORINE database (Coordination of Information on the Environment) and employ the output of European Quality of Life Survey (EQLS).

Another issue is whether to use individual data or aggregate them to a certain geographical scale, always considering the problem of the sample representativeness. The estimation function, at that point, will not contain subjective, but explanatory variables of average well-being and wealth. In this direction, it may be appropriate using, instead of the average per-capita income, the average per-capita GDP. When individual data are employed, it is worth remembering that the unobservable or subjective component retains, in the vast majority of applications, a strong weight, thus limiting the percentage of variation explained by the model ($R^2 < 40\%$). Conversely, the function based on aggregated data could be simpler to be specified with higher variation coefficients (Bravi and Sichera 2016).

4.2 Measuring the Ecosystem Services Quality (ESQ)

Data collection, sampling and geographical scale identification are issues linked to the ESQ (Ecosystem Services Quality) measurement. As mentioned before, the effort to create large databases of estimates, for different habitat and biomes, contrasts with the rapidly changing scenarios related to land cover and its uses that affect the ESQ level. Consequently, GIS (Geographical Information System) and the available information database (CORINE—Coordination of Information on the Environment) are essential in linking territorial data and economic values. The relevant literature shows many applications in this field. Between them, a specific tool seems to have the features needed to return multiple scenarios in real time; its name is SimulSoil. It has been developed thanks to the international project Life+ SAM4CP as a decision support system able to assist decision makers and planners in the assessment of the benefits delivered by the ecological and environmental services.

In particular, SimulSoil is an application for QGIS, an open source software, which examines the effects of the ESQ variation due to the changes in land uses. The calculation performed by the tool are based on the computational algorithm provided by InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), a model originated from a partnership between Stanford University, the Chinese Academy of Sciences, the University of Minnesota, the Stockholm Resilience Centre, The Nature Conservancy, and the World Wildlife Fund. Among the different measurements, the Habitat Quality (HQ) indicator seems to be suitable for capturing the ESs changing scenarios in qualitative as well as quantitative terms. HQ is based on the hypothesis that the areas with the highest quality host a greater diversity of native species, while the decrease in size of a specific habitat or biome lead to the decline of species survival. In other words, it joins information on land cover and its uses, interpreted in terms of naturalness level, with the spatial distribution of negative threats such as agricultural production, infrastructures, urban areas, etc. In this sense, the indicator does not only take into account the bio-physical characteristics of the soil, but attempts to include the effect of external elements. The habitat types considered by the simulator are 12, whereas the anthropic system, the agricultural areas and the infrastructural network, with main, secondary and local roads, are considered threats.

As an example, Fig. 3 represents the map of the HQ for a municipality located in Northern Italy. As it is possible to see, the HQ value varies between 0 (minimum level of HQ) and 1 (maximum level of HQ).

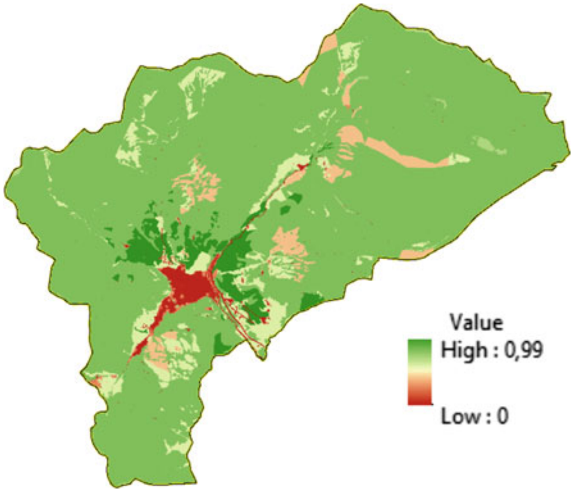

Fig. 3 Example of cartographic output of the HQ evaluation (elaboration by Pantaloni, Eco-welfare research project, DIST, Politecnico di Torino, 2019)

5 Further Developments of the Study

Considering the adoption of the LSA method for estimating the economic value of ESs, the next steps for the empirical application will be the following: (1) the geographical scale identification; (2) the SWB data collection (national or ad hoc survey); (3) the choice of some significant socio-economic indicators; (4) the evaluation of ESQ with the help of a GIS tool; (5) the implementation of econometric models and the estimation of benefits/costs.

Based on the research that has be done so far, the LSA seems to be a very promising methodology. In fact, with respect to other ESV methods bases on surveys and from the individual point of view, the SWB elicitation is a cognitively less demanding task and there is no reason to expect strategic behaviour, thus allowing to avoid biased estimates. Despite its potentialities, it has to be noticed that there are a number of preconditions for a successful application. In particular, the validity of the SWB data should be verified, paying particularly attention to the comparability among individuals. In this sense, the characteristics of the national surveys should respect the standards for a qualified analysis, thus ensuring the conditions for a reliable valuation. Finally, a certain amount of work in linking the information on the bio-physical characteristics of the soil and the benefits/costs valuation of environmental changes remains to be done. More specifically, the problem of ESQ measurement/simulation in relation to the geographical scale of SWB surveys must be carefully considered.

References

Alberini A, Kahn J (2006) Handbook on contingent valuation. Edward Elgar Publishing

Ambrey CL, Fleming CM (2011) Valuing scenic amenity using life satisfaction data. Ecol Econ 72:106–115

Arcidiacono A, Giaimo C, Talia M (2018) Priorità per il progetto urbanistico. Reti ambientali, nuovi standard e rigenerazione urbana. In: Moccia FD, Sepe M (eds) Sviluppare, rigenerare, ricostruire città. INU Edizioni, Questioni e sfide contemporanee, pp 166–179

Bateman IJ, Harwood AR, Mace GM, Watson RT et al (2013) Bringing ecosystem services into economic decision-making: land use in the United Kingdom. Science 341(6141):45–50

Bateman IJ, Harwood AR, Abson DJ et al (2014) Economic analysis for the UK National Ecosystem Assessment: synthesis and scenario valuation of changes in ecosystem services. Environ Resour Econ 57:273–297

Bertram C, Rehdanz C (2015) The role of urban green space for human well-being. Ecol Econ 120:139–152

Boxall PC, Adamowicz WL, Swait J, Williams M, Louviere JJ (1996) A comparison of stated preference methods for environmental valuation. Ecol Econ 18:243–253

Bravi M, Sichera M (2016) Valuing environmental and social quality impacts on subjective well-being. Aestimum 68:5–28

Brunetta G, Salizzoni E, Bottero M, Monaco R, Assumma V (2018) Measuring resilience for territorial enhancement: an experimentation in Trentino. Valori e Valutazioni 20:69–78

Clark AE, Frijters P, Shields MA (2008) Relative income, happiness, and utility: an explanation for the Easterlin paradox and other puzzles. J Econ Lit 46(1):95–14

Costanza R, d'Arge R, de Groot R et al (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

Costanza R, de Groot R, Sutton P et al (2014) Changes in the global value of ecosystem services. Glob Environ Change 26:152–158

Czajkowski M, Bartczak M et al (2014) Providing preference-based support for forest ecosystem service management. For Policy Econ 39:1–12

de Groot R, Brander L, van der Ploeg S et al (2012) Global estimates of the value of ecosystems and their services in monetary units. Ecosyst Serv 1:50–61

Doherty ST, Lemieux CJ, Canally C (2014) Tracking human activity and well-being in natural environments using wearable sensors and experience sampling. Soc Sci Med 106:83–92

Easterlin RA (1974) Does economic growth improve the human lot? Some empirical evidence. In: David PA, Reder MW (eds) Nations and households in economic growth: essays in honor of Moses Abramowitz. Academic Press, New York, pp 89–125

Freeman AM III, Herriges JA, Kling CL (2003) The measurement of environmental and resource values: theory and methods. Resources for the future. Routledge, Washington DC

Frey B, Stutzer A, Luechinger S (2010) Life satisfaction approach to environmental valuation. Ann Rev Resour Econ 2:139–160

Gascoigne WR, Hong D, Koontz L et al (2011) Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of The Dakotas, USA. Ecol Econ 70:1715–1725

Giannelli A, Giuffrida S, Trovato MR (2018) Madrid Río Park. Symbolic values and contingent valuation. Valori e Valutazioni 21:75–85

ISTAT (Istituto Nazionale di Statistica) (2017) BES 2017. Il Benessere Equo e Sostenibile in Italia. Roma. https://www.istat.it/it/files//2017/12/Bes_2017.pdf

Jobstvogt N, Watson V, Kenter J (2014) Looking below the surface: the cultural ecosystem service values of UK marine protected areas (MPAs). Ecosyst Ser 10:97–110

Kahneman D, Sugden R (2005) Experienced utility as a standard of policy evaluation. Environ Resour Econ 32:161–181

Kopmann A, Rehdanz C (2015) A human well-being approach for assessing the value of natural land areas. Ecol Econ 93:20–33

Krekel C, Zerrahn A (2017) Does the presence of wind turbines have negative externalities for people in their surroundings? Evidence from well-being data. J Environ Econ Manag 82:221–238
Laurans Y, Pascal N et al (2013) Economic valuation of ecosystem services from coral reefs in the South Pacific: taking stock of recent experience. J Environ Manage 116:135–144
Li Z, Folmer H, Xue J (2014) To what extent does air pollution affect happiness? The Case of The Jinchuan Mining Area, China. Ecol Econ 99:88–99
LIFE SAM4CP, Soil Administration for Community Profit. http://www.sam4cp.eu/en/
Louviere JJ, Flynn TA, Carson RT (2010) Discrete choice experiments are not conjoint analysis. J Choice Model 3(3):57–72
Luechinger S (2011) Life satisfaction and transboundary air pollution. Econ Lett 107:4–6
Ma S (2010) Hedonic valuation of ecosystem services using agricultural land prices. Master thesis in Agricultural, Food and Resource Economics. Michigan State University
Mayer M, Woltering M (2018) Assessing and valuing the recreational ecosystem services of Germany's National Parks using travel cost models. Ecosyst Serv 31:371–386
MEA (2005) Millennium ecosystem assessment ecosystems and human well-being: current state and trends assessment. Island Press, Washington
Menz T (2011) Do people habituate to air pollution? Evidence from international life satisfaction data. Ecol Econ 71:211–219
Mondini G (2016) Integrated evaluation for the management of new social challenges. Valori e Valutazioni 17:15–17
Natural Capital Project, InVEST. Integrated valuation of ecosystem services. https://naturalcapitalproject.stanford.edu/invest/
Nelson JP, Kennedy PE (2009) The use (and abuse) of meta-analysis in environmental and natural resource economics: an assessment. Environ Resour Econ 42:345–377
Newell LW, Swallow SK (2013) Real-payment choice experiments: valuing forested wetlands and spatial attributes within a landscape context. Ecol Econ 92:37–47
Rehdanz C, Welsch H, Narita D, Okubo T (2015) Well-being effects of a major natural disaster: the case of Fukushima. J Econ Behav Organ 116:500–517
Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. J Polit Econ 82(1):34–55
Sekulova F, van den Bergh J (2013) Climate change, income and happiness: an empirical study for Barcelona. Glob Environ Change 23:1467–1475
TEEB (2010) The economics of ecosystems and biodiversity report for business. Executive summary. United Nations Environment Programme and European Commission
Tsurumi T, Imauji A, Managi S (2018) Greenery and subjective well-being: assessing the monetary value of greenery by type. Ecol Econ 148:152–169
Voke M, Fairley I, Willis M et al (2013) Economic evaluation of the recreational value of the coastal environment in a marine renewable deployment area. Ocean Coast Manag 78:77–87
von Möllendorff C, Hirschfeld J (2016) Measuring impacts of extreme weather events using the life satisfaction approach. Ecol Econ 121:108–116
Welsch H (2002) Preferences over prosperity and pollution: environmental valuation based on happiness surveys. Kyklos 55:473–494
Welsch H (2007) Environmental welfare analysis: a life satisfaction approach. Ecol Econ. 62:544–551
Welsch H (2009) Implications of happiness research for environmental economics. Ecol Econ 68:2735–2742
Welsch H, Biermann P (2014a) Fukushima and the preference for nuclear power in Europe: evidence from subjective well-being data. Ecol Econ 108:171–179
Welsch H, Biermann P (2014b) Electricity supply preferences in Europe: evidence from subjective well-being data. Resour Energy Econ 38:38–60
Welsch H, Kuhling J (2009) Using happiness data for environmental valuation: issues and applications. J Econ Surv 23(2):385–406

Welsch H, Kühling J (2010) Pro-environmental behavior and rational consumer choice: evidence from surveys of life satisfaction. J Econ Psychol 31:405–420
Welsch H, Kühling J (2011) Are pro-environmental consumption choices utility-maximizing? evidence from subjective well-being data. Ecol Econ 72:75–87
Yuan L, Shin K, Managi S (2018) Subjective well-being and environmental quality: the impact of air pollution and green coverage in China. Ecol Econ 153:124–138

Spatial Implications of EPC Rankings Over Residential Prices

Carlos Marmolejo-Duarte, Ai Chen and Marina Bravi

Abstract Empirical evidence has found a correlation between Energy Performance (EPC) rankings and housing prices. Though, little attention has been devoted to research the spatial implications of EPC marginal prices. This paper attempts to fill this gap using a geographical-weighted-regression, departing from listing prices for Barcelona. The results suggest the existence of a premium equivalent to 1.7% for each EPC ranking, which nearly double the previous reported evidence in this city. Also, the impact shows a non-stationary distribution across urban space. As a matter of fact, the higher the impact, the lower the price of apartments and their quality. The apartments portraying the larger impact are located in peripheral areas inhabited by medium and low-income population. So, the equity of less wealthy population witnesses the largest brown discount.

Keywords Hedonic pricing · Energy label · Spatial stationarity · Residential market

1 Introduction

In Europe, buildings are responsible for 40% of energy consumption and 38% of CO_2 emissions (Arcipowska et al. 2014), implying economic, geopolitical and environmental concerns. So, in 2002 the European Commission addressed the Energy Performance of Buildings Directive (EPBD)-2002/91/EC-; its main instrument to improve the energy performance of buildings is the Energy Performance Certificate (EPC). This certificate informs potential users about the performance of property to be transacted. As a result, consumers might capitalize into a market premium the

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benefits of efficient premises such as energy savings and environment conservation. The growing evidence, reviewed in the next section, confirms the existence of a market premium for efficient buildings; nonetheless, none of them explore whether it is stationary across the space.

In Spain, the late transposition of EPBD has made it mandatory to include an EPC in the property market only since 1st June 2013. So, the studies exploring the hedonic agenda of EPC rankings are scarce but enough to confirm a small premium for efficient buildings. Nonetheless, this finding cannot hold in the future due to the increases of energy costs: in 2015, Spanish households' energy expenditure was 361 euros/year while for EU 28 it was 327 euro (Eurostat 2016). For that reason, in this paper, (1) the existing evidence is revisited in order to analyze whether EPC marginal price has recently increased, and (2) it is explored whether EPC impact over prices is homogenous across the urban space; and finally, (3) in the case of non-stationarity we identify the urban, social and property attributes correlated to such variation. In doing so apartments' listing prices for Metropolitan Barcelona are analyzed using conventional and geographical/locally weighted regressions. Results suggest that: EPC price impact has increased in relation to previous research; while EPC marginal prices are non-stationary, they are correlated with socioeconomic and housing attributes.

The remainder of the paper is organized as follows. First, a brief literature review is offered; second, the methodology, study area and data are described; next, the results are analyzed; finally, in the concluding section the findings are discussed within the framework of public policy.

2 Brief Literature Review

Table 1 details a selection of case studies researching the impact of EPC rankings on housing prices. All of them use the hedonic approach and are based on transaction or listing prices; most of them consider EPC ranks as categorical measures of energy efficiency and report marginal prices in terms of semi-elasticities. It is worth saying that while most of the studies report a positive correlation between prices and energy efficiency, in some cases this relation is reversed. This latter is the case of Oxford in the study of Bio Intelligence Service et al. (2013) and is produced by a poor control of location variables. For this reason, in this paper large efforts have been made in order to take into consideration the large quantity of attributes influencing prices. Also, it is evident that the impact is larger in the selling market than in the leasing one.

The very different hedonic agendas found across the EU respond to differences in: climate, income, energy/housing prices and, perhaps, environmental concerns. In general, the studies made in Spain do report a relatively small impact in relation to northern countries. Nevertheless, such studies require to be revisited since both of them were produced using data just after the EPBD transposition came into force. With the exception of the work of Chegut et al. (2014) that has found a "gentrification"

Table 1 Selected EPC housing studies

Case study	EPC ranking scale	Marginal impact of EPCs		From energy ranking X to Y (Y/X)	Type of prices	Authorship
		Sale	Rent			
Netherlands	Cont.	3.60%		Step	TP	Brounen and Kok (2011)
	Cate.	10.10%		A/D		
		5.50%		B/D		
		2.10%		C/D		
		−0.50%		E/D		
		−2.30%		F/D		
		−4.80%		G/D		
Vienna	Cont.	10–11%	5–6%	Step	LP	Bio Intelligence Service et al. (2013)
Lower Austria		5–6%	4.40%	Step		
Brussels_Flandes		4.30%	3.20%	Step		
Brussels _Capital		2.90%	2.60%	Step		
Brussels_Wallonia		5.40%	1.50%	Step		
Lille		3.20%	*	Step		
Marseille		4.30%	*	Step		
Ireland_Urban		1.70%	1.40%	Step		
Ireland_Rural		3.80%	1.40%	Step		
Oxford		−0.40%	−4.00%	Step		
England, Wales	Cate.	5.00%		A,B/D	TP	Fuerst et al. (2015)
		1.80%		C/D		
		−0.70%		E/D		
		−0.90%		F/D		
		−6.80%		G/D		

(continued)

Table 1 (continued)

Case study	EPC ranking scale	Marginal impact of EPCs		From energy ranking X to Y (Y/X)	Type of prices	Authorship
		Sale	Rent			
Ireland	Cont.	1.30%	0.50%	Step	LP	Hyland et al. (2013)
	Cate.	9.30%	1.80%	A/D		
		5.20%	3.90%	B/D		
		1.70%	*	C/D		
		*	−1.90%	E/D		
		−10.60%	−3.20%	F,G/D		
Turin	Cont.	26.44 Euro/m^2		Step	LP	Bottero and Bravi (2014)
	Cate.	*		A,B,C,D,E,F,G	TP	Fregonara et al. (2017)
Metropolitan Barcelona	Cont.	0.85%		Step	LP	Marmolejo-Duarte (2016)
	Cate.	9.62%		A/G		
		*		C/G		
		4.00%		D/G		
		2.00%		E/G		
		*		F/G		
Barcelona, Valence, Alicante	Cont.	1.40%		Step	LP	Marmolejo-Duarte and Chen (2019b)
Madrid, Bilbao, Seville, Vitoria, Malaga	Cate.	9.80%		A,B,C/D,E,F,G	OV	De Ayala et al. (2016)
		5.40%		A,B,C,D/E,F,G		

Notes *No significant impact found; EPC ranking scales: Continuous (Cont.) and Categorical (Cate.); Type of Prices: Transaction Price (TP), Listing Price (LP) and Opinion Value (OV) process for the London offices certified under the BREEAM scheme, none of the studies have researched the spatial implications of EPC impact as it is done in this paper as next explained.

3 Study Area, Data and Methodology

3.1 Study Area

Barcelona metropolitan area (AMB) is selected as a study case. In order to identify the limits of this agglomeration the travel-to-work method based on interaction value (Roca et al. 2009) has been used. Such approach also allows to detect subcentres, which is relevant since accessibility to centralities might impact on prices. As a result, the functional AMB is formed by 184 municipalities comprising 3,759 km^2 and 5.22 million inhabitants (Fig. 1).

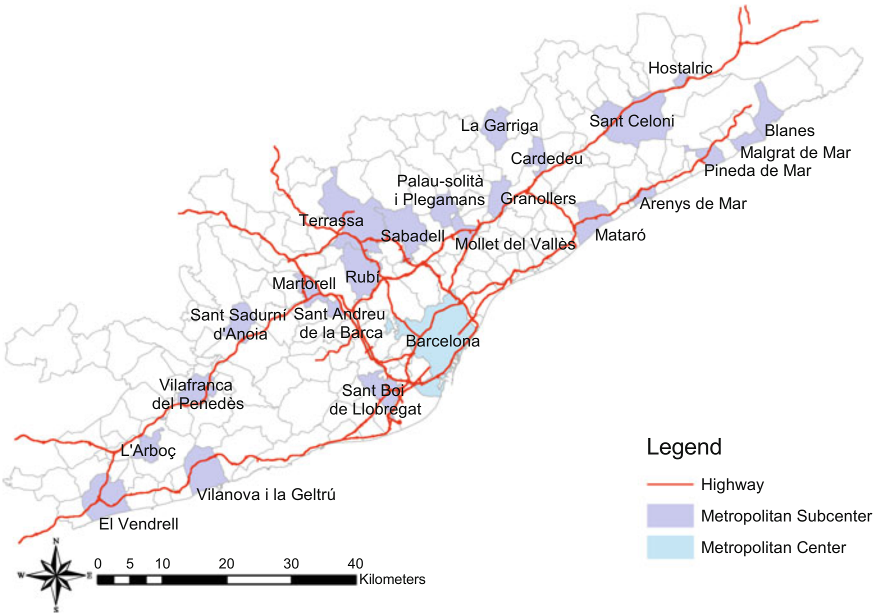

Fig. 1 Delimitation of the functional AMB

3.2 Methodology

After having delimited the study area, the methodology comprises 5 steps:

(1) First, an ordinary-least-square (OLS) hedonic model has been calibrated in order to identify the marginal price of EPC ranking.
(2) Second, the same model has been re-calibrated eliminating the EPC ranking as an independent variable, but maintaining all the remaining significant attributes. The residuals of such model have been saved.
(3) Third, the residuals of the aforementioned model have been used as a dependent variable in a Geographical Weighted Regression (GWR) using solely the EPC ranking as the independent variable. This procedure enormously contributes to save computing resources.
(4) Fourth, using the Monte Carlo test, it has been investigated whether the coefficient for EPC ranking depicts a non-stationary variation across the metropolis.
(5) Finally, those statistically significant local coefficients for EPC rankings have been used to identify their correlation with socioeconomic and housing attributes.

3.2.1 Ordinary-Least-Square Model

In the literature there is little advice on the functional form that hedonic models shall adopt (Can 1992; Sheppard 1999; Malpezzi 2003; Epple et al. 2018). Nonetheless, the semi-log function has been intensively used in the context of property analysis. Marmolejo and Gonzalez (2009) summarized the advantages of semi-log function: (i) it helps to normalize the price and residual distributions which is fundamental for OLS analysis; (ii) the resulting coefficients are semi-elasticities (i.e. coefficients express marginal price variation in percent terms) so, the used form is:

$$ln(P)_i = \beta_i + \sum_{s=1}^{n} \beta_{is} AS_{is} + \sum_{m=1}^{n} \beta_{im} EA_{im} + \sum_{a=1}^{n} \beta_{ia} S_{ia} + \varepsilon_i \quad (1)$$

where: the logarithm of price *P* of an apartment *i* depends on a set of variables related to: *AS* architectural structural attributes; *EA* environmental and accessibility attributes; and *S* socio-economic attributes while ε is the error.

In the AS dimension, there are covariates and factors related to physical structural features (e.g.: area and dwelling's quality) and facilities (e.g.: lift, heating or air-conditioner). The construction year is correlated with energy efficiency, since in Spain there have been at least two construction codes with implications on thermal isolation. So, older houses, especially those constructed before 1981, exhibit a lower performance compared to those constructed after 2007 where advanced techniques and criterions for energy efficiency are applied. This As-dimension also includes the EPC rank.

The *EA* dimension includes environmental and accessibility indicators, such as noise pollution, next-to-sea location, employment density, accessibility to highways and train stations as well as distances to centralities.

In the *S* dimension, education level and income are key factors. It includes the percentage of residents holding a university degree living around each of the analyzed apartments. In order to depict a wider picture of the socio-economic structure of the city, a Principal Component Analysis (PCA) has been computed departing from the professional positions (e.g. managers, clerks, blue collar workers, etc.). The resulting principal-components represent proxies for high, medium and low-income population. Socioeconomic indicators are relevant for price formation and "green-market-premiums" since income and education are correlated with purchasing power, social prestige and environmental concerns (Banfi et al. 2008; Himmelberg et al. 2005).

3.2.2 Geographically-Weighted-Regression Model

Since the primary interest is to study the possible variation of EPC rank marginal price, a GWR has been used. This approach has many advantages: (i) it considers the impact of independent variables in a more flexible way, (ii) it resolves autocorrelation issues, and (iii) represents a "soft window" approach to submarket identification.

The GWR adjusts as many regressions as there are observations. In these regressions, the further away the observations are from the pivotal point, the less weight (i.e. importance) they have in the estimation of the *B* coefficients (one different for each regression). The weighting matrix is calculated as follows:

$$w_{ij} = \left\{1 - \left(\frac{d_{ij}}{h_i}\right)^2\right\}^2 if\ d_{ij} < h_i\ otherwise = 0 \tag{2}$$

where w is the weighting space matrix, i is the pivotal point of the regression, j is each of the N observations included in the local regression and h is the distance from the *Nth j* point (Charlton et al. 2005). When the density of the observations is not constant throughout the space, it is advisable to use an adaptive kernel, making it possible to relax the geometry of the analysis area, which may not be isotropic from point i.

As it has been said, the dependent variable in the GWR-Model are the residuals of model I (after removing the EPC ranking as explanatory variable) and the only independent variable in the GWR-Model is the EPC ranking.

3.3 Data

Selling listing prices for apartments is the primary source of information. Such information has been retrieved from Habitaclia, one of the leading web-based property listings in Catalonia. The original dataset comprises 40,844 flats and includes architectonic, structural attributes as well as geo-locations. Data refers to April 2016, it is to say, almost 3 years after the RD 235/2013 made it mandatory to include EPC ranking in real estate advertising. Despite such obligation, in the sample only 15.28% of the listings does include EPC rankings.

In order to control all the location attributes that might influence prices (i.e. environmental quality, accessibility and socioeconomic structure of neighborhoods) a comprehensive GIS has been built departing from the data-sources detailed in Table 2.

All the contextual information has been incorporated into each of the analyzed dwellings using a spatial query departing from a buffer of 300 meters of radius around each of the dwellings. In order to eliminate outliers a twofold approach has been used: (i) first, all the cases with price values located beyond ± 2 Std. Dev from the average price have been removed, (ii) second, the remaining of the cases have been depurated using the Mahalanobis Distance. This latter procedure allows to remove the cases whose price is not explained by the covariates but rather by other unmeasured aspects, such as landscaping or specific decorations (Li 2005). The depurated sample includes 5,497 cases.

Table 2 shows the statistical description of sample´s attributes. The average values are: 217,205 Euro; 86.8 m^2; and 1.36 bathrooms. Regarding the facilities of condominium, 10% of apartments are equipped with swimming pool and 67% have a lift; 46% of the listed apartments have air conditioners and 68% are equipped with heating systems. In terms of quality of finishes/equipment, 34% of the advertisings claim for high-quality kitchens and 6% have chimneys; meanwhile 12% have a terrace larger than 20 m^2. The presence of terraces and balconies in very dense and hot Mediterranean cities is very appreciated by consumers.

The average construction/full-refurbishment year is 1972, 70% of the sample has been constructed before 1981 when non-thermal isolation was required by law, 22% between such year and 2007 when the more restrictive technical building code (CTE) was approved, the remaining 7% was built after that year, implying a better compliance with energy efficiency criteria. Regarding EPC ranking the average class is 2.73, where the most efficient class in Spain is $A = 7$ and the worst is $G = 1$, only 16% of the sample is ranked as class A, B or C. All in all, it depicts a housing stock where thermal energy efficiency has a large room for improvement.

Figure 2 shows the average EPC ranking for municipalities containing more than 25[1] apartments. Interestingly, the coastal southern area, in the Garraf County, depicts a relative low energy efficiency benchmark. This zone comprises a relatively diverse typology of municipalities ranging from metropolitan subcentres, such as Vilanova, to more touristic cities such as Castelldefels and Sitges. In the interstitial municipalities of such poles, an important number of sprawling developments emerged during

[1] 25 is the average of apartments by municipality no considering the municipality of Barcelona.

Table 2 Descriptive statistics of variables for the depurated sample

Variables	N	Min.	Max.	Media	Std.Dev.	Sources
Architectonic attributes (AS)						
Price (Euro)	5,497	47,800	830,000	217,205	145,908	A
Unitary price (Euro/m^2)	5,497	505	10,172	2,457	1,230	A
Area m^2	5,497	20	258	86.82	29.65	A
Num. baths	5,497	0	4	1.36	0.55	A
Condo swimming pool	5,497	0	1	0.10	0.30	A
Lift	5,497	0	1	0.67	0.47	A
High-quality kitchen	5,497	0	1	0.34	0.48	A
Air cond.	5,497	0	1	0.46	0.50	A
Heating	5,497	0	1	0.68	0.47	A
Chimney	5,497	0	1	0.06	0.23	A
Recently refurbished	5,497	0	1	0.18	0.39	A
EPC rank (A = 7, G = 1)	5,497	1	7	2.73	1.22	A
A,B,C EPC rank	5,497	0	1	0.16	0.36	A
Large terrace	5,497	0	1	0.12	0.32	A
Construction year	5,497	1881	2016	1972	25	A
Built (<1981)	5,497	0	1	0.70	0.46	A
Built (1981–2007)	5,497	0	1	0.22	0.42	A
Built (>2007)	5,497	0	1	0.07	0.26	A
Environment & accessibility attributes (EA)						
Near-to-sea 200 m	5,497	0	1	0.03	0.18	C

(continued)

Table 2 (continued)

Variables	N	Min.	Max.	Media	Std.Dev.	Sources
Highway ramp	5,497	0	1	0.89	0.32	C
Near-to-train-station	5,497	0	1	0.53	0.50	C
Distance-to-highway (km)	5,497	0.01	10.73	1.98	1.54	C
Distance-to-subcentre (km)	5,497	0.01	17.47	4.11	2.91	C
Distance-to-CBD (km)	5,497	0.12	60.65	16.34	14.31	C
Noise annoyance (%)	5,497	5.15	77.43	38.58	11.56	B
Employment density (Jobs/km^2)	5,497	6.00	7.89	3.56	3.35	B
Socioeconomic attributes (S)						
University pop (%)	5,497	0.01	0.51	0.15	0.10	B
High-income PC	5,497	−2.39	2.61	0.23	0.98	B
Medium-income PC	5,497	−1.46	2.09	0.42	0.52	B
Med-low-income PC	5,497	−2.67	3.43	−0.15	0.88	B

Notes Own estimation using data from: (A) Habitaclia listing database (2016); (B) Dwelling and population census INE (2001): Data from 2011 Census have been discarded due to unrepresentativeness at census tract level; (C) Tele Atlas (2010) and GIS-own-vectorization (2016): Accurate distance among census tracts has been calculated using TransCAD. In brackets is the year of the source of information

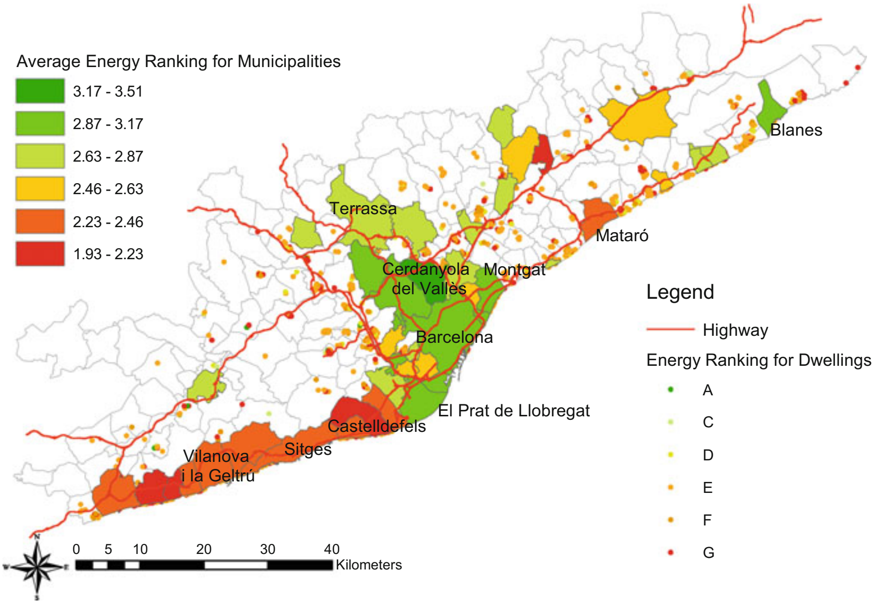

Fig. 2 Distribution of EPC rank at municipal and dwelling's level

the second part of the 20th Century, most of them of low quality. This same trend of low-quality houses, in a lesser extent, is also located in some suburbs located at the Pre-littoral mountain range in the Maresme Coast and around Montseny area. On the contrary, Barcelona and some of the nearest municipalities that have concentrated the development of recently completed homes do exhibit a better average performance. The uneven distribution of energy efficient apartments along the city reinforces the need to explore the spatial implications on price formation.

4 Results

4.1 The Impact of EPC Ranking on Housing Prices

Using similar information from November 2014, Marmolejo-Duarte (2016) reported that each of the EPC ranks increases 0.85% the price of flats in Barcelona, while in our model (OLS-Model 1 in Fig. 3), such premium increases up to 1.7%. Implying that 15 months after the first results reported in Barcelona the importance of EPC ranking has almost doubled. Nonetheless, according to beta coefficients (calibrated using standardized values), in relation to other attributes energy efficiency remains one of the less important.

	OLS	*Model 1 (Including EPC rank)*				*Model 2 (Excluding EPC rank)*			
	R2	0,795				0,794			
	adjusted R2	0,794				0,793			
	Sigma (SE)	0,270				0,270			
	Variable	***B***	***SE***	***Beta***	***Sig.***	***B***	***SE***	***Beta***	***Sig.***
	Intercept	9,958	0,038		0,000	9,981	0,038		0,000
Architectonic attributes (AS)	Area sq m	0,014	0,001	0,715	0,000	0,014	0,001	0,721	0,000
	Area (sq m)^2	-3,51E-05	0,000	-0,380	0,000	-3,56E-05	0,000	-0,386	0,000
	Num baths	0,117	0,009	0,108	0,000	0,122	0,009	0,112	0,000
	Lift	0,109	0,011	0,086	0,000	0,113	0,011	0,090	0,000
	Condo swimming pool	0,164	0,013	0,084	0,000	0,165	0,013	0,084	0,000
	Large terrace	0,145	0,012	0,078	0,000	0,141	0,012	0,076	0,000
	Air cond	0,086	0,008	0,072	0,000	0,088	0,008	0,074	0,000
	Heating	0,084	0,009	0,066	0,000	0,087	0,009	0,069	0,000
	High quality	0,151	0,022	0,044	0,000	0,145	0,022	0,042	0,000
	High quality of kitchen	0,049	0,008	0,039	0,000	0,049	0,008	0,040	0,000
	Lift x story level	0,008	0,002	0,037	0,000	0,008	0,002	0,036	0,000
	EPC Rank	0,017	0,003	0,034	0,000				
	Recently refurbished	0,043	0,010	0,028	0,000	0,049	0,010	0,032	0,000
	Chimney	0,068	0,017	0,026	0,000	0,063	0,017	0,024	0,000
Envrionment & Accessibility Attributes (EA)	Employment density	2,67E-05	0,000	0,151	0,000	2,71E-05	0,000	0,153	0,000
	Distance to highway (km)	0,038	0,003	0,098	0,000	0,039	0,003	0,100	0,000
	Near to sea 200m	0,225	0,021	0,068	0,000	0,219	0,021	0,066	0,000
	Highway access	0,122	0,015	0,065	0,000	0,122	0,015	0,065	0,000
	Distance to subcentre (km)	0,013	0,002	0,065	0,000	0,013	0,002	0,065	0,000
	Noise annoyance	0,003	0,000	0,053	0,000	0,003	0,000	0,054	0,000
	Near train station	0,030	0,008	0,025	0,000	0,031	0,008	0,026	0,000
	Distance to CBD (km)	-0,003	0,000	-0,073	0,000	-0,003	0,000	-0,074	0,000
Socioeconomic attributes (S)	University pop (%)	0,023	0,001	0,388	0,000	0,023	0,001	0,385	0,000
	Med low income PC	0,046	0,007	0,068	0,000	0,046	0,007	0,068	0,000

Fig. 3 Estimation of OLS with EPC and without EPC variables

The apartments' AS, AE & S attributes statistically significant at 99% of confidence explain almost 80% of the price variation.

- In the architectonic structural dimension (AS) the most important attribute is the built area, the introduction of the squared area with a negative coefficient suggests the existence of diminishing returns in price formation (i.e. the larger the flat, the lower the marginal price increment). The presence of a lift and a swimming pool are the next attributes to enter in this dimension, implying an increase of 10.9 and 16.4% respectively in listing prices. Near in importance is the presence of a large terrace, which contributes to increase prices in 14.5%. It is worth saying that large terraces tend to be preset in penthouses (àtics in Catalan) enjoying natural light, privileged views and quietness. So, their presence might be proxying for a privileged house situation. The interaction coefficient for the attribute “level * lift” reveals that high stories do increase the price of apartments only if they are lift serviced. The presence of air conditioner and heating increase prices 8.6 and 8.4% respectively signaling the importance of thermal comfort in a context where, despite the climate benignancy, buildings in general are poorly isolated.

- In the (EA) dimension employment density is the most important variable. Such density has been intensively used as an indicator of centrality in urban studies. Dense employment means ease of interaction, increased urban accessibility and presence of services. Accessibility to CBD is also an important variable; the semi-elasticity of this attribute suggests that each kilometer that the apartment is separated from the municipality of Barcelona the price decreases 0.3%. Nonetheless, distance to functional subcentres does not necessarily follow that rationale, since the positive sign suggest that prices increase 1.3% for each km that such distance increases. This latter finding is coherent with the fact that dynamic property markets have been located far from historical subcentres. The positive sign of distance to highways imply different things. On the one hand, metropolitan-highways are located in peripheral areas, so being far from such areas imply centrality; on the other hand, such infrastructures produce noise and car emissions. The third covariate in importance is the proximity to sea which increases 22.5% prices. The positive sign of noise annoyance requires an explanation. In this case noise annoyance refers to the proportion of households that declared in the Census that environmental noise is a problem in their neighborhood. Although, environmental noise is basically produced by cars, it is also produced by services such as shops, schools and mainly leisure activities happening both in private and public spaces. For that reason, it proxies for well-serviced zones where open-air activities occur.
- Finally, in the (S) social dimension the model highlights the percentage of people holding a university degree as the most import locative variable. This attribute is related both to income and social perception of the space, since well-educated population tend to have relatively high salaries at the time that it is seen as a desirable source of positive externalities. In this dimension also enters the principal-component related to low medium-low income population, comprised by clerks and even qualified blue-collar working population, despite the fact they do not hold a university degree they have an acceptable income.

Model 2 is specified in the same manner than Model 1, except that EPC ranking has been deliberately excluded as an independent variable. As it can be seen, most of the covariates and factors maintain both their relative importance and semi-elasticity (the maximal variation in semi-elasticity terms is 0.6%). Nonetheless, the adjusted R^2 slightly falls in relation to Model 1, confirming that EPC ranking does play a role in price formation. The residuals of Model 2 have been used in the GWR model next explained.

4.2 Does EPC Ranking has a Stationary Impact on Residential Prices?

As discussed prior, in order to analyze whether EPC ranking has a stationary impact on price formation, a GWR model has been implemented. According to conclusions of Fotheringham et al. (2003) and Brunsdon et al. (1998), the lower the AIC, the higher the adjustment of the model, although an extremely small AIC signals an overfitting issue (Guo et al. 2008). Considering this warning, in this study the optimal bandwidth band is bounded by 200–300 m following a cross-verification process.

Significance of the spatial variability in GWR estimation can be examined more formally by conducting a Monte Carlo Test (see Hope 1968) and its results indicate non-stationary spatial impacts, if *p*-value is found to be less than 0.05.

According to Table 3, GWR-model exhibits an R^2 suggesting that 17% of the variance of residuals of Model 2 can be explained by the EPC ranking when spatial flexibility is allowed. This variable appears as significant at 99% of confidence and, as expected, it is positive in all the quartiles, although some cases have a negative unexpected sign (i.e. the lower the energy efficiency measured by means EPC ranking, the higher the price). Furthermore, according to the Monte Carlo Test, the impact of EPC ranking on prices is not stationary across the space. Figure 4 depicts the spatial distribution of EPC local-coefficients from the GWR analysis. The colors represent the importance of EPC rank according to such coefficient. As it can be seen dwellings with negative energy impact on housing prices locate mainly in three areas: (1) southern AMB (in municipalities such as Sitges, Calafell, El Vendrell, etc.); (2) middle-northern AMB (mainly Llinars del Valles); and (3) middle and northern Barcelona. Municipalities with green color are the most positive sensitive area and located in subcentres of AMB (mainly Terrassa and Sabadell) and Sant Marti District in Barcelona.

4.3 Relationship between EPC Ranking Variation and Urban, Social and Housing Attributes

So far, the results suggest that there is a non-stationary impact of EPC ranking on price formation. Although most of the cases result into a positive expected sign there are some exceptions where local-coefficients for EPC rank have resulted with a reversed sign. In order to explore this situation, and more generally, the trends on EPC rank variation the cases: (1) have been selected if the local coefficient for EPC rank is statistically significant at 90% of confidence, (2) the selected cases have been clustered in 4 groups. Group 1 clusters all the local negative coefficients[2] (138

[2] In order to double check the results of the GWR model, a specific OLS model has been implemented only with the 138 cases where the local GWR coefficient is negative. In this latter OLS model the variable to explain is the residuals from MOD 2, and the unique explaining variable is the EPC rank. The resulting OLS coefficient is negative and equivalent to -0.055 (sig $= 0.01$) which is almost the

Table 3 Estimation results for geographically-weighted-regression model

Geographically-weighted-regression model (3.0)					
R^2	0.186		*AIC*	281.542	
R^2 adjusted	0.170		Sigma (SE)	0.246	
B distribution statistics				*Monte Carlo significance test*	
	Lower-quartile	*Mean*	*Upper-quartile*	*P-values*	
Intercept	−0.122	−0.060	0.010	0.000***	
EPC_Ord	0.004	0.019	0.032	0.000***	
ANOVA					
	Sum of squares	*df*	*Mean square*		
OLS_residuals	398.7	2		*N* nearest-neighbours	282
GWR_improvement	72.5	99.03	0.733	Num. locations to fit	5497
GWR_residuals	326.2	5395.97	0.060		
	F	*Sig.*			
	4.917	0.000			

Note ***Significant at 0.01% level. Dependent variable: residuals for MOD 2. This procedure has been computed using GWR 3.0

cases), Group 2, 3, and 4, roughly have the same quantity of positive cases following a tercile criteria (471 cases each one). As a result, only 1,550 cases are analyzed (see Fig. 5).

From the spatial distribution (Fig. 5), it seems that larger positive impacts of EPC ranking locate in three areas: (1) the largest subcentres, such as Terrassa and Sabadell; (2) the northern Maresme coastal area, such as Canet de Mar and Arenys de Mar; (3) some districts in Barcelona. Conversely, Group 1 cases exhibiting a negative impact concentrate in Sitges.

Figure 6 contains the average value for each of the AS, EA, and S attributes of the analyzed subsample for each of the four groups. According to Fig. 6 the following conclusions can be drawn:

- There is a clear (inverse) correlation between the impact of EPC ranking price and quality of apartments. Namely the higher the impact, the lower the unitary price, built area, quality of kitchen, number of bathrooms, presence of condominium

same than the average of the GWR local coefficients. These results endorse the findings reported here.

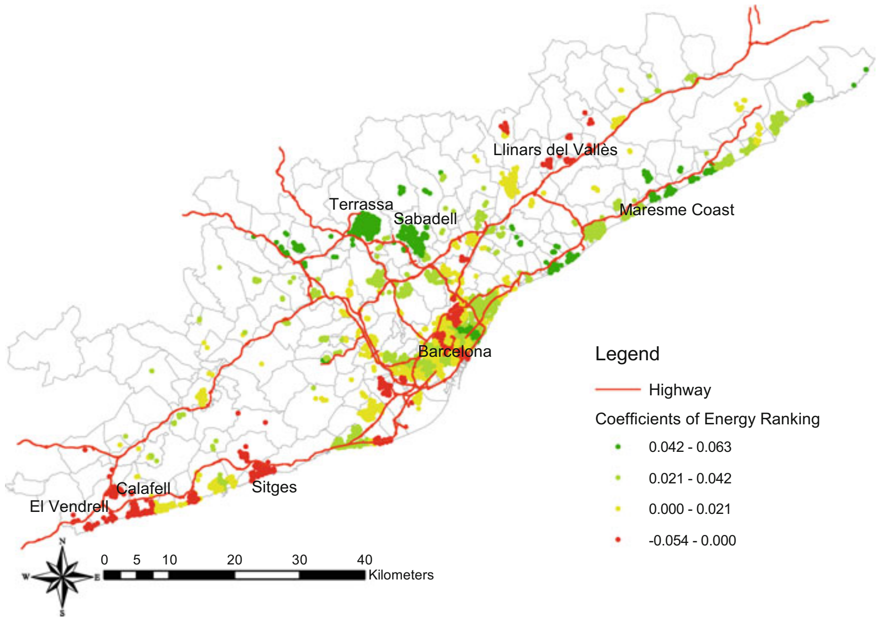

Fig. 4 Distribution of EPC local-coefficients from GWR

facilities such as swimming pool. Less clear is the relationship with the presence of terrace, construction year or heating.

- Also, there is a correlation with locative factors. The larger the EPC ranking impact, the smaller the proximity to train (suburban train and subway) and metro stations, the higher the proximity to metropolitan-highways (located in peripheral locations), and smaller the annoyance of noisy (well serviced) zones.
- Finally, in the (S) social dimension, the larger the impact, the smaller the proportion of well-educated population, and the fewer the presence of high-income population.

On the other hand, the areas where the local-coefficient for EPC ranking is reversed have: relatively new dwellings, depicting the largest average price, with state-of-the-art qualities and facilities, located next to the sea and decidedly populated by the wealthy population. It seems, therefore, that in this coastal submarket the energy performance in buildings is not the main priority for households, producing, in that way, an erratic outcome. At the same time, the larger impact of EPC rakings is located in areas of poor-quality housing inhabited by low income population. In such areas, oriented towards tourism, the proximity to sea, and amenities such as swimming pool, are the main drivers of prices irrespectively the energy efficiency of housing.

5 Conclusions

Several hedonic pricing studies have explored the impacts of mandatory EPC labels on dwellings' price among the European Union (EU). However, the majority of them investigates areas with temperate oceanic climate (Bio Intelligence Service et al. 2013; Brounen and Kok 2011; Fuerst et al. 2015; Hyland et al. 2013), while in Mediterranean climates the evidence on EPC market premiums for efficient housing is scarcer. In Spain the seminal evidence reported by De Ayala et al. (2016) and Marmolejo-Duarte (2016) shows a very small impact of EPC ranking on selling prices. Nonetheless, the reactivation of the national real estate market, after the 2007–2015 crisis, and mainly the impressive increase in the price of utilities claims for revisiting such conclusions. This paper helps to fill that gap by studying the recent hedonic agenda of EPC rankings in Barcelona, one of the largest urban agglomerations in the EU. In doing so, listing information of selling apartments is analyzed using a hedonic approach. The results of the OLS model suggest that each EPC rank increases 1.7% the selling price of apartments; that's almost the double in relation to previous findings (Marmolejo-Duarte 2016). *Thus, the first conclusion of the study reported here is the increase in importance of EPC ranking in a relatively short period of time*. However, compared to results of other climatic zones, the G-A class improvement is still modest: as said, in Barcelona price increase is 10.2%, whereas in Ireland it is 19.9%, in the Netherlands is 15% and in England 12% as reported in Table 1.

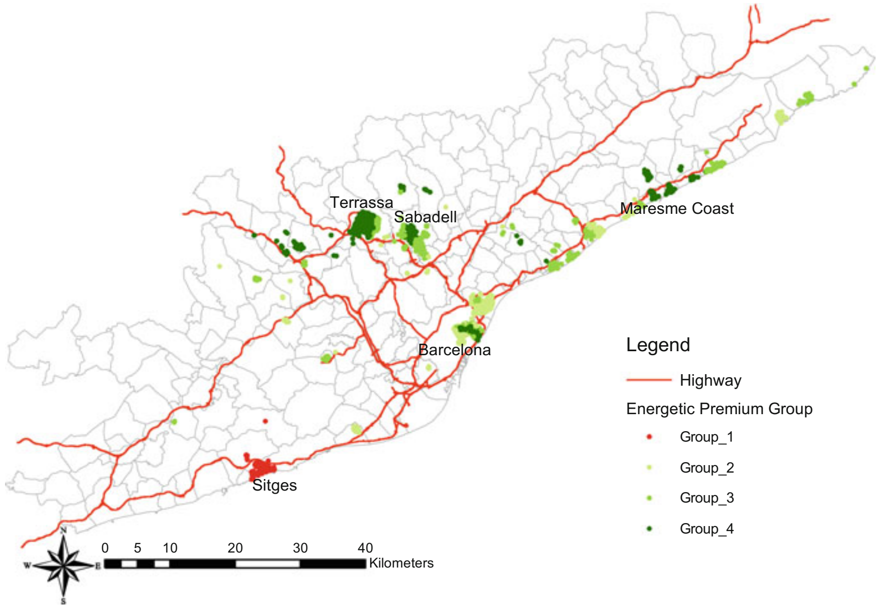

Fig. 5 Distribution of EPC significant local-coefficients from GWR

Group	***1***	***2***	***3***	***4***	***ANOVA TEST***	
N	138	472	470	470		
Average B EPC rank local coefficient	-0.05	0.03	0.04	0.05		
	Mean	Mean	Mean	Mean	F	Sig.
Architectonic attributes (AS)						
Price (Euro)	353,264	205,647	163,012	*153,626*		
Unitary price (Euro/Sq. m)	3,809	2,401	1,914	1,843	170.6	0.000
Area sq. m	95.91	83.85	85.96	84.92	7.2	0.000
Num. baths	1.67	1.32	1.32	1.25	23.4	0.000
Condo swimming pool (%)	34%	6%	13%	7%	35.2	0.000
Lift (%)	0.67	0.69	0.7	0.69	0.2	0.918
High quality of kitchen (%)	38%	29%	35%	28%	3.4	0.017
Air cond. (%)	0.46	0.43	0.42	0.37	1.9	0.136
Heating (%)	90%	59%	67%	72%	17.4	0.000
Chimeney (%)	0.06	0.02	0.04	0.04	1.5	0.200
Recently refurbished (%)	15%	24%	19%	16%	3.6	0.012
High quality	0.04	0.02	0.03	0.02	0.9	0.440
EPC rank (A=7, G=1)	2.36	3.13	2.83	2.72	14.8	0.000
A,B,C EPC Rank (%)	12%	21%	18%	11%	5.8	0.001
Large terrace (%)	24%	10%	11%	10%	7.9	0.000
Construction year	1983	1973	1978	1974	10.7	0.000
Built before 1981 (%)	50%	73%	63%	71%	11.3	0.000
Built between 1981 and 2007 (%)	43%	15%	26%	21%	16.9	0.000
Built after 2007 (%)	7%	12%	12%	7%	2.6	0.049
Environment & Accesibility attributes (EA)						
Near to sea 200m	25%	3%	1%	3%	53.9	0.000
Highway access	99%	92%	79%	87%	19.9	0.000
Near train station	62%	62%	47%	40%	19.4	0.000
Distance highway (km)	0.80	2.18	1.93	1.87	28.0	0.000
Distance to subcentre (km)	6.84	5.24	4.46	3.35	73.5	0.000
Distance to CBD (km)	33.35	12.63	22.31	23.09	143.0	0.000
Noise annoyance (%)	37.94	41.90	37.54	33.54	53.9	0.000
Employment density (jobs/sq km)	178	4143	2417	2208	90.2	0.000
Socioeconomic attributes (S)						
University pop (%)	0.24	0.13	0.11	0.12	146.3	0.000
High income PC	1.58	0.14	-0.18	-0.05	147.6	0.000
Medium income PC	0.23	0.55	0.33	0.50	87.9	0.000
Med low income PC	-0.40	0.11	-0.05	-0.31	35.6	0.000

Fig. 6 Statistical description for 4 groups

In general, the reviewed studies have found the impact of EPC ranking to be larger in the selling market in relation to the leasing one, and larger in cheap, small and rural located houses, perhaps because such dwellings are targeted to people with family budgets more sensitive to energy savings. Nonetheless, none EPC study has researched the spatial implications of energy efficiency marginal price. An exception is the work of Chegut et al. (2014) that reports a "gentrification" (sic) process for the London office market. According to these authors, in such scenario a new BREEAM certified building exhibits a marginal market premium lower than the previous certified neighboring office building, implying in that way a spatial competence. In Barcelona, Marmolejo-Duarte (2016) also reports that EPC ranking only becomes statistically significant when location control variables are introduced into models, suggesting a kind of spatial dependence that must be extensively explored. For that reason, the second objective of this research is to explore whether EPC ranking agenda is stationary across the city. In order to investigate such item, a geographical weighted regression model has been implemented. For the sake of simplicity, the process has consisted in regressing the residuals of OLS hedonic model in which EPC ranking has not been introduced. *The results, refrained by Monte Carlo Test, suggest that EPC ranking coefficients are not the same across the metropolis of Barcelona*. On the contrary, there are deep variations: as a matter of fact, in a selected pocket of the metropolis the sign of the local-coefficients is reversed. Looking closer this erratic "residential submarket", it can be noticed that it is formed by state-of-the-art, relatively new coastal group of dwellings (including the "exclusive" Sitges area), located precisely in a zone inhabited by wealthy population. So, what is clear is that, in this area, energy efficiency is not a priority in relation to other residential and locational attributes (for example in Sitges, dwellings facing the extremely expensive waterfront were constructed when compliance with isolation requirements was scarce), making the coefficient for local EPC ranking appear as erratic.

The deeper analysis of local EPC ranking coefficient undercovers more serious menaces coming from the price formation in relation to energy efficiency. It seems there is a clear correlation between the importance of EPC rank on price formation to the quality, location and socioeconomic conditions. The larger the impact of EPC ranking on property prices, the lower the quality, less central and less wealthy the neighborhood where dwellings are located. It is to say, the areas depicting the worst of the architectonic conditions of apartments inhabited by the less wealthy population are those where EPC rankings have a larger impact on housing prices. This finding has enormous implications for public policy from the social cohesion perspective, since precisely low-income areas are inhabited by less educated population with large barriers to find economic resources leading to housing retrofit. So, a pretty well intended environmental policy, such as energy labels coming from the EPBD might have negative unexpected social consequences. By increasing the negative impact of low energy efficiency, an important brown discount appears, undervaluing the main asset of poor population. There are some possible explanations for this finding. On the one hand, there is the fact that low quality energy efficiency conditions imply a larger impact of low-income family budgets coming from energy bills. On the other hand, we see the fact that in low quality market segments most of the amenities and facilities such as lift, air conditioning & heating systems, large terraces or even swimming pool are absent. Therefore, in absence of quality differentiating attributes, EPC energy ranking may play an incorrect quality differencing role (Marmolejo-Duarte and Chen 2019a). For that reason, it is necessary to review the strategies regarding the communication strategy of the EPC scheme, as well as, the implications of efficient homes over household's budgets and the environment. As well to construct robust indicators of architectonic quality in order to better isolate the impact of energy efficiency on housing prices.

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References

Arcipowska A, Anagnostopoulos F, Mariottini F et al (2014) Energy performance certificates across the EU. A Mapping of National Approaches: 60

Banfi S, Farsi M, Filippini M et al (2008) Willingness to pay for energy-saving measures in residential buildings. Energy Econ 30:503–516. https://doi.org/10.1016/j.eneco.2006.06.001

Bio Intelligence Service, Lyon R, IEEP (2013) Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries. In: Final report prepared for European Commission (DG Energy): Paris, France, 19 April 2013

Bottero M, Bravi M (2014) Valutaziones dei benefici conessi al riasparmio energetico degli edifice: un approccio económetrico. Ambiente e Sicurezza: 15–24

Brounen D, Kok N (2011) On the economics of energy labels in the housing market. J Environ Econ Manag 62:166–179. https://doi.org/10.1016/j.jeem.2010.11.006

Brunsdon C, Fotheringham S, Charlton M (1998) Geographically weighted regression. J Roy Stat Soc D-Sta 47:431–443. http://www.jstor.org/stable/2988625?origin=JSTOR-pdf

Can A (1992) Specification and estimation of hedonic housing price models. Reg Sci Urban Econ 22:453–474. https://doi.org/10.1016/0166-0462(92)90039-4

Charlton M, Fotheringham S, Brunsdon C (2005) Geographically weighted regression. In: ESRC National Centre for Research Methods, University of Leeds, Leeds

Chegut A, Eichholtz P, Kok N (2014) Supply, demand and the value of green buildings. Urban Stud 51:22–43. https://doi.org/10.1177/2F0042098013484526

De Ayala A, Galarraga I, Spadaro JV (2016) The price of energy efficiency in the Spanish housing market. Energy Policy 94:16–24. https://doi.org/10.1016/j.enpol.2016.03.032

Epple D, Quintero L, Sieg H (2018) A new approach to estimating hedonic equilibrium models for metropolitan housing markets. *Johns Hopkins Carey Business School Research* Paper No. 18–12. https://doi.org/10.2139/ssrn.3216207

Eurostat-European Commission (2016) Energy transport and environment indicators. Luxembourg

Fotheringham AS, Brunsdon C, Charlton M (2003) Geographically weighted regression: the analysis of spatially varying relationships. Wiley/University of Newcastle, West Atrium/UK

Fregonara E, Rolando D, Semeraro P (2017) Energy performance certificates in the Turin real estate market. J Eur Real Estate Res 10:149–169. https://doi.org/10.1108/JERER-05-2016-0022

Fuerst F, McAllister P, Nanda A et al (2015) Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. Energy Econ 48:145–156. https://doi.org/10.1016/j.eneco.2014.12.012

Guo L, Ma Z, Zhang L (2008) Comparison of bandwidth selection in application of geographically weighted regression: a case study. Can J Forest Res 38:2526–2534. https://doi.org/10.1139/X08-091

Himmelberg C, Mayer C, Sinai T (2005) Assessing high houses prices: bubbles, fundamentals and misperceptions. J Econ Perspect 19:67–92. https://doi.org/10.1257/089533005775196769

Hope AC (1968) A simplified Monte Carlo significance test procedure. J R Stat Soc B: 582–598. https://www.jstor.org/stable/2984263

Hyland M, Lyons RC, Lyons S (2013) The value of domestic building energy efficiency—evidence from Ireland. Energy Econ 40:943–952. https://doi.org/10.1016/j.eneco.2013.07.020

Li F, Norrbin S, Rasmussen D et al (2005) Hedonic regression models when unmeasured quality differences are present. In: Florida State University, Tallahassee, FL

Malpezzi S (2003) Hedonic pricing models: a selective and applied review. Housing Economics and Public Policy: 67–89. https://doi.org/10.1002/9780470690680.ch5

Marmolejo-Duarte C (2016) La incidencia de la calificación energética sobre los valores residenciales: un análisis para el mercado plurifamiliar en Barcelona. Inf Constr 68:156–168. https://doi.org/10.3989/ic.16.053

Marmolejo-Duarte C, Chen A (2019a) The uneven price impact of energy efficiency ratings on housing segments. Implications for public policy and private markets. Sustainability 11:372. https://doi.org/10.3390/su11020372

Marmolejo-Duarte C, Chen A (2019b) La incidencia de las etiquetas energéticas EPC en el mercado plurifamiliar español: un análisis para Barcelona, Valencia y Alicante. Ciudad y Territorio Estudios Territoriales, Vol. (LI), 199. https://upcommons.upc.edu/bitstream/handle/2117/133075/CyTET%20199_Marmolejo-Chen.pdf?sequence=1&isAllowed=y

Marmolejo-Duarte C, González-Tamez C (2009) Does noise have a stationary impact on residential values? J Eur Real Estate Res 2:259–279. https://doi.org/10.1108/17539260910999992

Roca-Cladera J, Marmolejo-Duarte C, Moix M (2009) Urban structure and polycentrism: towards a redefinition of the sub-centre concept. Urban Stud 46:2841–2868. https://doi.org/10.1177/2F0042098009346329

Sheppard S (1999) Hedonic analysis of housing markets. Handb Reg Urban Econ 3:1595–1635. https://doi.org/10.1016/S1574-0080(99)80010-8

An Analysis of the Energy Efficiency Impacts on the Residential Property Prices in the City of Bari (Italy)

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Abstract With reference to the current topic of the energy efficiency of residential properties, the aim of this research is to analyze the contribution of the energy performance component on the housing prices. The study has been carried out on a sample of two hundred residential properties recently sold and located in the city of Bari (Italy). In addition to the characteristics of energy performance, the main influencing factors considered by buyers and sellers in the transactions have been detected. For this purpose, a data-driven technique has been implemented, that employs a genetic algorithm to identify the best functional expressions. The outputs obtained highlight an appreciable influence of the energy factors on the housing prices. The results could be a useful support for both the private and public actors operating in the field of residential property management.

Keywords Energy efficiency · Energy performance · Housing prices · Genetic algorithm · Influencing factors

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1 Introduction

The topic of the energy efficiency of buildings plays an increasingly important role in the international policies in order to contain the energy consumption of buildings and, in general, to reduce the impact of CO_2 emissions and greenhouse gases in the environment.

In Italy, the energy efficiency goal has been specified by the Legislative Decree No. 102 promulgated in 2014, that provides for a program to improve the energy performance of buildings aimed at saving 20 Mtoe/year of primary energy and 15.5 Mtoe/year of total energy by 2020 (Italian Ministry of Economic Development 2017).

The construction sector represents the main focus of the energy issue: in fact, it consumes about 40% of the EU's final primary gross energy and about 75% of the present buildings are inefficient. This is the main input from which the need for a decisive action of energy retrofit is developed, aimed at accelerating the renovation of the buildings in order to make them more attractive to consumers. The benefits resulting from these operations are both environmental and economic, contributing to the growth of the construction sector that alone accounts for about 9% of the EU's Gross Domestic Product (ENEA 2017).

Currently there are several tools for monitoring and promoting energy efficiency in the countries of the European Union. Through the Directive 2012/27/EU (2012), a series of measures for energy containment and, in general, for a more conscious use of energy sources, has been defined, aimed at achieving 20% improvement in energy retrofit by 2020 across the European Union. The installation of heat and energy consumption counters in every property units located in buildings with centralized heating system has become mandatory since December 31, 2016.

In recent decades, also in Italy the energy policies (Italian Legislative Decree 2005; Italian Law 2016; Italian Law Decree 2013) have been characterized by a positive and significant change: new regulatory instruments have been introduced and new technical and fiscal measures have been implemented. Among these, the 65% tax deductions for expenses incurred by December 31, 2017 for the implementation of energy efficiency actions have been an important incentive for the optimization of renewable energy resources. The current Italian regulation for energy efficiency in the households (Italian Ministry of Economic Development 2015) targets specific actions to be eligible for tax deduction: *(i)* the decrease in energy requirements for heating, *(ii)* the interventions aimed at improving the thermal insulation of buildings (e.g. through the replacement of the window frames), *(iii)* the installation of thermal solar panels, *(iv)* the substitution of winter air conditioning systems through condensation boilers and heat pumps.

The overall potential savings on a national scale that can be achieved by adopting specific technical criteria on new or refurbished buildings, have been estimated equal to 5.0 Mtoe/year in the period 2021–2030, respect to the maximum value of 9.0 Mtoe/year that could be reached, subdivided between 3.5 Mtoe/year for the residential sector and 1.5 Mtoe/year for the office sector (Federici and Martini 2017).

In recent years, in the European and international context, the strategies aimed at increasing the energy efficiency of existing and new buildings highlight and demonstrate the importance and the relevance of the issue under analysis (Berto et al. 2018; Del Giudice and De Paola 2018; Khan et al. 2018). However, the studies on the impacts of the building energy performance on the Italian real estate market are still in the early stages (Fregonara et al. 2017; Manganelli et al. 2019), and the research developed mainly focuses on the economic and financial conveniences of the retrofit investments rather than on the relationship between the energy efficiency and the market value (Copiello and Gabrielli 2017; Morano et al. 2017). Actually, the topic of the buildings energy efficiency is still quite recent in Europe and mainly in Italy: it is only with the Directive 2002/91/EC that the European Community has promulgated the guidelines for the buildings energy performance calculation, by introducing the mandatory Energy Performance Certification (EPC) in the construction, sale and lease phases of a property; furthermore, people awareness about the energetic issue and the respective response of the market seem to be quite new. Indeed, the market transactions between the buyers and the sellers of residential properties highlight different behaviors as regards the energetic issue, which depend on both the "sensitization" actions promoted by the local Public Administrations and the social and economic conditions of the specific territorial contexts.

At international level, the analysis of the effects of the energy performance of residential properties on selling prices has already been studied by several researchers (Waters and Elder 2007). In recent years, in fact, there has been an increasing speculation on the linkages between the selling prices and the energetic component of buildings. Although, generally, professionals and academics perceive a positive relationship between property prices and energy performance, there is still a lack of solid and balanced evidence to support the financial conveniences that can be obtained from high energetic characteristics in the residential sector.

Over the past 30 years, the several studies that have focused on examining the housing market in the residential sector have simultaneously explored the nature of the relationship between the energy efficiency and the property value (Dinan and Miranowski 1989; Halvorsen and Pollakowski 1981; Johnson and Kaserman 1983; Laquatra 1986; Quigley and Rubinfeld 1989). Frequently, researchers have shown that there is a direct relationship between the energy efficiency and the housing prices, mainly due to the high attention for the energy retrofit in buildings during the last decade, which has led to a renewed interest in measuring the contribution of the energy component in real estate markets. Brounen and Kok (2011) have carried out the first empirical research on a large scale, studying the correlations between the energy labels and the housing prices in the Netherlands. The results obtained have demonstrated that the energy efficiency has a positive influence on the property selling prices. Similar results were obtained by Högberg (2013) that has valued the impact of energy performance on residential property selling prices in Sweden: through a hedonic process, the research has confirmed the expected outputs of a positive influence of the energy performance improvements on the selling prices.

However, recent studies have led to opposite results, by showing an inverse correlation between the energy components and the housing prices. Fuerst and McAllister

(2011), with reference to the UK context and implementing a hedonic regression method on a study sample, have not found any significant functional links between the property energy performance and the respective housing prices and/or rents. Other studies have shown similar outputs (Murphy 2014; Zalejska-Jonsson 2014), highlighting a lack of awareness of the positive effects in terms of economic savings generated by property energetic improvements and the use of innovative technologies for the achievement of high levels of energy efficiency.

2 Aim

The topic of the present paper concerns the framework outlined. Regarding the residential property segment of an Italian city, the aim of the research is to examine the contribution of the property energy performance on the housing selling prices. The results obtained may be a reference for the various public and private actors operating in the territory: *(i)* for investors (real estate funds, pension funds, etc.), for construction companies and for individuals owners of properties, that could check ex ante the advantages—in terms of market value increases against the necessary refurbishment costs—related to the energy efficiency interventions that determine higher energy labels of the properties; *(ii)* for credit institutions, that will be able to ascertain to what extent the loan granted for energy retrofit actions is compensated by the increase in the property market values; *(iii)* for the Public Administrations, that could verify the sensitivity of the local contexts towards the energy saving issues and, consequently, better calibrate the incentive policies and the quality and the intensity of communication (Guarini 2016; Morano et al. 2014; Calabrò et al. 2019). Furthermore, even if the present research focuses on residential private properties, the issue of the energy efficiency impacts on the property values is extremely important also for public buildings.

The correlations between the property prices and the main intrinsic and extrinsic variables considered by the buyers and the sellers in the negotiation phases (e.g. total surface, presence of the parking, presence of the lift, distance from the nearest subway, distance from the nearest highway, etc.) have been explained through an econometric analysis. For this purpose, an innovative Automated Valuation Methodology (AVM), called Evolutionary Polynomial Regression, has been implemented, that uses multi-objective genetic algorithms to search those model expressions that simultaneously maximize the accuracy of the data and the parsimony of the final mathematical functions. The analysis has carried out in the context of the city of Bari, that is the main city of the Apulia region (Southern Italy). The study sample consists of two hundred residential units sold in the two-year period 2016–2017 throughout the municipal territory. In recent years, the city of Bari has been affected by a growing focus on energy policies, with particular regard to the problem of energy savings by adopting a Sustainable Energy Plan and implementing the European project “Smart Cities” (Di Turi and Stefanizzi 2015), in which the requests for energy efficient renovations of domestic buildings in order to reduce energy bills, to improve social status (Pettifor et al. 2015) and thermal comfort, or to increase property values (Jacob 2006) are broadly accepted. From the climatic point of view, the city of Bari is characterized by a temperate and windy climate, with temperatures that during the winter seasons oscillate between +5.3 and +12.6 °C and in the summer periods range between + 18.5 and +27.5 °C, and by the presence of east and mistral winds for most of the year. For this city, as for most cities in Southern Italy, the energy efficiency especially concerns the phenomenon of the summer cooling than the winter heating.

The paper is structured as follows. In Sect. 3, the case study and the variables considered in the model have been illustrated. In Sect. 4, the implemented methodology has been explained. In Sect. 5, the application of the AVM to the case study has been described and the main results obtained in terms of specific statistic performances and empirical reliability of the functional relationships have been outlined and the results have been interpreted. Finally, in Sect. 6, the conclusions of the work have been discussed.

3 Case Study

The case study concerns a sample of two hundred residential properties located in the city of Bari (Southern Italy) and sold in the two-year period 2016–2017. For each residential unit of the selected sample, the main factors that contribute to the formation of the selling prices in the market segment considered, have been identified. These are the characteristics that, according to the experience of appraisers and real estate agents consulted, are the most influent determinants on the residential selling prices. Therefore, with the support of the estate agents operating in the city of Bari, for each property of the sample, the explanatory variables considered are the following:

- the *unit selling price*, expressed in €/m^2, that represents the dependent variable of the model [P];
- the *total surface* of the property, expressed in square meters of gross floor area of the property [S];
- the number of the *bathrooms* in the property [B];
- the *floor* on which the property is located [F];
- the presence of the *lift* [L]. In the model this variable is considered as a dummy variable, in particular the absence of the service is indicated with the value "zero", whereas the presence is represented by the value "one";
- the presence of the *parking* [C]. In the model this variable is interpreted as a dummy variable, in particular the value "zero" indicates the absence of the parking space, whereas the value "one" denotes its presence;
- the quality of the *maintenance condition* of the apartment, taken as a qualitative variable and differentiated, through a synthetic evaluation, by the categories "to be restructured" [Mp], "good" [Mg] and "excellent" [Me]. Following the logic of the dummy variables, the score "one" is assigned to the category that defines the specific quality of each property, and the score "zero" for the remaining two

categories (Hardy 1993). In particular, the "to be restructured" state refers to properties that require significant refurbishment interventions, due to the fact that the functionality of the property is compromised by the inappropriate conditions of the elements that compose it; the "good" state indicates properties whose maintenance conditions are acceptable and whose functions can be conducted without heavy interventions. Finally, the "excellent" state refers to buildings characterized by construction and aesthetic high quality, possibly affected by recent redevelopment and renovation initiatives;

- the *EPC label* [*E*], expressed, according with the current regulations, through the denominations from A4 (the highest level) to G (the lowest level). In the present research, the EPC labels from A4 to A are gather into a single explanatory variable (E_A). Therefore, the variables considered are specified by the following abbreviations, which recall the label they belong to: E_A, E_B, E_C, E_D, E_E, E_F, E_G. Each parameter is interpreted as a dummy variable, assigning a score equal to "one" to the EPC label of the property and, consequently, the score equal to "zero" to all the others;
- the *age of the building* in which the residential unit is located [*Y*]. This variable is calculated as the difference between the year when the property was sold and the year of construction of the building;
- the distance from *the nearest highway*, expressed in kilometers it takes to get there by car [*T*];
- the distance from *the nearest subway*, expressed in kilometers it takes to walk to it [*W*];
- the *municipal trade area* in which the property is located, considering the geographical distribution developed by the Italian Revenue Agency, because of the different location characteristics that contribute to the formation of the selling prices. In particular, five trade areas are defined by the Italian Revenue Agency: "central", "semi-central", "peripheral", "suburban" and "rural". With regard to the city of Bari, the Italian Revenue Agency considers four trade areas: "central" [*Uc*], "semi-central" [*Usc*], "peripheral" [*Up*], "suburban" [*Usb*]. For each property, the score "one" is assigned if the property belong to the specific trade area, whereas the score "zero" is reported for all the remaining locational factors.

4 The Method

The method implemented is the *Evolutionary Polynomial Regression*. This technique uses a simple genetic algorithm engine, in order to combine numerical and symbolic regression methods using polynomial structures (Giustolisi and Savic 2009). The method is a versatile symbolic regression tool based on experimental data. The generic expression is given as Eq. (1) shows:

$$Y = a_0 + \sum_{i=1}^{n} \left[a_i \cdot (X_1)^{(i,1)} \cdot \ldots \cdot \left(X_j\right)^{(i,j)} \cdot f\left((X_1)^{(i,j+1)} \cdot \ldots \cdot \left(X_j\right)^{(i,2j)} \right) \right] \quad (1)$$

where *n* is the number of additive terms, a_i are numerical parameters to be valued, *Xi* are candidate explanatory variables, (i, l)—with *l = (1, …, 2j)*—is the exponent of the *l-th* input within the *i-th* term in Eq. (1), *f* is a function constructed by the process. The exponents *(i, l)* are also selected by the user from a set of candidate values (real numbers). The structure of *f* is set by the user, according to any physical insight. The number and the complexity of the solutions that the methodology will generate depend on the maximum number of terms allowed and on the possible exponents that the user defines in the preliminary phase.

The central idea of the methodology is to search the best form of the function, that is a combination of independent variable vectors (the chosen variables, model inputs), by performing a regression with the Least Squares method to obtain the value of the coefficients of each variable.

The accuracy of each equation returned is checked through the Coefficient of Determination (COD), defined in Eq. (2):

$$COD = 1 - \frac{N-1}{N} \cdot \frac{\sum_N \left(y_{estimated} - y_{\det ected}\right)^2}{\sum_N \left(y_{\det ected} - mean(y_{\det ected})\right)^2} \quad (2)$$

where $y_{estimated}$ are the values of the dependent variable estimated by the methodology, $y_{detected}$ are the collected values of the dependent variable, *N* is the sample size in analysis. The model performance is higher when the COD is close to the unit value.

Another potentiality of the proposed methodology is the ability to simultaneously pursue different objective functions. In this sense, it is possible to define an optimal Pareto frontier of the prefixed objectives, usually conflictual, such as *(i)* the maximization of the model accuracy, through the satisfaction of the appropriate statistical criteria of verification of the equation; *(ii)* the maximization of the model's parsimony, through the minimization of the number of terms (a_i) of the equation; *(iii)* the reduction of the complexity of the model, through the minimization of the number of the explanatory variables (*Xi*) of the final equation. In this way, a range of models is offered to the operator, among which it is possible to choose the most appropriate solution according to the specific needs, the knowledge of the phenomenon in analysis and the type of experimental data used.

5 Application of the Model

5.1 Equations

The methodology is implemented considering the structure of the basic model identified in Eq. (1), without the *f* function selected. Each term of the algebraic expression is assumed as a combination of the inputs, coincident with the explanatory variables raised to the proper numerical exponents. In particular, in order to obtain a wide range of solutions, the possible exponents are in total eleven, with the maximum reachable value equal to “3” and the minimum value equal to “−3” (−3, −2, −1.5, −1, −0.5, 0, 0.5, 1, 1.5, 2, 3).

In accordance with the mathematical formulations generally found in current literature (Cassel and Mendelsohn 1985) the log-linear model has been used.

The implementation of the methodology has generated eleven models, reported in Table 1, that show different direct and inverse relationships between the dependent variable of the model (selling prices) and the independent explanatory variables chosen. Each of the models is characterized by a different number of additive terms and consequently by a different number of variables and, moreover, by a different level of accuracy in terms of COD. In particular, the models identified progressively present a growing number of terms and independent variables, sometimes also combined with others in the same term or repeated several times in the expression.

Although it involves a complication in terms of reading and interpretation of the phenomenon, this circumstance is compensated by a gradually increasing degree of precision. The COD relating to the models obtained, in fact, grows from a minimum value of 42.25%, obtained for model (1), up to a maximum value of 71.38% corresponding to the model (10). The performance indicators show on average a high statistical reliability of the models obtained.

It should be observed that an increase in the precision in the explanation of the observed prices (i.e. in terms of the growth of COD) does not correspond to an excessive increase in the complication of the functional relations. For this reason, in this circumstance, it is considered appropriate to focus on the last equation—model (10)—characterized by additive terms of simple interpretation and a COD equal to 71.38%. The root mean squared error (RMSE) is equal to 3.426% for the model chosen. The mean absolute percentage errors (MAPE), that is the average percentage error between the prices of the original sample and the values estimated, is equal to 3.589%. The maximum absolute percentage errors (MaxAPE), that is the maximum percentage error between the prices of the original sample and the values estimated by the model, is 14.052%.

Analyzing the model (10), the variables selected by the methodology as the most influential in the explanation of the housing selling prices in the city of Bari are the following: the lowest EPC label (E_G), the highest EPC label (E_A), the “excellent” maintenance conditions (*Me*), the presence of the lift (*L*), the total surface of the property (*S*), the distance from the nearest subway (*W*), the “to be restructured” maintenance conditions (*Mp*), the location of the property in a suburban trade area (*Usb*). With reference to the energetic influencing factors and to the maintenance conditions of the properties, the model considers that the “extreme” conditions of these variables (E_A and E_G, *Me* and *Mp*) mainly contribute on the housing prices formation. Therefore, the housing prices of the chosen sample are significantly affected by the extreme values for the energetic variable, and are characterized by an almost “indifferent” appreciation for the intermediate EPC labels. It should be also noted that the model does not consider significant the variable “floor” on which the prop-

Table 1 Equations obtained by the implementation of the methodology

Eq. (n)	Model	COD [%]
(1)	$ln(P) = +0.6107 \cdot L^{0.5} + 7.1988$	42.25
(2)	$ln(P) = +0.30766 \cdot Me^{0.5} + 0.46816 \cdot L^{0.5} + 7.1384$	53.71
(3)	$ln(P) = -0.23614 \cdot E_G + 0.24189 \cdot Me^{0.5} + 0.34941 \cdot L^{0.5} + 7.3284$	58.02
(4)	$ln(P) = -0.21255 \cdot W^{0.5} - 0.41822 \cdot E_G + 0.273 \cdot E_A^{0.5} + 0.29685 \cdot Me^{0.5} + 7.9022$	60.79
(5)	$ln(P) = -0.43059 \cdot W^{0.5} + 0.0076775 \cdot W^2 - 0.47423 \cdot E_G + 0.28905 \cdot E_A^{0.5} + 0.30412 \cdot Me^{0.5} + 8.1479$	64.45
(6)	$ln(P) = -0.36887 \cdot E_G + 0.22497 \cdot E_A^{0.5} + 0.25022 \cdot Me^{0.5} + 0.25083 \cdot L^{0.5} - 0.02257 \cdot S^{0.5} \cdot W^{0.5} + 7.7344$	65.32
(7)	$ln(P) = -0.23272 \cdot E_G^{0.5} \cdot T^{0.5} + 0.23352 \cdot E_A^{0.5} + 0.24478 \cdot Me^{0.5} + 0.24409 \cdot L^{0.5} - 0.025211 \cdot S^{0.5} \cdot W^{0.5} + 7.7867$	67.13
(8)	$ln(P) = -0.12946 \cdot W^{0.5} - 0.25464 \cdot E_G^{0.5} + 0.21839 \cdot E_A^{0.5} + 0.24989 \cdot Me + 0.20111 \cdot L^{0.5} - 0.000078427 \cdot S^2 \cdot Mp^{0.5} \cdot Usb + 7.6283$	68.16
(9)	$ln(P) = -0.1826 \cdot W^{0.5} - 0.34709 \cdot E_G^{0.5} \cdot Uc^{0.5} + 0.24652 \cdot E_A^{0.5} + 0.24084 \cdot Me + 0.19985 \cdot L^{0.5} - 0.0095321 \cdot S \cdot Mp^{0.5} \cdot Usb + 7.7157$	70.69
(10)	$ln(P) = -0.30713 \cdot E_G^{0.5} + 0.24637 \cdot E_A^{0.5} + 0.22598 \cdot Me + 0.5608 \cdot L^{0.5} - 0.024144 \cdot S^{0.5} \cdot L^{0.5} \cdot W^{0.5} - 0.000087575 \cdot S^2 \cdot Mp^{0.5} \cdot Usb + 7.4529$	71.38

erty is located (*F*), even if, in empirical terms, it is well known that the residential units placed on the highest floors—particularly those on the top floor—are generally more affected by the action of the cold in winter and the heat in summer.

The mathematical expression of the model (10) allows to immediately verify the empirical consistence of the signs of some explanatory variable coefficients. In particular, the model highlights the inverse correlation between the unit selling prices and the EPC-G label (E_G), whereas it outlines the direct proportionality between the unit housing prices and EPC-A label (E_A) and the "excellent" maintenance conditions (*Me*). The other variables are combined with each other, so the interpretation of the functional relationships requires a more accurate analysis.

5.2 Empirical Analysis of the Functional Links in the Model

In order to quantitatively specify the contribution of each independent variable selected by the model (10) in Table 1 in the formation of the selling prices, an exogenous simplified approach has employed that, instead of determining the partial derivative of the dependent variable with respect to the *i-th* variable, provides for the variation of the *i-th* variable studied in the variation interval in the observed sample, keeping constant the values of the other variables. In Fig. 1 the functional relationships obtained are represented.

The results obtained lead to interesting considerations.

First of all, the "extreme" EPC labels (E_G and E_A) have a significant influence on the housing selling prices, equal to −26.44% for the EPC-G label and +27.94% for the EPC-A label. In the case of the "excellent" maintenance conditions (*Me*) the percentage of increase in housing prices is equal to +25.36%. Graph IV in Fig. 1 shows a direct relationship between the variable "presence of the lift" (*L*) and the property prices: in particular, the increase in prices recorded following the presence of the lift is equal to +16.61%. The functional relationship shown in the graph V of Fig. 1 confirms the empirical evidence of a decrease in housing prices at a higher distance from the nearest subway (*W*): by analyzing the marginal changes in selling prices according with variations of *W* in the range of values allowed in the study sample—from 0 to 12 km—an important contribution of the variable is observed if the apartments are located near the subway, whereas the furthest residential units are progressively less influenced by this variable. These considerations are summarized in Table 2: it is clear that up to a 1 km distance from the nearest subway, the weight of the variable *W* on the property prices is over 20%, whereas for higher distances there is a contribution lower than 10%.

As regards the impact of the two dummy variables *Usb* (location of the property in a suburban trade area) and *Mp* (the "to be restructured" maintenance conditions), as the model returns functional relationships that provide the significance of their contribution on housing prices when the two variables are present at the same time, it is only possible to analyze their "combined" incidence, i.e. both variables are equal to a unit value—the property characterized by a "to be restructured" maintenance conditions and, simultaneously, located in a suburban trade area. In this circumstance,

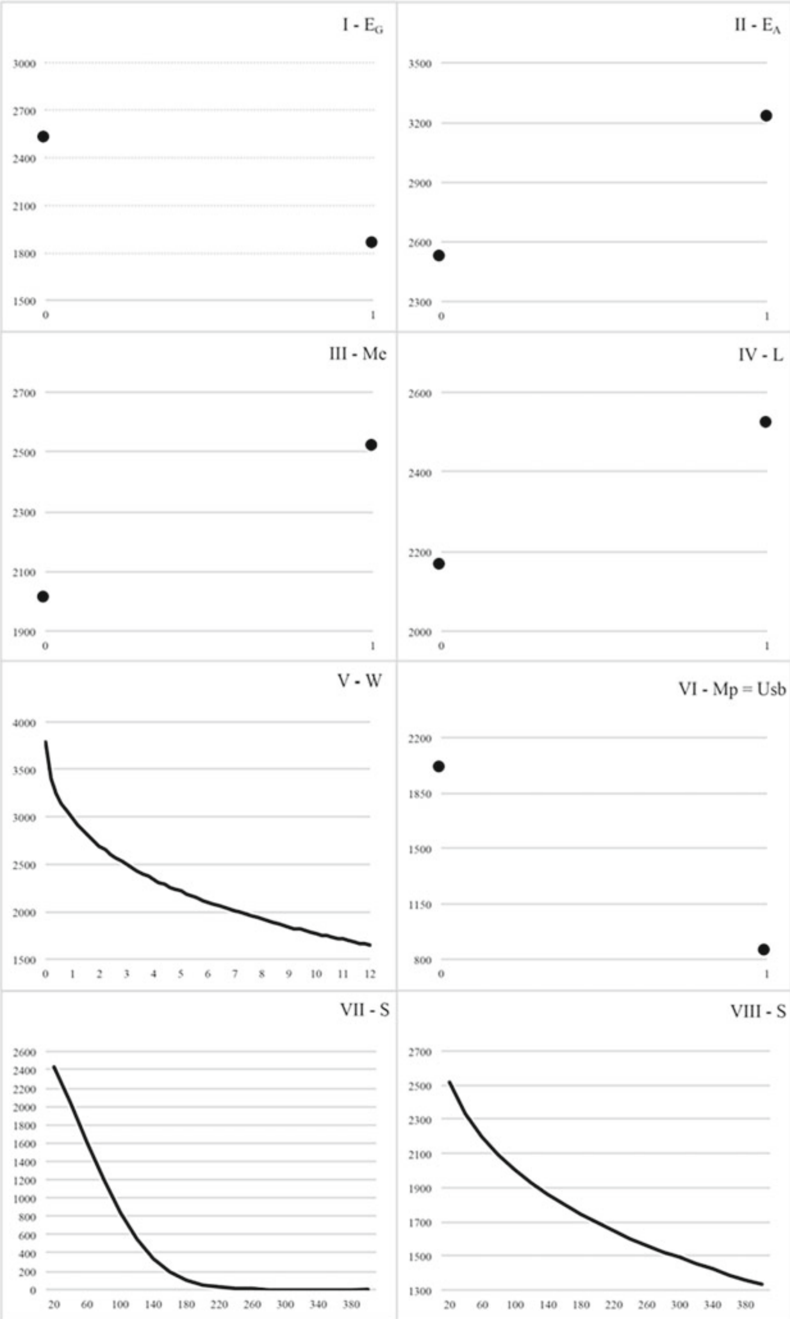

Fig. 1 Evolutionary trend of the variations of the unit housing prices (€/m^2) according to the variables of the model

Table 2 Marginal variations in selling prices related to the variable distance from the nearest subway

W (km)	Δ Unit selling prices [%]
0–1	−21.36
1–2	−9.48
2–3	−7.35
3–4	−6.24
4–5	−5.52
5–6	−5.00
6–7	−4.61
7–8	−4.30
8–9	−4.04
9–10	−3.82
10–11	−3.64
11–12	−3.48

an inverse correlation between the housing prices and the two independent variables considered is highlighted: in particular, the unit selling prices decrease by 57.68%.

Finally, with regard to the total surface of the property (*S*), the model selects this characteristic among those able to explain the phenomena of the property prices formation, but in combination with other factors: in particular, it is combined, in an additive term (fifth of the second member's addendum), with the variables presence of the lift (*L*) and distance from the nearest subway (*W*), and, in another additive term (sixth of the second member's addendum), with the "to be restructured" maintenance conditions (*Mp*) and the location of the property in a suburban trade area (*Usb*). Graphs VII and VIII in Fig. 1 describe two different situations. The first (Graph VII) in which the dummy variables that are combined with the surface (*L, Mp* and *Usb*) are characterized by a value equal to "one", and the second (Graph VIII) in which *Mp*/*Usb* (or both) is equal to "zero" and the presence of the lift is verified ($L = 1$). The results obtained from these two analyzes confirm the empirically expected phenomena: in both cases, the functional relationship between the unit selling prices and the total surface is inverse, but the weight of the size of the apartment is more important in the circumstances characterized by a "depressed" market demand, i.e. affected by properties located in a suburban trade area (*Usb*) and with "to be restructured" maintenance conditions (*Mp*). In these situations, if the unit selling price decreases are on average equal to −25%—for 20 m^2 amplitude classes—up to properties with a total surface equal to 120 m^2, for larger surfaces the unit prices "collapse", highlighting an absence of the sale market for these types of residential properties (Table 3). On the other hand, the contribution of the characteristic total surface to the housing prices is lower when the presence of "to be restructured" maintenance conditions (*Mp*) and the location of the property in a suburban trade area (*Usb*) are not verified: in this contingence, the contribution of the total surface is on average equal to −3% (Table 4).

Table 3 Variations in selling prices related to the variable total surface

S (m^2)	Δ Unit selling prices [%]
20–40	−16.54
40–60	−20.81
60–80	−25.49
80–100	−30.12
100–120	−34.58
120–140	−38.82
140–160	−42.81
160–180	−46.58
180–200	−50.11
200–220	−53.41
220–240	−56.51
240–260	−59.41
260–280	−62.12
280–300	−64.65
300–320	−67.02
320–340	−69.23
340–360	−71.29
360–380	−73.22
380–400	−75.01

6 Conclusions

As regards the context of the city of Bari (Southern Italy), the present research aims to analyze the possible contribution of the energy performance component on the housing selling prices. The study has been carried out on a sample of two hundred residential properties sold in the period 2016–2017, for which, in addition to the characteristics of energy performance, the main influencing factors that in the reference market segment are involved in the selling phenomena have been detected.

The implementation of a data-driven technique has allowed to select a model characterized by a good statistical reliability and, at the same time, by a discrete simplicity in the empirical interpretation of the functional relationships between the housing prices and the explanatory variables. The model obtained has shown that the highest (E_A) and the lowest (E_G) energy performance label identify the main contributions on the housing prices for the sample considered. In particular, the "extreme" EPC labels have a significant influence on the housing selling prices, by determining a variation (respectively negative for EPC-G and positive for EPC-A) equal to approximately 27.00%. This phenomenon could be explained due to the fact that the highest energy performance usually characterizes new properties or apartments affected by recent renovations, i.e. residential units that present excellent

Table 4 Variations in selling prices related to the variable total surface

S (m^2)	Δ Unit selling prices [%]
20–40	−7.30
40–60	−5.65
60–80	−4.78
80–100	−4.23
100–120	−3.83
120–140	−3.53
140–160	−3.29
160–180	−3.09
180–200	−2.92
200–220	−2.78
220–240	−2.66
240–260	−2.55
260–280	−2.46
280–300	−2.37
300–320	−2.30
320–340	−2.23
340–360	−2.16
360–380	−2.10
380–400	−2.05

maintenance conditions. On the other hand, the lowest energy performance level (EPC-G) pertains to properties characterized by "to be restructured" maintenance conditions and/or by obsolete technological elements.

It is not by chance that the poor conservative state is characterized by a significant weight, although the variable "to be restructured" maintenance conditions influences the selling prices only when it is combined with the location of the property in a suburban trade area, denoting the effective identification, through the model selected, of a high complementarity between these two characteristics.

Although the results obtained refer to the context of the city of Bari, the work is part of the research topic inherent the energy issue in progress and, together with other studies completed and presented in the reference literature, can be a useful reference tool for future insights of the impacts of the energy component in the process of the housing selling prices formation.

Finally, it should be noted that for the city of Bari, which is located in Southern Italy, the energy efficiency concerns more the phenomenon of the cooling in summer than the heating in winter. In this sense, it may be interesting to propose a comparison between the results obtained for the city of Bari and the outputs related to a study sample located in a city in Northern Italy, eventually in a geographical context more dynamic from the social and economic point of view.

References

Berto R, Stival CA, Rosato P (2018) Enhancing the environmental performance of in-dutrial settlements: an economic evaluation of extensive green roof competitiveness. Build Environ 127:58–68

Brounen D, Kok N (2011) On the economics of energy labels in the housing market. J Environ Econ Manag 62(2):166–179

Calabrò F, Cassalia G., Tramontana, C. (2019). Evaluation approach to the integrated valorization of territorial resources: the case study of the Tyrrhenian area of the metropolitan city of Reggio Calabria. In: Calabrò F et al. (eds) ISHT 2018, Smart innovation, systems and technologies, vol 101, pp 3–12

Cassel E, Mendelsohn R (1985) The choice of functional forms for hedonic price equations: comment. J Econ 18(2):135–142

Copiello S, Gabrielli L (2017) Analysis of building energy consumption through panel data: the role played by the economic drivers. Energy Build 145:130–143

Del Giudice V, De Paola P (2018) Real estate economics, management and investments: new perspectives and frontiers. Buildings 8(3):40

Dinan T, Miranowski J (1989) Estimating the implicit price of energy efficiency improvements in the residential housing market: a hedonic approach. J Urban Econ 25(1):52–67

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

Di Turi S, Stefanizzi P (2015) Energy analysis and refurbishment proposals for public housing in the city of Bari, Italy. Energy Policy 79:58–71

ENEA (2017) Annual Energy Efficiency Report 2017. Available online http://www.efficienzaenergetica.enea.it/

Federici A, Martini C (2017) Efficienza energetica negli edifici: a che punto siamo?. Ingenio. 54. Available online http://www.ingenio-web.it/

Fregonara E, Rolando D, Semeraro P (2017) Energy performance certificates in the Turin real estate market. J Eur Real Estate Res 10(2):149–169

Fuerst F, McAllister P (2011) The impact of energy performance certificates on the rental and capital values of commercial property assets. Energy Policy 39(10):6608–6614

Giustolisi O, Savic D (2009) Advances in data-driven analyses and modelling using EPR-MOGA. J Hydroinformatics 11:225–236

Guarini MR (2016) Self-renovation in Rome: ex ante, in itinere and ex post evaluation. In: Gervasi O et al. (eds) ICCSA 2016, LNCS, vol 9789, pp 204–218

Halvorsen R, Pollakowski HO (1981) Choice of functional form for hedonic price equations. J Urban Econ 10(1):37–49

Hardy MA (1993) Regression with dummy variables. Sage Publications (93)

Högberg L (2013) The impact of energy performance on single-family home selling prices in Sweden. J Eur Real Estate Res 6(3):242–261

http://www.agenziaentrate.gov.it

Italian Legislative Decree No. 102, July 4, 2014

Italian Legislative Decree No. 192, August 19, 2005

Italian Law No. 232, December 11, 2016

Italian Law Decree No. 63, June 4, 2013

Italian Ministry of Economic Development (2015) Inter-Ministerial Decree June 26, 2015—Application of energy performance calculation methods and definition of requirements and minimum requirements for buildings. Available online https://www.mise.gov.it

Italian Ministry of Economic Development (2017) Annual Report on Energy Efficiency Results achieved and targets for 2020. Available online www.sviluppoeconomico.gov.it/

Jacob M (2006) Marginal costs and co-benefits of energy efficiency investments: the case of the Swiss residential sector. Energy Policy 34:172–187

Johnson RC, Kaserman DL (1983) Housing market capitalization of energy-saving durable good investments. Econ Inq 21(3):374–386

Khan MMA, Ibrahim NI, Mahbubul IM, Ali HM, Saidur R, Al-Sulaiman FA (2018) Evaluation of solar collector designs with integrated latent heat thermal energy storage: a review. Sol Energy 166:334–350

Laquatra J (1986) Housing market capitalization of thermal integrity. Energy Econ 8(3):134–138

Manganelli B, Morano P, Tajani F, Salvo F (2019) Affordability assessment of energy-efficient building construction in Italy. Sustainability 11(1):249

Morano P, Tajani F, Locurcio M (2017) GIS application and econometric analysis for the verification of the financial feasibility of roof-top wind turbines in the city of Bari (Italy). Renew Sustain Energy Rev 70:999–1010

Morano P, Locurcio M, Tajani F, Guarini MR (2014) Urban redevelopment: a multi-criteria valuation model optimized through the fuzzy logic. In: Murgante B et al. (eds) ICCSA 2014, LNCS, vol 8581(3), pp 161–175

Murphy L (2014) The influence of the energy performance certificate: the Dutch case. Energy Policy 67:664–672

Pettifor H, Wilson C, Chryssochoidis G (2015) The appeal of the green deal: empirical evidence for the influence of energy efficiency policy on renovating homeowners. Energy Policy 79:161–176

Quigley JM, Rubinfeld DL (1989) Unobservables in consumer choice: residential energy and the demand for comfort. Rev Econ Stat 71(3):416–425

Waters M, Elder B (2007) Green values and the UK residential market: the impact of energy performance certificates on property value (No. eres2007_316). European Real Estate Society (ERES)

Zalejska-Jonsson A (2014) Impact of energy and environmental factors in the decision to purchase or rent an apartment: the case of Sweden. J Sustain Real Estate 5(1):66–85

Scenarios of Climatic Resilience, Economic Feasibility and Environmental Sustainability for the Refurbishment of the Early 20th Century Buildings

Grazia Napoli, Antonella Mamì, Simona Barbaro and Serena Lupo

Abstract This paper aims to examine the theme of energy retrofit within the circumscribed field of refurbishment interventions on load-bearing masonry buildings built in the early 20th century. These include a remarkable share of the fabric of many European cities and, in particular, they can be found in geographical areas characterized by a Mediterranean (mild) climate. The main objective is to increase the climate resilience of the buildings by verifying the economic feasibility and the environmental sustainability of the interventions, and moreover by observing the specific architectural features of the buildings. We put forward alternative retrofit solutions carrying out synoptic comparisons of several technological solutions and types of materials, assisted by the use of digital tools such as BIM. In order to increase the environmental compatibility of the intervention, this article carries out a closer examination of the comparison between the employment of nanostructured, conventional—of synthetic origin- and natural materials. The selection of the best intervention solution required the elaboration of an iterative flexible integrated process of assessment of energy, technological, economic, environmental and architectural aspects. The methodology we propose here is applied to the case study of Palazzo Utveggio (Palermo, Italy).

Keywords Energy retrofit · Economic feasibility · Building refurbishment · Architectural heritage · Environmental sustainability

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1 Introduction

Existing building heritage may be divided into two main categories: energivorous buildings erected between the 1960s and 1990s and passive buildings, abounding in bioclimatic solutions, which were built until the appearance of the Modern Movement.

Energy retrofit interventions on existing buildings must therefore consider a great variety of technological, structural, architectural and energy characteristics and must weigh up differentiated types of interventions.

When it is the case of buildings of particular architectural value, and with refined construction features, it is necessary to enhance their passive building characteristics by analyzing and restoring all the devices and expedients used in the construction as a defence from hot and cold weather before implementing any technical solutions of intervention. Besides, it is necessary to preserve and safeguard the specific features and values that become morphologic-constructive constraints: these buildings need specific care and a contextualized method of design approach for the intervention. This approach refers to the debate on the forms of preservation of historical buildings which may be regarded as acceptable and is opposite to the Façadism, according to which only the façade is retained (Richards 1994). However in Italy, the Façadism is not adoptable for buildings of such high cultural value. Traditional buildings are connoted by an intrinsic resilience *ab origine*, which can certainly be increased both in the structural dimension and in the energy aspect; this is often somewhat affected by posthumous interventions of doubtful quality and lacking awareness.

Of course, the choice of the solutions implies the selection of materials from the quite broad market offer and becomes an instrument for the achievement of living comfort and environmental sustainability of the interventions.

The operative implementation of energy retrofits is conditioned by economic feasibility that can be achieved through the Discounted Cash Flow Analysis (DCFA), the outcome of which depends significantly on the market prices of the chosen materials and on the energy price trend. In particular, the use of innovative materials, which have not yet reached a full industrial maturity, can be penalized by very high prices and by the non-inclusion in the DCFA of all positive externalities such as, improvement of the comfort degree, reduction of greenhouse gas emissions, low ecological footprint, use of secondary raw materials.

Many European countries use several financial instruments of environmental policy for partially compensating private costs in exchange for social benefits and for leveraging investments in energy retrofit of buildings (iNSPiRe 2014), such as:

- provision of incentives to owners of real estate subjected to energy retrofit, e.g. ‘Conto termico’ in Italy, incentives for passive houses in Austria, Residential Energy Efficiency Credit Line REECL in Bulgaria, Green Deal in Great Britain;
- financing of energy audit studies in Finland;
- granting of loans at subsidized interest rates, e.g. in Great Britain and Austria;
- tax breaks in France, Bulgaria and Italy.

The assessment of energy retrofitting actions falls under the evaluation of complexity, which is a challenge that the estimative discipline has to face when environmental and territorial, architectural and historical goods are involved in a project. In this context, financial and economic evaluations and multicriteria models play a key role (Figueira et al. 2005; Napoli 2014, 2018; D'Alpaos and Bragolusi 2018) as they may support the decision-making process at different levels, from a single retrofitting action to a urban or territorial strategy (Beccali et al. 2017; Lombardi et al. 2017). They may also elaborate different procedures depending on the retrofit type, such as the construction of nZEB buildings (Barthelmes et al. 2016), or the retrofit of existent residential buildings (Gagliano et al. 2017; Mangialardo and Micelli 2019; Verbeek and Hans 2005), as well as of historical-architectural monuments (Fiore et al. 2016; Nesticò and Pipolo 2015) or of public buildings (Napoli et al. 2017a). Furthermore, evaluations can assume morphogenetic connotations (Napoli 2015) as they are able to produce useful information (Napoli et al. 2017b) to modify the alternatives in order to harmonize different project objectives, such as energy, environmental and economic, and to reach the best possible solution.

This paper proposes a methodology that can be applied into the specific field of energy retrofit interventions on buildings erected in the early 20th century. The buildings, which constitute the fabric of a large number of districts in Italian and European cities (Mibact 2015; EN 16883:2017), have a structure made of load-bearing masonry or a mixed structure and we thought it appropriate to analyze them in relation to their geographical location, characterized by the usually temperate Mediterranean climate.

The main objective is to increase the climatic resilience (Mamì 2012) of traditional buildings, respecting their architectural characteristics so to grant a good degree of comfort, even in conditions of heavily modified climate (mild winters, humid-hot summers with always more frequent episodes of torrid heat and variable humidity); at the same time we aim to verify the possibility to achieve economic and financial expedience and environmental sustainability.

We propose and explore alternative retrofit solutions which, though included in a wider project on the entire building, concern interventions on exterior walls (which constitute a significant percentage of the enclosure), carrying out specific synoptic comparisons between different types of materials (nanostructured, conventional—of synthetic origin- and natural).

Furthermore, we have developed the analysis and enhancement of the building original devices for passive heating and cooling, that is the thermoregulation, also in the absence of heating and cooling systems, thanks to the relation with the atmospheric agents (sun and wind in particular) (Franco et al. 2015, 2017). As a matter of fact, the passive cooling of this type of buildings used to be obtained thanks to the significant thickness of the walls, to devices of defence from direct sunrays and to natural ventilation systems aimed to push away masses of hot air in the summer season (Rodriguez-Linan et al. 2017).

In order to verify the actual feasibility of the interventions in the current market conditions, we carried out detailed price surveys so to determine the investment costs and took into consideration the fiscal incentives provided by the Italian laws. The methodology we have used is tested on a case study: Palazzo Utveggio (Palermo, Italy), a building with highly valued architectural and artistic qualities.

2 The Proposed Method

The technological and architectural peculiarities of heritage buildings constructed in the early 20th century, the attention to environmental compatibility of interventions and the client's economic feasibility constitute the elements upon which the method proposed here is focused. This method was elaborated to support the planning of several alternative energy retrofits employing different materials available on the market and included a feedback practice.

Our method is composed of the following steps (Fig. 1):

- Documental and morphologic-constructive analysis;
- Clime and energy analysis;
- Laws and constraints analysis;
- Energy retrofit and alternative technological solutions;
- Energy balance and economic analysis;
- Energy efficiency and economic feasibility tests;
- Choice of the best alternative.

2.1 Documental and Morphologic-Constructive Analysis

A large number of the urban buildings erected in the early decades of the 20th century has a high architectural quality and is the result of designs by architects and engineers who were well known and active on the local territory and often also in the rest of the country. It is appropriate to carry out a documental analysis of the archives which can provide information on the original plans and the possible existing transformations. Moreover, it is useful to acquire information on the contractors, on the—mostly local—materials used and on the building techniques.

Following a specific geometric and building survey, possibly implemented with interactive systems such as the Building Information Modelling, with dedicated libraries families, it is necessary to analyze the typo-morphological aspects of the building, the technological specificities and to identify the current performance that the building offers under multiple dimensions, such as structural, technological, energetic, morphological and, if the case, artistic aspects.

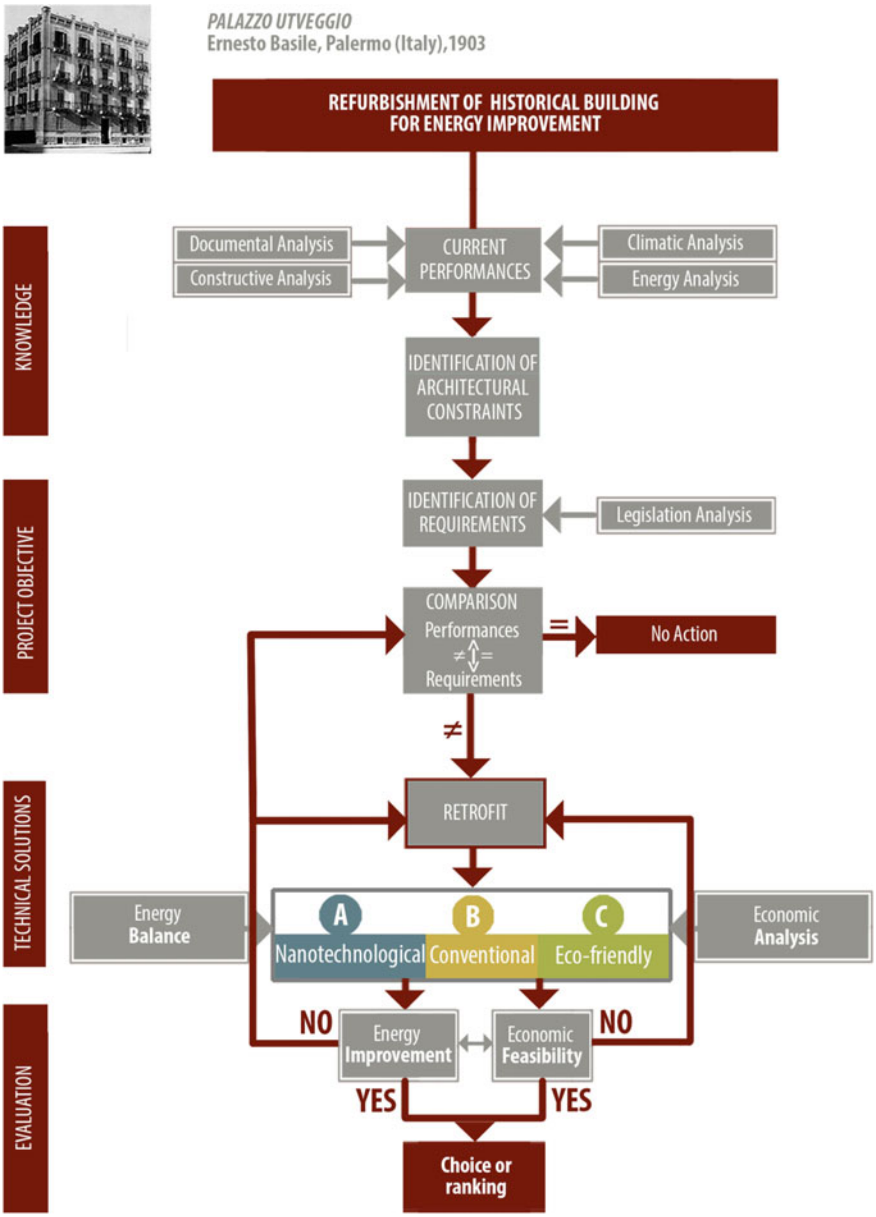


Fig. 1 Structure of the proposed method

2.2 Clime and Energy Analysis

The climatic analysis, which includes wind and sun analyses, provides plenty of specific data on the environmental and urban context in which the building is located. In a systemic vision and aided by updated software, the contextual dynamics of temperatures and winds, the sun diagram, the morphology of the blocks and the single building allow to investigate the current energy performance of the building and of its indoor environment, the thermic behaviour of single elements and of the building system in relation to environmental factors over different seasons. This is essential to determine discomfort conditions, the requirements of thermal input and primary energy, and the need to implement new performances through retrofit interventions in order to obtain greater energy efficiency and a better living quality.

2.3 Laws and Constraints Analysis

In order to meet the requirements of environmental sustainability and energy savings, the rules and regulations encourage an adjustment of the building leading to full energy efficiency within the thresholds of presumable living comforts. In the case of historical buildings, bound by specific legislative and non legislative dispositions, the objective must necessarily be to 'improve' their energy performance, or rather to define the best possible solution towards efficiency but always respecting and safeguarding their valuable qualities and characteristics of cultural interest. It is therefore necessary to identify the normative obligations that those who are going to carry out an intervention on the buildings must respect; besides, it is necessary to determine the formal, morphological and construction constraints singled out in the building as they impose invariability, compatibility and integration (Pinto et al. 2017). The requirements connected to the users' wellbeing and comfort as well as energy savings requirements, though codified in normative dispositions, find their limits in the acknowledged and physically intercepted values of the edifice, this is a condition which imposes a revision of thresholds and objectives.

Such specificity makes it as indispensable as ever to develop an operative method contemplating feedback practices in order to reconsider design objectives and intervention solutions.

2.4 Energy Retrofit and Alternative Technological Solutions

The solutions for the increase of the energy performance of the building must be refined starting from the performance analysis and the climatic analysis. As said above, the priority is to enhance the original bioclimatic characteristics; the system integration must follow all other priorities and it must involve the lowest possible energy consumption. Above all, for winter heating, the interventions on the enclosure are of primary necessity (exterior walls, roofs, and possibly solid ground floors) because of its role of interface with the outdoor environment. It is almost always impossible to create an external wall 'coating' for the types of building which are the subject of this study, because of the characteristic façades and plaster. Therefore, we are left with the possibility to work in a careful and compatible way on the interior surfaces by integrating several insulating sheathing boards and, as regards doors and windows, especially on glass surfaces which can be replaced with double glazing.

The market offers a wide range of specific materials which can also be combined together. At present we can choose highly innovative materials, such as nanostructured ones, conventional materials, natural and eco-compatible ones. In any case, we can work on the number of layers, on the thickness and on the specificity of the materials according to their thermal conductivity, density, and thermo-hygrometric regulation ability, as well as to their durability and costs.

For summer cooling it is important to rely on the inertial masses of the walls, on cross and stack ventilation for the circulation of air masses so that the hot air and humidity can be more easily pushed away.

It is crucial to know well the building and the possible solutions in order to develop consistent and compatible integrations which may grant the efficient functioning of the whole building-system (exclusion of thermal bridges, unknown relations and inconsistencies, incompatibility and reciprocal harmfulness of the solutions).

2.5 Energy Balance and Economic Feasibility

The economic feasibility of energy retrofitting alternatives is assessed by applying the DCFA, that discounts the flow of annual revenues and costs. It has been chosen because is able to verify whether the real estate owners reach the economic feasibility also when numerous constraints are introduced in order to respect the architectural characteristics of historical buildings. Another requirement is to verify how much the use of innovative or eco-friendly materials can be competitive at market prices in comparison to the common in use materials. The cost of the alternative, in fact, is strongly influenced by the prices of the chosen materials and by the reduction in energy consumption that is converted into monetary savings on the cost of bills.

Financial instruments provided for by law may support economic feasibility. Currently, the Italian "Conto Termico 2.0" (Ministerial Decree 16/02/2016) provides incentives to public and private entities for energy retrofit of buildings. The awarding of incentives is differentiated on the basis of the following factors: type of retrofitting action, public or private applicant, transmittance and climatic zone. The incentive is calculated according to the conditions in Fig. 2 and then is divided into five annual instalments, or is disbursed in a single instalment when it is lower than a minimum value.

Another instrument of environmental policy is the tax benefit as the tax deduction on IRPEF (personal income tax) or on IRES (corporate income tax) provided by

Type of action		Percentage of admissible cost	Maximum admissible cost	Maximum value of incentive
i. Opaque horizontal structure: roofing insulation	external internal ventilated roof	40% (50% in zones E, F)	200 €/sq.m 100 €/sq.m 250 €/sq.m	*i* + *ii* + *iii* ≤ 400,000 €
ii. Opaque horizontal structure: flooring insulation	external internal	40% (50% in zones E, F)	120 €/sq.m 100 €/sq.m	
iii. Opaque vertical structure: insulation outer walls	external internal ventilated facades	40% (50% in zones E, F)	100 €/sq.m 80 €/sq.m 150 €/sq.m	
Replacement of window frames, in temperature control rooms		40%	350 €/sq.m zones A, B 100 €/sq.m zones A,B	75,000 € 100,000 €
Sunshade system Automatic Sunshade Devises		40%	150 €/sq.m 30 €/sq.m	30,000 € 5000 €

Fig. 2 The "Conto Termico 2.0" incentives for public entities

the 2018 Italian Budget Law (Law 205/2017) for work on the external envelope of existing residential buildings (Fig. 3). The deduction is divided into 10 annual instalments.

Type of action	Percentage of deduction of the cost of the action	Maximum deduction	Deduction distribution
On wrapping existing buildings (e.g. walls, windows, roofs, floors)	65%	60,000 €	10 annual instalments
On common parts of condominium buildings	70% or 75%	40,000 €	

Fig. 3 Tax deductions (Law 205/2017)

2.6 Verification of Energy Efficiency and Economic Feasibility

The comparison between the baseline energy performances and those of the retrofitting alternatives allows to quantify the energy saving and to know the corresponding energy class of the building.

If the increase in energy efficiency is slight, especially over the costs and the used resources, we return to the stage of processing the retrofitting solution, by modifying for example the type of action and materials, or to the stage of the objectives of the project. The economic feasibility of an energy retrofitting action are measured by the Net Present Value NPV and the Internal Rate of Return IRR, which are calculated on the basis of the cash flow according to the following formulas:

$$NPV = -C_0 + \sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+r)^t} \tag{1}$$

$$-C_0 + \sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+IRR)^t} = 0 \tag{2}$$

where: C_0 is the investment cost at the year 0; R_t is the revenue at the year t; C_t represents the operating cost at the year t; r is the discount rate; n is the numbers of years in the time frame of the analysis.

With reference to the specific scope of this study, R_t is the operating income corresponding to the savings on the annual cost of the energy vector (electricity, methane, etc.) and the revenue from any tax benefits. The economic feasibility is verified for NPV $\geq$ 0 and for IRR > r_s, where r_s is a threshold value of the discount rate that represents the opportunity cost of the capital.

3 Case Study: Palazzo Utveggio (Palermo, Italy)

The case study chosen is Palazzo Utveggio (built in 1903 on a project by Ernesto Basile, Sicilian architect exponent of international modernism and Italian Liberty) as a representative case of the high architectural quality buildings that constitute the middle and upper class districts of the north expansion of Palermo between the end of 19th century and the first decades of the 20th century along via Libertà. Today the property is owned by the 'Istituto dei ciechi' of Palermo. The recognition of the historical-artistic value of the property is attested by a decree of constraint (April 1977) of the 'Assessorato alla Pubblica Istruzione' of the Region of Sicily, which declares "Palazzo Utveggio of historical-artistic interest, for the senses and for the effects of Law n. 1089/1939".

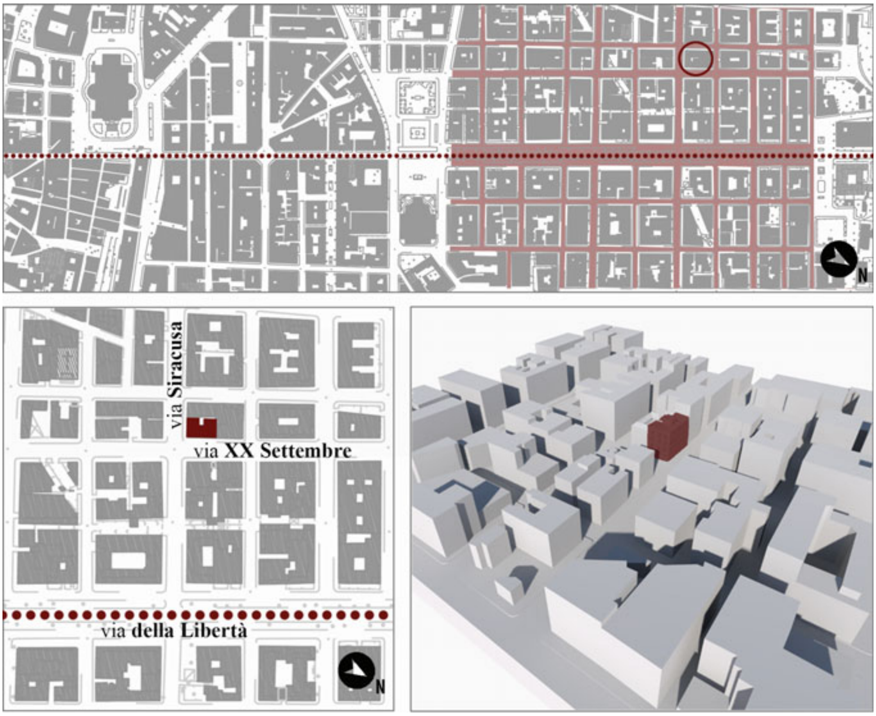


Fig. 4 Location of Palazzo Utveggio in the 19th century expansion zone

3.1 Documental and Morphological-Constructive Analysis

Palazzo Utveggio is located in an area where, between 1891 and 1892, the National Exhibition curated by Basile took place. The land was developed later in square blocks along with the construction of via Libertà. Palazzo Utveggio, which occupies an angular lot between via XX Settembre and via Siracusa (Fig. 4), has a symmetrical plant and rises on 4 levels, excluding the basement floor, with a courtyard to the rear (Vassallo 2012).

The Documental analysis relates the sketches, watercolours and drawings of project by Basile to the existent building through a survey within 2016–2017. In the absence of documentation attesting the transformative process of the building construction, we can find significant volumetric and compositional differences, as the coping roof was characterized, in the original drawings of the project, by a hipped roof adorned with wrought iron decorations which perhaps were never made; today there is an impluvium roofing instead, and, in correspondence of the stairwell, a cubic turret with a single compartment (Fig. 5).

The building was studied through old and current photos, surveys, archival research and CAD measured drawings. The three-dimensional and computerized

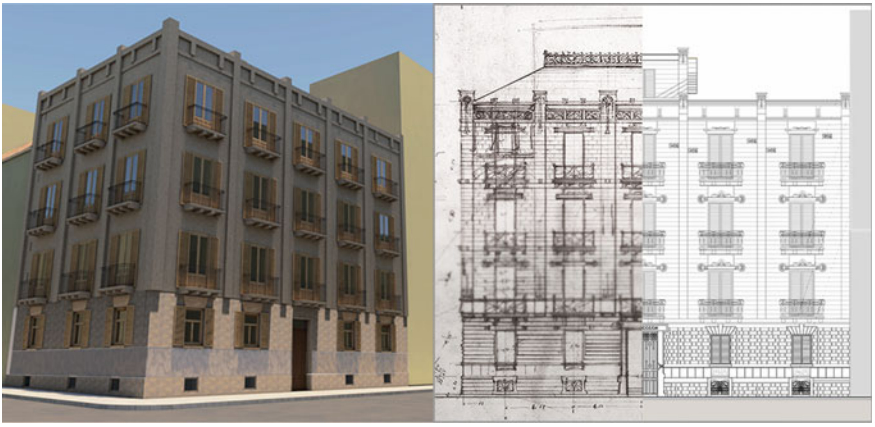


Fig. 5 Left: Render (BIM Software). Right: comparison between the sketch by Basile in 1900 and the current CAD drawing 2016-2017

Fig. 6 Details of the frescoed vault, the flooring in cement tiles and the basement of the front in via XX Settembre

model of Palazzo Utveggio was built through the CAD and BIM model (*Archicad 20—Graphisoft*) for implementation in the energy calculation software (*Termolog Epix 8—Logical soft* s.r.l).

The morphological-constructive analysis is declined in the study of the rich material and decorative apparatus (especially in the main fronts), of the masonry structures (made with biocalcarenite ashlars), of the stained glass and of the technological partitions (floor, roofing, ceilings, etc.) (Fig. 6).

3.2 Clime and Energy Analysis

The climatic analysis consists in the study of the dominant winds, of the solar path and of their environmental impact to macro and microscale. The orography and the compact volumetries of the regular blocks do not allow the wind channelling. In

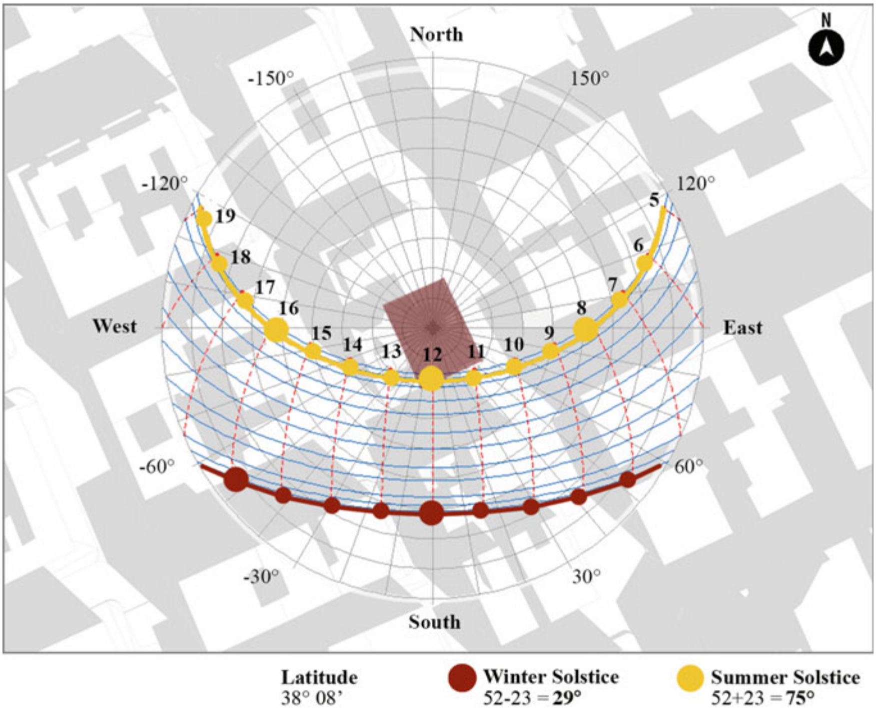


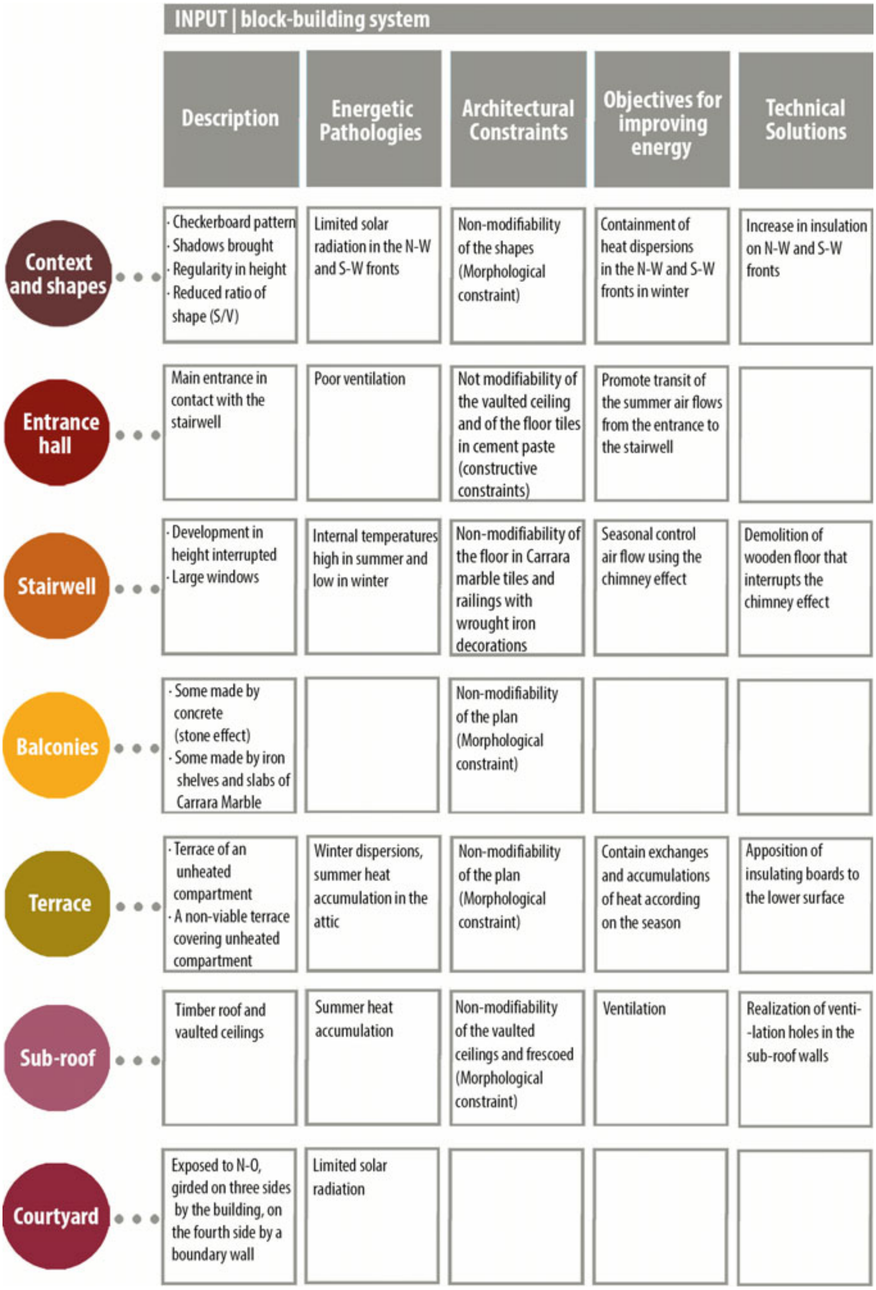
Fig. 7 Solar chart in the area of Palazzo Utveggio

particular, the data of the solar path relative to the building were analysed highlighting the conditions on the solstices (Fig. 7).

The preparatory analyses are useful for the energy analysis. The inputs of the energy calculation software are the data regarding both the block-building system (Fig. 8) and the construction system of the building (Fig. 9) that translates the geometric and constructive information from the 3D BIM model of Palazzo Utveggio in thermo technical information within the energy audit software. Further inputs are the thermal data on the hourly temperatures of the reference locality and on the relationship between them, and the primary energy requirements in a non-stationary but dynamic mode (Fig. 10). According to the results of the energy audit, Palazzo Utveggio was assigned to the energy-efficiency class E.

3.3 Laws and Constraints Analysis in Palazzo Utveggio

There is currently no organic energy retrofit legislation on architectural heritage, but a series of approaches to energy efficient use in historical heritage (e.g. UNI—EN 16883:2017).



INPUT | block-building system

	Description	Energetic Pathologies	Architectural Constraints	Objectives for improving energy	Technical Solutions
Context and shapes	· Checkerboard pattern · Shadows brought · Regularity in height · Reduced ratio of shape (S/V)	Limited solar radiation in the N-W and S-W fronts	Non-modifiability of the shapes (Morphological constraint)	Containment of heat dispersions in the N-W and S-W fronts in winter	Increase in insulation on N-W and S-W fronts
Entrance hall	Main entrance in contact with the stairwell	Poor ventilation	Not modifiability of the vaulted ceiling and of the floor tiles in cement paste (constructive constraints)	Promote transit of the summer air flows from the entrance to the stairwell	
Stairwell	· Development in height interrupted · Large windows	Internal temperatures high in summer and low in winter	Non-modifiability of the floor in Carrara marble tiles and railings with wrought iron decorations	Seasonal control air flow using the chimney effect	Demolition of wooden floor that interrupts the chimney effect
Balconies	· Some made by concrete (stone effect) · Some made by iron shelves and slabs of Carrara Marble		Non-modifiability of the plan (Morphological constraint)		
Terrace	· Terrace of an unheated compartment · A non-viable terrace covering unheated compartment	Winter dispersions, summer heat accumulation in the attic	Non-modifiability of the plan (Morphological constraint)	Contain exchanges and accumulations of heat according on the season	Apposition of insulating boards to the lower surface
Sub-roof	Timber roof and vaulted ceilings	Summer heat accumulation	Non-modifiability of the vaulted ceilings and frescoed (Morphological constraint)	Ventilation	Realization of venti--lation holes in the sub-roof walls
Courtyard	Exposed to N-O, girded on three sides by the building, on the fourth side by a boundary wall	Limited solar radiation			

Fig. 8 Analysis of the input data of the block-building system

INPUT | constructive system

	Description	Energetic Pathologies	Architectural Constraints	Objectives for improving energy	Technical Solutions
External solid wall	Bearing masonry in biocalcarenite ashlars (th. 42x22x25 cm) from Aspra and Santa Flavia quarries	High thermal transmittance and inertia	· Original plaster · Pictorial and relief decorations	Containment of thermal migrations in winter (N-W and S-W) and irradiation In summer (S-E and S-W)	External thermal coating on N-W and S-W fronts and internal thermal sheating on S-E and S-W fronts
Basement floor	Simple floor with stone screed	Thermal migrations towards unheated compartment (basement)	Efficiency objectives not necessary for the use of spaces		
Floor type	Simple wooden floor with stone screed		Non-modifiability of the flooring, made by tiles in cement paste (constructive constraints)		
Ceiling	· Traditional "camorcanna" vaults · Wooden flat ceiling		Non-modifiability of vaults with paintings (constructive constraints)		
Roofing	Pitched roofs with timber structure, and Marseillaise tiles	Heat accumulation during summer months		Attic ventilation	Realization of ventilation holes
Doors	Outside door and entrance doors to housing units in solid wood with fan-light and wrought iron grate		Morphological constraints	Encouraging seasonal exchange and control of incoming and outgoing air flows	Opening in the summer months of the fan-light
Windows	Windows with single glass and wooden frame	High thermal transmittance	Morphological constraints	Reduce the heat transfer in the summer months and contain heat dispersions in the winter months	Glass replacement with low-emissivity double glazing

Fig. 9 Analysis of the input data of the constructive system

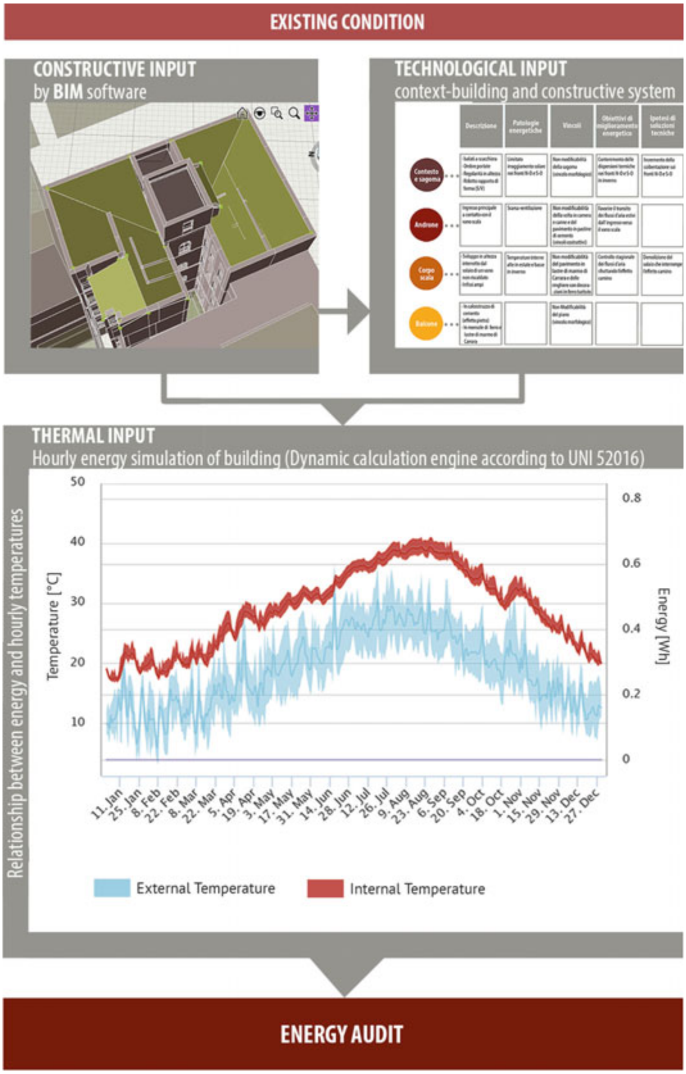


Fig. 10 The inputs data of the energy audit software

The identification of the constraints imposed by the characteristics of the building is the specificity and the added value of the method which, nevertheless its complexity, reveals the more critical factors of the retrofitting intervention. Some of the most specific constraints are identified through the mapping of the elements of high architectural values in addition to the overall morphological-constructive structure: the floorings and ceilings. The floorings are made with cement tiles in drawing, which compose a weave of dense and coloured geometries with a strong aesthetic impact, in staterooms in Carrara marble tiles in the filter and common spaces. The ceilings, arched wooden "camorcanna" vaults, result in almost all the rooms decorated with frescoes by Salvatore Gregorietti (appreciated painter and decorator of the Liberty Palermo style) (Fig. 6).

The main fronts of the building (via XX Settembre, via Siracusa), as representatives of Basile's stylistic facies, are considered constraints, because of historical plaster Li Vigni (particular kind of lime mixture, dolomitic sand and colourings, endowed with extraordinary durability and stone effect, that was patented and diffused in Palermo in the Liberty period) and of the polychrome tiles (Fig. 5).

3.4 Energy Retrofit and Alternative Technological Solutions

The objective of the retrofit is the improvement of the thermal performances although the method is commonly used, the approaches to pursue it can be different depending on the choice of techniques and materials. We chose the following:

- Nano-structured technical and materials → A (*nano-tech*);
- Techniques and materials commonly used in the market → B (*conventional*);
- Technical and materials of natural origin → C (*eco-friendly*).

The main criteria, on whose basis the identification of the three retrofitting solutions produces different scenarios, are: the insulating power with regard to the Alternative A, the cost with regard to the Alternative B, and the environmental impact with regard to the Alternative C, of the materials chosen with the mapping of the constraints and the understanding of the systemic working of the building (Genova et al. 2018).

In particular, it is considered appropriate to act on:

- Passive ventilation. Ventilation is allowed by the planned demolition of the floor and ceiling on the stack of central staircase and by the mechanical opening of the window fan-light of the apartment doors. These actions aim to trigger the chimney effect (ascending hot air flows). Also, the realization of ventilation holes in the attic facilitates the passive cooling (Figs. 11, 12 and 13);
- Insulation of the building envelope (in vertical parts) on which the three retrofit alternatives are concentrated. According to the degrees of freedom left by the constraints for the insulation it was considered to intervene with the exterior sheating (fronts on the inner courtyard) and interior sheating (main fronts). As regard the windows, the presence of certain decorative silhouettes in the frames and in the shutters allows the substitution of the single glass with double glazing with vacuum (gas, Nanogel, etc.). We decided not to replace the frame because the wood of the windows is an excellent insulating material. The roofing (horizontal part of the building envelope) with an attic between the impluvium roof and the vaulted ceilings does not require retrofit: this is already an effective insulating system especially in temperate climates with mild winters, a specific condition of city of Palermo (Figs. 11, 12 and 13).

PASSIVE VENTILATION		
Front doors: • Opening of the window frames (fan-light)	**Stairwell:** • Demolition of the turret floor • Demolition of the arched ceiling	**Roofing:** • Realization of holes in the sub-roof walls

	INSULATION OF THE BUILDING ENVELOPE			
	ENERGY RETROFIT	A Nanotechnological	B Conventional	C Eco-friendly
External solid walls	Apposition of **exterior** insulating sheating boards	Board of silica aerogel reinforced with PET fibres (30 mm)	Board of sintered expanded polystyrene EPS (40 mm)	Kenaf fiber sheating board (40 mm)
External solid walls	Apposition of **interior** insulating sheating boards	Gypsum plasterboards pre--coupled with silica aerogel (20 mm)	Gypsum plasterboards pre--coupled with EPS (50 mm)	Gypsum plasterboards pre--coupled with expaded cork (50 mm)
Window & door frames	Replacement of **glasses** with insulating products	Insulating double glazing with nanogel insert (1,6 cm)	Low-emissivity double glazing with argon insert (2,4 cm)	Low-emissivity double glazing with argon insert (2,4 cm)
Window & door frames	Integration of **door frame**	(thickness until 1 cm)	(thickness until 2 cm)	(thickness until 2 cm)

Fig. 11 Passive ventilation and insulation of the building envelope

With regard to the rooms, the presence of frescoed vaulted ceilings suggests no intervention. In any case, wooden vaulted ceilings, floors mainly in wood, and cavities that they generate are excellent solutions of thermal and acoustic insulation. Moreover there are no heat flows between the rooms to the various levels, since the latter having to find in the same temperature conditions.

Figure 14 shows the output of the energy audit that was carried out on the existing condition (EC), as well as on the 3 retrofitting alternatives, namely A, B and C. It results that the global primary energy consumption (KWh/m^2*y) of the building was almost halved, whereas the energy class reached the more efficient class E.

3.5 Energy Balance and Economic Feasibility

The energy balances of the retrofitting alternatives were provided and compared to the baseline balance to verify whether the energy performance objectives set for the Palazzo Utveggio were reached. If none of the alternatives satisfied them, the method requires the return to the step of retrofitting alternatives or of reformulation of the project objectives.

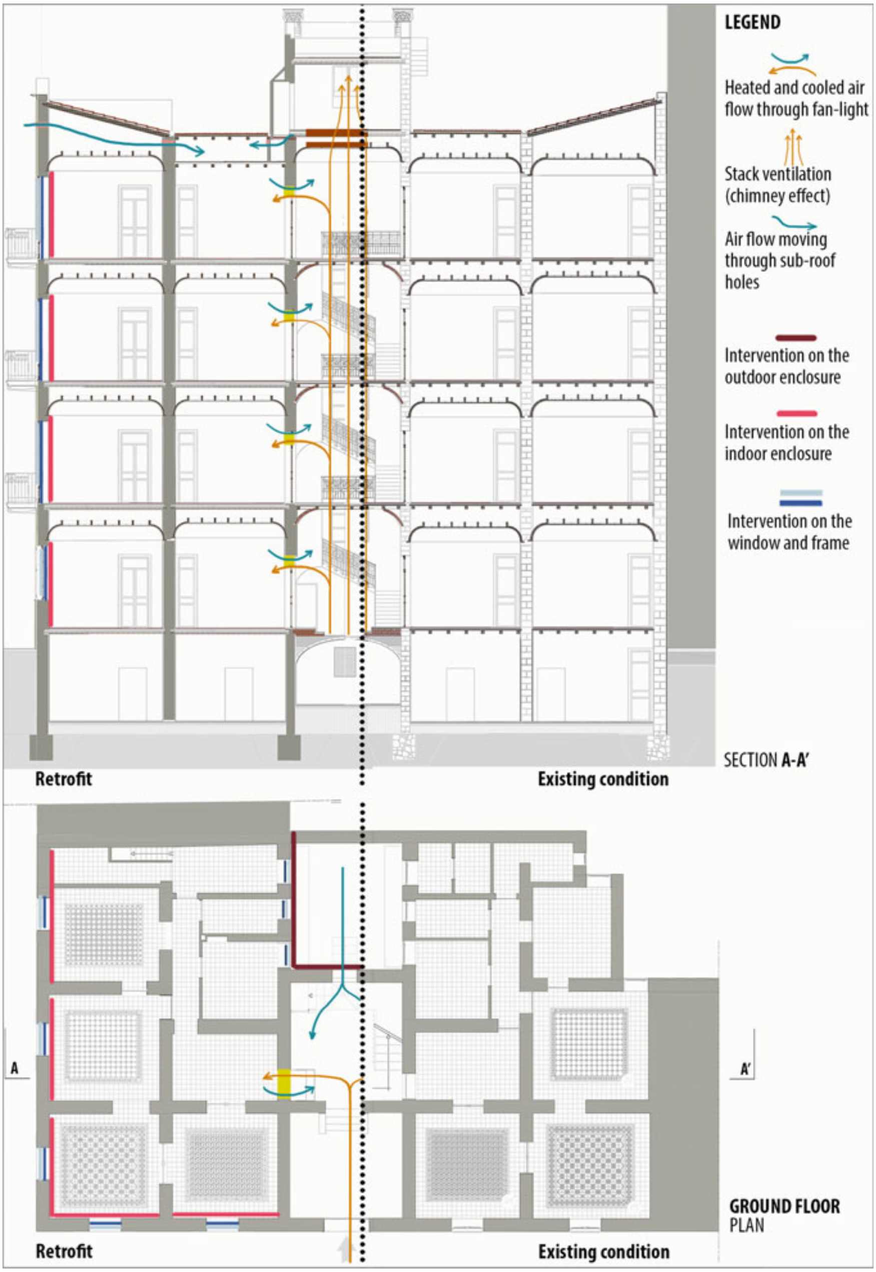


Fig. 12 The retrofit interventions (building section and plan)

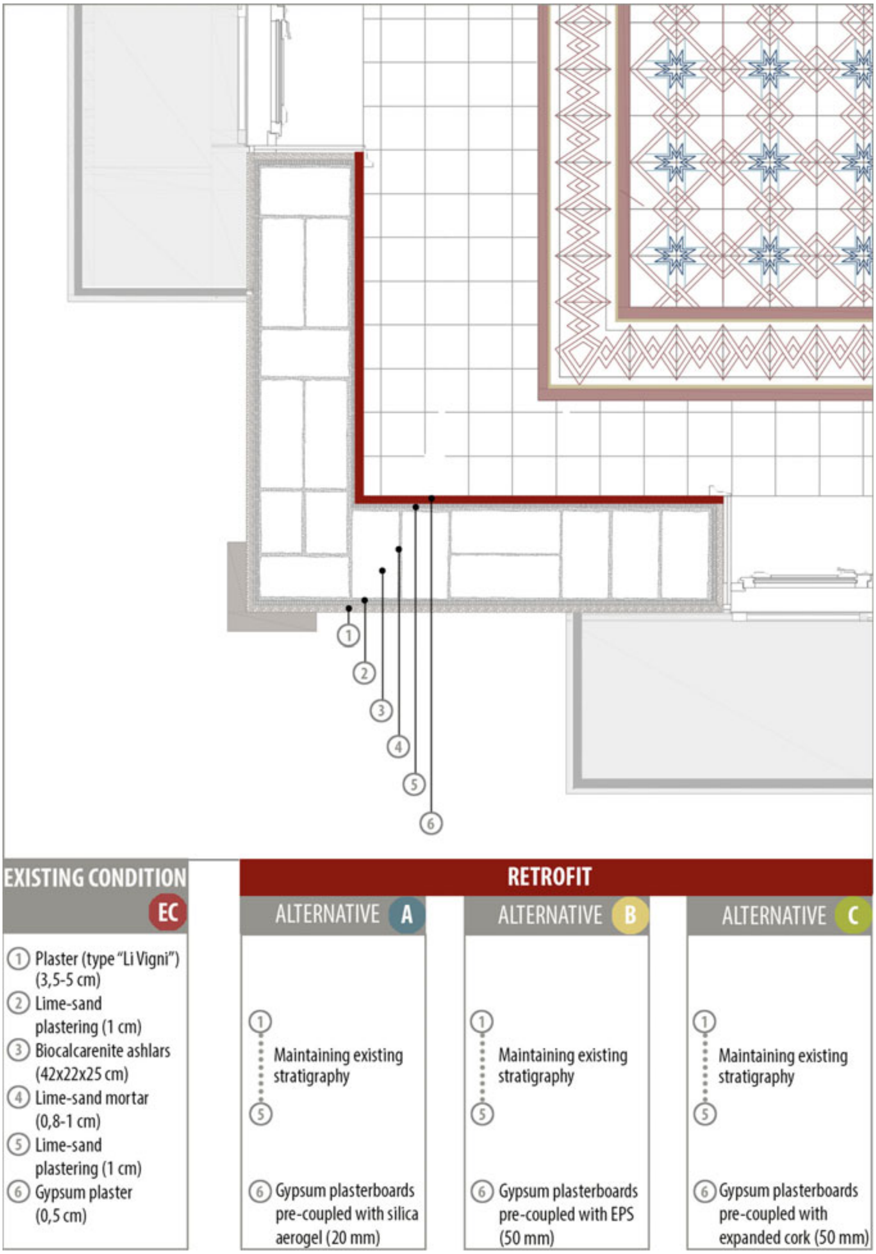


Fig. 13 The external solid wall with reference to each alternative

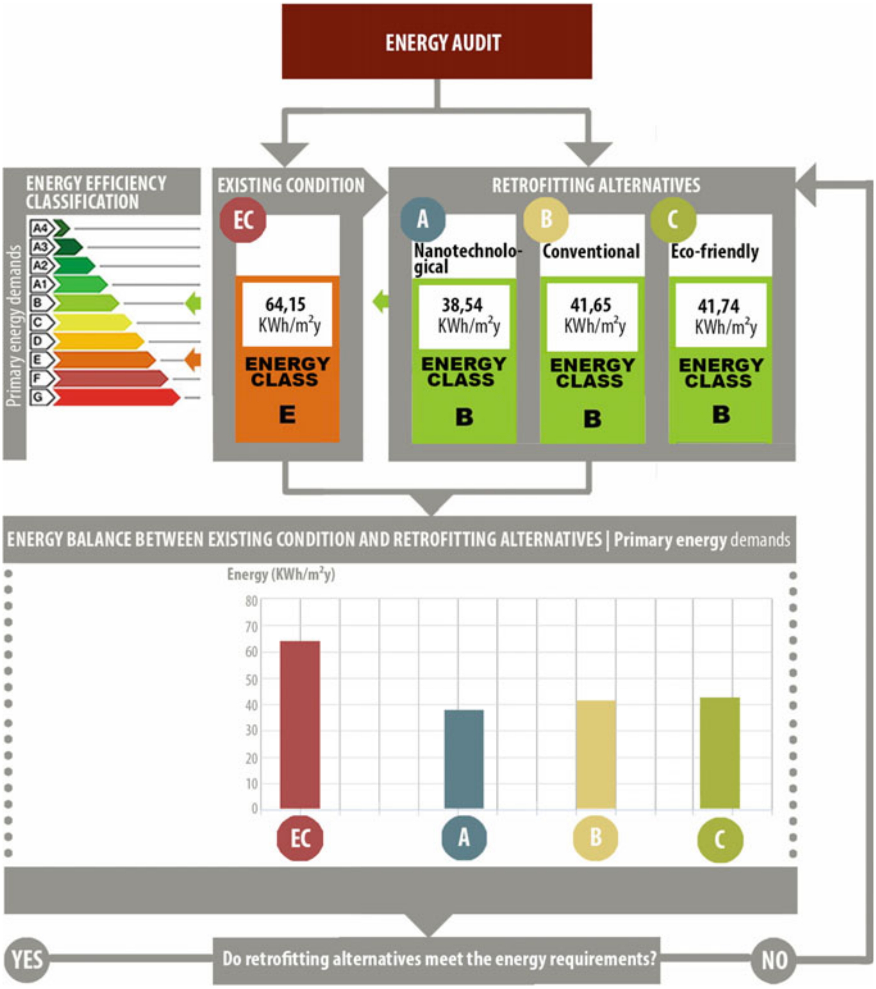


Fig. 14 Outputs from the energy audit software

The economic analysis was carried out by appraising the cash flow of the retrofitting alternatives with regard to three possible scenarios:

- *Scenario S1—None fiscal advantage*. The alternatives are not supported by any fiscal advantages;
- *Scenario S2—Incentives*. The alternatives receive the incentives provided by the "Conto Termico 2.0";
- *Scenario S3—Tax deductions*. The alternatives were implemented applying the tax deductions on personal or corporate income tax.

Type of action	A Nanotechno-logical		B Conventional		C Eco-friendly	
	€	%	€	%	€	%
Passive Ventilation	3317	1	3317	2	3317	3
External Insulation of opaque envelope	164,796	52	60,204	44	43,659	35
Internal Insulation of opaque envelope	67,696	22	19,598	15	26,842	21
Window Insulation	46,805	15	33,990	25	32,884	26
Other works	30,820	10	19,236	14	18,507	15
TOTAL COSTS	313,418		136,345		125,210	

Fig. 15 The implementation cost of the energy retrofitting alternatives

After defining the scenarios, the cash flow elements are defined:

- the time horizon was set equal to 20 years (the economic life of the action);
- the unitary period of analysis was the year;
- the costs were divided into cost of energy and the cost of the alternatives implementation. The unit cost of electricity was € 0.27/KWh and it was assumed an annual increase of 0.05%. The costs of the alternatives were appraised according to the Price List of the Sicily Region of 2018, whereas the prices of other works or materials, as internal and external insulating panels, were obtained through a direct market survey. The total implementation costs of each alternative are shown in Fig. 15;
- there were two groups of revenues, the operating revenues and those deriving from any incentives or tax deductions. The former were equal to the annual energy savings from the energy audit multiplied by the energy cost. The latter, corresponding to the "Conto Termico 2.0" incentives, were calculated by applying the coefficients in Fig. 2 to the cost of each alternative and then were divided into 5 annual instalments. Since all alternatives concern opaque envelope and window frames, this kind of incentives can only be requested by a public ownership of the building, and it may be compared to the effects of other fiscal instruments of environmental policy. The revenues resulted from the tax deductions on IRPEF or IRES were obtained by applying the coefficients in Fig. 3 to the cost of each alternative, and then were divided into 10 annual instalments;
- the discounting rate in terms of opportunity cost of capital was set equal to 2.95%, which was the profitability of the Italian Treasury Bonds (BTP) in November 2018.

Combining all the previous factors, the cash flows of the alternatives were calculated for the three scenarios, obtaining nine different cash flows that are reported, in a simplified form, in Fig. 16.

Cash Flow	Year 0	1	2	...	5	6	...	10	11	...	19	20
Alternative A												
Cost of the action (€)	-313,418											
Cost of energy (€/kWh)		0.270	0.271	...	0.275	0.276	...	0.282	0.282	...	0.295	0.296
Energy savings (kWh)		57,620	57,620	...	57,620	57,620	...	57,620	57,620	...	57,620	57,620
Revenues (€)		15,557	15,635	...	15,871	15,950	...	16,272	16,353	...	17,019	17,104
Incentive (€)		23,689	23,689	...	23,689	0	...	0	0	...	0	0
Revenues with Incentive (€)		39,246	39,324	...	39,560	15,950	...	16,272	16,353	...	17,019	17,104
Tax Deductions (€)		20,372	20,372	...	20,372	20,372	...	20,372	0	...	0	0
Revenues with Tax Deductions (€)		35,930	36,007	...	36,243	36,323	...	36,644	16,353	...	17,019	17,104
Alternative B												
Cost of the action (€)	-136,345											
Cost of energy (€/kWh)		0.270	0.271	...	0.275	0.276	...	0.282	0.282	...	0.295	0.296
Energy savings (kWh)		51,766	51,766	...	51,766	51,766	...	51,766	51,766	...	51,766	51,766
Revenues (€)		13,977	14,047	...	14,258	14,330	...	14,619	14,692	...	15,290	15,366
Incentive (€)		10,908	10,908	...	10,908	0	...	0	0	...	0	0
Revenues with Incentive (€)		24,884	24,954	...	25,166	14,330	...	14,619	14,692	...	15,290	15,366
Tax Deductions (€)		8,862	8,862	...	8,862	8,862	...	8,862	0	...	0	0
Revenues with Tax Deductions (€)		22,839	22,909	...	23,121	23,192	...	23,481	14,692	...	15,290	15,366
Alternative C												
Cost of the action (€)	-125,210											
Cost of energy (€/kWh)		0.270	0.271	...	0.275	0.276	...	0.282	0.282	...	0.295	0.296
Energy savings (kWh)		51,597	51,597	...	51,597	51,597	...	51,597	51,597	...	51,597	51,597
Revenues (€)		13,977	14,047	...	14,258	14,330	...	14,619	14,692	...	15,290	15,366
Incentive (€)		10,017	10,017	...	10,017	0	...	0	0	...	0	0
Revenues with Incentive (€)		23,994	24,064	...	24,275	14,330	...	14,619	14,692	...	15,366	15,366
Tax Deductions (€)		8,139	8,139	...	8,139	8,139	...	8,139	0	...	0	0
Revenues with Tax Deductions (€)		22,070	22,139	...	22,350	22,422	...	22,709	14,644	...	15,240	15,316

Fig. 16 Cash flows of the retrofitting alternatives

Scenarios	A Nanotechno-logical NPV* €	A IRR %	B Conventional NPV* €	B IRR %	C Eco-friendly NPV* €	C IRR %
Scenario S1 none fiscal advantage	-68,648	0.38	79,394	8.56	89,517	9.69
Scenario S2 incentives	36,882	4.56	127,986	13.45	134,140	14.66
Scenario S3 tax deductions	100,583	7.03	153,014	14.71	157,125	15.82

*NPV for r = 2.95%

Fig. 17 NPV and IRR of the retrofitting alternatives

The Net Present Value (NPV) and the Internal Rate of Return (IRR) were calculated by applying respectively the Formulas (1) and (2) to measure the economic feasibility of the three alternatives (Fig. 17).

4 Verification of Energy Efficiency and Economic Feasibility of the Alternatives

The results of the energy audit indicate that all the alternatives, A, B, and C, produce a considerable improvement in energy efficiency as their total energy consumption decrease significantly, respectively by 44.3, 39.8, and 39.6% in comparison to the baseline level, causing an upgrade of the building energy class from E to B (Fig. 14). This means that the alternatives B Conventional and C Eco-friendly have very good performances but lower than that of the alternative A, which used advanced nano-technological materials.

This first ranking is compared to the results of the economic feasibility. Figure 18 shows the NPVs against the discount rate in the scenarios S1, S2 and S3, and furthermore, a red line indicates the threshold discount rate.

In the scenario S1, the alternative A is not cost-effective, despite generating great energy efficiency, because of the high cost of the innovative nano-technological materials which is not sufficiently compensated by the flow of the bill savings. The alternatives B and C, on the other hand, reach a great economic feasibility even at high discount rates.

The implementation of incentives in the scenario S2 makes economically feasible all the alternatives, although the alternatives B and C maintain their economic performances much higher than that of the alternative A, which keeps a positive NPV only for discount rates up to 4.56%.

In the scenario S3, the tax deductions lead to an even more intense increase of all the NPVs and confirm the alternatives B and C as the best ones, while the NPV of the alternative A reduces its gap compared to that of the others.

The analysis of the IRRs gives analogous results, as only the IRR of the alternative A Nano-tech in the scenario S1 is lower than the discount rate threshold, while the maximum IRR is equal to 15.82% for the alternative C Eco-friendly in the scenario with tax deductions.

5 Conclusions

This work reasserts the specificity of the intervention on existing buildings and the completeness of traditional buildings. It shows how the latter already responded to the needs of living standards through building techniques and expedients, often in a refined way, following scenarios of needs which were complete although they certainly need to be revised today. Thus, each retrofit plan has to begin from the enhancement of the systemic functioning of the building. Starting from there, the actions which seem to be the most effective are those which aim at integrating the bioclimatic functioning with accurate solutions, but as non-invasive as possible: circumscribed and occasionally minimal solutions, which achieve satisfactory results in terms of living comfort and considerable economic savings.

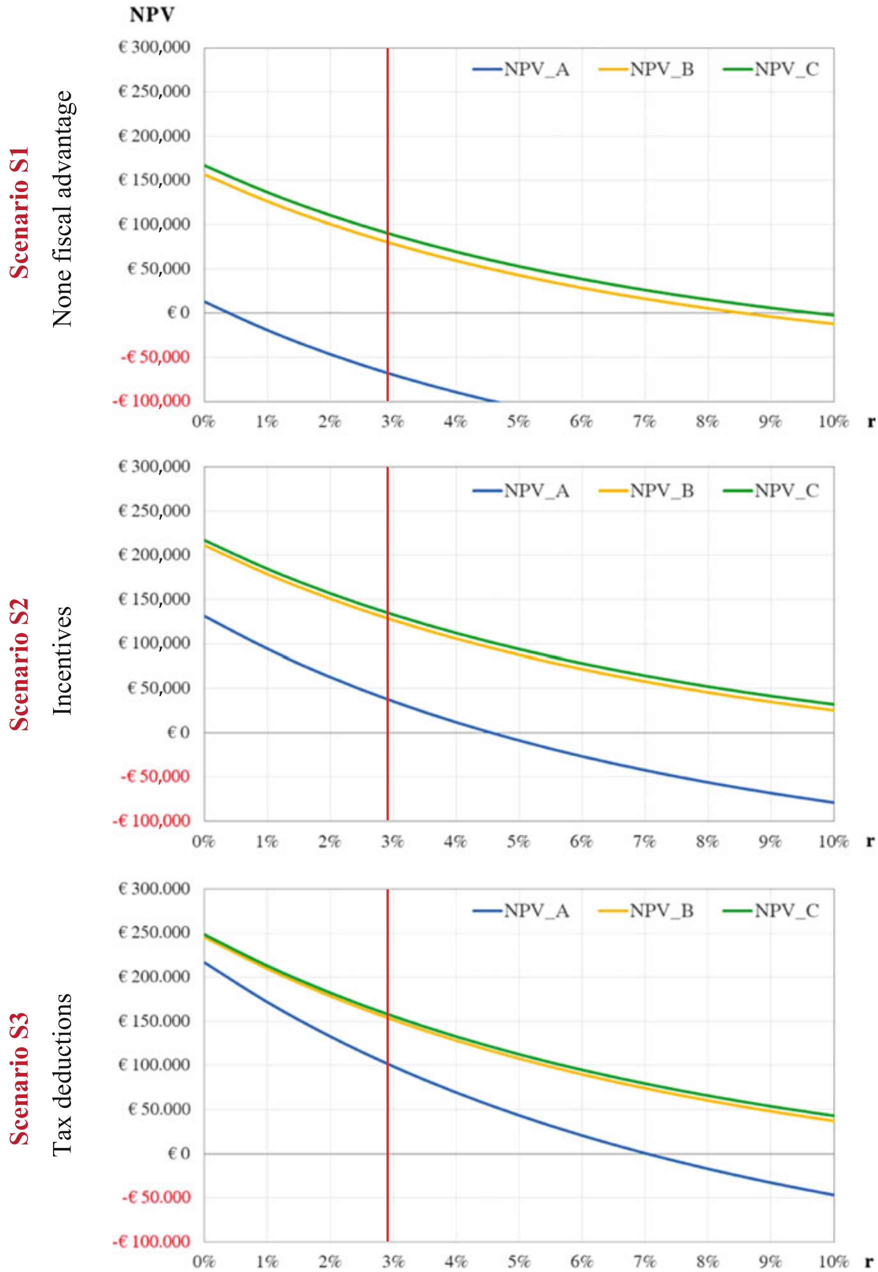


Fig. 18 The NPVs of the alternatives in different fiscal scenarios

The choice of eco-compatible bio-based materials, often inspired by tradition and already corroborated by ethical reasons (they are sustainable, low carbon, with a low ecological footprint, etc.), proves to be duly successful and to provide good value for money. Of course, in the sustainable dimension, they are preferred to conventional materials of synthetic origin, just as effective, and to innovative materials with high technological value, which are remarkably effective but still too expensive.

The outcomes also confirm the need for a multidisciplinary approach to the refurbishment of the existing real estate asset, including also the case of energy improvement, to verify whether the proposed alternatives reach the economic feasibility and generate private profits as well as social benefits.

This study shows how the economic analysis may support whichever private decision-making process of owners, developers, or designers, and also may assume a morphogenetic function in the process of designing the alternatives, especially when the feedback between the phases of planning the alternatives and of checking the results is provided.

In addition, economic analyses may also contribute to measuring the effectiveness of the financial instruments of environmental policy applied to the energy retrofit of buildings. In fact, even if these instruments caused lower public revenues (in the case of tax deduction) or higher public expenditures (in the case of incentives), they are nevertheless compensated by several positive environmental externalities, such as lower primary energy consumption, reduction of pollution and greenhouse effect, and by positive microeconomic and macroeconomic impacts as they support technological innovation and induce increased private investments.

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References

Barthelmes VM, Becchio C, Bottero M, Cognati SP (2016) L'analisi del costo ottimale per la definizione di strategie di progettazione energetica: il caso di un "nearly-Zero Energy Building". Valori e Valutazioni 16:61–75

Beccali M, Ciulla G, Lo Brano V, Galatioto A, Bonomolo M (2017) Artificial neural network decision support tool for assessment of the energy performance and the refurbishment actions for the non-residential building stock in Southern Italy. Energy 137:1201–1218

D'Alpaos C, Bragolusi P (2018) Approcci valutativi alla riqualificazione energetica degli edifici: Stato dell'arte e future sviluppi. Valori e Valutazioni 20:79–94

EN 16883:2017 Conservation of cultural heritage—guidelines for improving the energy performance of historic buildings

Figueira J, Greco S, Ehrgott M (2005) Multiple criteria decision analysis. State of the art survey. Springer

Fiore P, Nesticò A, Macchiaroli M (2016) The energy improvement of monumental buildings. An investigation protocol and case studies. Valori e Valutazioni 16:49–59

Franco G, Magrini A (2017) Historical buildings and energy. Springer International

Franco G, Magrini A, Cartesegna M, Guerrini M (2015) Towards a systematic approach for energy refurbishment of historical buildings. The case study of Albergo dei Poveri in Genoa, Italy. Energy Build 95:153–159

Gagliano A, Giuffrida S, Nocera F, Detommaso M (2017) Energy efficient measure to upgrade a multistory residential in a nZEB. AIMS Energy 5(4):601–624

Genova E, Fatta G (2018) The thermal performances of historic masonry: *In-situ* measurements of thermal conductance on calcarenite stone walls in Palermo. Energy Build 168:363–373

iNSPiRe (2014) Summary of policies and incentives relevant to retrofit in the EU-27. www.inspirefp7.eu. Last accessed 7 Jan 2019

Lombardi P, Abastante F, Torabi Moghadam S, Toniolo I (2017) Multicriteria spatial decision support systems for future urban energy retrofitting scenarios. Sustainability 9(7):1252–1265

Mamì A (2012) Safety as design requirement in the intervention on architectural and building heritage. In: Pinto MR (ed) Built environment recovery, maintenance and management. Study for the enhancement of built, urban and environmental resources. Fridericiana Editrice Universitaria, pp 65–69

Mangialardo A, Micelli E (2019) Off-site retrofit to regenerate multi-family homes: evidence from some European experiences. In: Calabrò F et al. (eds) ISHT 2018, SIST 101, pp 629–636

Mibact (Ministero per i Beni e le Attività Culturali) Italia (2015) Linee di indirizzo per il miglioramento dell'efficienza energetica nel patrimonio culturale. Architettura, centri e nuclei storici ed urbani. http://www.beniculturali.it/mibac/export/MiBAC/sito-MiBAC/Contenuti/MibacUnif/Comunicati/visualizza_asset.html_156066123.html

Napoli G, Gabrielli L, Barbaro S (2017a) The efficiency of the incentives for the public buildings energy retrofit. The case of the Italian Regions of the "Objective Convergence". Valori e Valutazioni 18:25–39

Napoli G (2018) The complexity of value and the evaluation of complexity: social use value and multi-criteria analysis. In: Mondini G, Fattinnanzi E, Oppio A, Bottero M, Stanghellini S (eds) Integrated evaluation for the management of contemporary cities. Results of SIEV 2016. Series: Green energy and technology, Springer International Publishing, pp 187–198. https://doi.org/10.1007/978-3-319-78271-3_15

Napoli G (2015) Financial sustainability and morphogenesis of urban transformation project. In: Gervasi O et al. (eds) Computational science and its applications—ICCSA 2015, vol 9157. Springer International Publishing, pp 178–193. https://doi.org/10.1007/978-3-319-21470-2_13

Napoli G, Giuffrida S, Valenti A (2017b) Forms and functions of the real estate market of Palermo. Science and knowledge in the cluster analysis approach. In: Stanghellini S, Morano P, Bottero M, Oppio A (eds) Appraisal: from theory to practice. Results of SIEV 2015. Series: Green energy and technology. Springer International Publishing, pp. 191–202. https://doi.org/10.1007/978-3-319-49676-4_14

Napoli G, Schilleci F (2014) An application of analytic network process in the planning process: the case of an urban transformation in Palermo (Italy). In: Murgante B et al (eds) Computational science and its applications—ICCSA 2014, vol 8581. Springer International Publishing, pp. 300–314. https://doi.org/10.1007/978-3-319-09150-1

Nesticò A, Pipolo O (2015) A protocol for sustainable building interventions: financial analysis and environmental effects. Int J Bus Intell Data Min 10(3):199–212. https://doi.org/10.1504/IJBIDM.2015.071325

Pinto MR, De Medici S, Senia C, Fabbricatti K, De Toro P (2017) Building reuse: multi-criteria assessment for compatible design. IJDST 22(2):165–193

Richards J (1994) Facadism. Routledge

Rodriguez-Linan C, Morales-Conde MJ, Perez-Galvez F, Rubio de Hita P, Lopes-Alonso S (2017) Environmental assessment and energy certification for the sustainable restoration of a traditional residential building. In: Mercader-Moyano P (ed) Sustainable development and renovation in architecture, urbanism and engineering. Springer, pp 192–202

Vassallo G (2012) Il restauro e il recupero di Palazzo Utveggio di Ernesto Basile a Palermo. C&V progetti Editore

Verbeeck G, Hens H (2005) Energy savings in retrofitted dwellings: economically viable. Energy Build 37:747–754

An Integrated Decision Support System for the Sustainable Evaluation of Pavement Technologies

Giancarlo Paganin, Marta Dell'Ovo, Alessandra Oppio and Francesca Torrieri

Abstract The choice of different kind of technologies to be adopted for the construction of road pavement is a subject of great interest both in the international and in the Italian context. Pavement is one of the most expensive component in the road infrastructure system. The analysis of the literature, as well as the empirical experiences, shows that from a sustainable perspective the decision problem concerning the choice of technologies to be adopted, has turned the attention towards evaluation methodologies able to integrate aspects that are not directly measurable in monetary terms, such as the environmental aspects (Zhang et al. 2010; Lidicker et al. 2013; Torres-Machi et al. 2017). The present contribution proposes an Integrated Evaluation System to support the choice between two different road paving technologies, namely interlocking concrete blocks paving and bituminous conglomerate. In order to evaluate the most convenient and sustainable option by considering economic and environmental costs, the proposed approach is based on the integration of different evaluation models, each capable of capturing multiple and complementary aspects. Specifically, the Life Cycle Costing Analysis (LCCA) has been firstly applied, as a decision criterion introduced by the Legislative Decree 50/2016 for the evaluation of the financial aspects related to the entire products' life cycle. The results obtained are then verified according to the Whole Life Costing (WLC) approach, by introducing also the "Event related costs" in addition to the main environmental costs. Finally, the choice between the different road paving alternatives has been sup-

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ported by a Multicriteria Analysis, that allows to carry on the comparison between the two abovementioned options by a comprehensive analytical framework based on the economic, social and environmental dimensions of sustainability. The proposed evaluation approach allows to test the robustness and the degree of suitability of the alternative options under investigation by pointing out the trade-off among all the aspects involved and by integrating three different methodologies.

Keywords Road pavement · Project sustainability · Life cycle cost analysis · Whole life costing · Multicriteria analysis · Event related costs

1 Introduction

In 2017 there were about 113,500 accidents in urban areas in Italy, some of which were caused by poor road surface conditions due to inefficient maintenance and safety of the road network (Istat 2017). The problem is especially acute in urban areas, where deteriorated infrastructures, obsolescent facilities and serious congestion problems are resulting in economic loss, environmental damage and societal harm (ACI–Istat 2017).

Considering that urban roads represent a large percentage of total roads all over the world and in particularly in Italy they amount to 79% of the total network (Istat 2013), the choice of a sustainable pavement typology, as a part of the road infrastructure, can play a relevant role in reducing energy consumption, improve safety (fatalities, injuries, property damage), and reducing construction, maintenance, as well as rehabilitation costs (FHWA 2010).

In this context, the choice between different types of pavement, based not only on the criterion of the minimum investment cost, but also on the entire life cycle of the product with particular attention to maintenance and management costs and to social and environmental sustainability impacts (Holt et al. 2011; Nassiri et al. 2013) is strategic.

Actually sustainable pavements refer to technical characteristics that encompasses the pavement's ability to achieve the engineering goals for which it has been constructed, to preserve and improve surrounding ecosystems, to efficiently use financial, human, and environmental resources and finally to meet basic human needs such as health, safety, equity, employment, comfort and happiness (FHWA 2010). Even when benefits and costs are difficult to be quantified, it is important to use a consistent approach in analyzing trade-offs between different pavement typologies, by including the priorities and values of the organization or project, costs, impact magnitude, duration, and risk.

Therefore, the growing awareness about the potential environmental and social externalities, has turned the attention towards methodologies which are able to integrate within the evaluation process also aspects that are not directly measurable in monetary terms, such as environmental and social aspects (Zhang et al. 2010; Lidicket et al. 2013; Torres-Machi et al. 2017).

Under this perspective, the whole life cycle of the product and the "Event-related costs" are two essential aspects to be taken into consideration.

The present paper proposes an Integrated Decision Support System for the evaluation of different road pavement technologies, namely interlocking concrete blocks pavement and bituminous conglomerate.

In order to evaluate the most convenient and sustainable option, not only from a financial, but also from an economic, social and environmental point of view, the proposed methodology is based on the integration of different evaluation models, each capable of capturing multiple and complementary aspects.

Firstly, Life Cycle Costing Analysis (LCCA) has been applied as a decision criterion introduced by Legislative Decree 50/2016 for the evaluation of financial aspects related to the products' entire life cycle, then verified according to the Whole Life Costing (WLC) approach, by introducing also the "Event related costs".

In order to take into account the qualitative aspects, that are difficult to be measured in monetary terms, a Multicriteria Analysis has been developed with the aim to point out the trade-off between the two pavement options according to a wide set of criteria, rather than to the only financial discount criterion of the LCCA and the WLC.

The paper is structured as follows: Sect. 2 presents the evaluation approach with specific reference to the types of road pavements to be compared; in Sect. 3 the project alternatives and the application of the proposed methodologies are described and results discussed. Then preliminary conclusions on the base of the analysis carried out and future prospects for research follow.

2 Methods and Materials

Products in general have a life cycle: they are produced from raw materials, used by consumers, and eventually disposed. A product's life cycle is generally broken down into six stages (Wimmer and Züst 2003):

- product design;
- raw material extraction and processing;
- manufacturing of the product;
- packaging and distribution to the consumer;
- product use and maintenance;
- end-of-life management: reuse, recycling and disposal.

In every stage of their life cycle, products interact with other systems: therefore life cycles are called open cycles. Moreover, life cycle approach can be split into two main branches: Life Cycle Costing Analysis and Life Cycle Assessment.

Life Cycle Costing Analysis (LCCA) is a method of economic evaluation of the project, which analyses the overall costs related not only to the construction phase, but also to the maintenance, operating and disposal ones until the end of the expected life cycle, that are essential in order to take a certain investment decision. By comparing the life cycle costs of various solutions, this method allows to identify the most cost-effective alternative, that is the one with lowest LCC. According to the technical standard ISO 14044, Life-Cycle Assessment is the environmental oriented part of the Life cycle approach and a tool for examining the total environmental impact of a product through every step of its life—from obtaining raw materials through producing it in a factory, selling it in a store, using it in the workplace or at home, and disposing of it. It is an objective procedure used to evaluate the environmental impacts associated with a product's entire life cycle, through the quantitative determination of all exchange flows between the product system and the ecosphere with respect to all the transformation processes involved, from the procurement of materials (these may be recycled instead of new ones) to their end for this product (i.e. disposal or recycling into a new product). The objective of the LCCA is to determine, among various alternatives of a project, the one with the lowest environmental impact for the entire life cycle.

When undertaking investment option appraisals, many variables in addition to LCC variables can impact on the value-for-money assessment and they should be taken into account. For certain forms of construction procurement, these additional variables represent a relevant part of the investment options' evaluation and appraisal process and they can be considered as Whole Life Cost (WLC) variables. Typically, the difference between WLC and LCC analysis is that the variables for WLC can include a wider range of externalities or non-construction costs, such as finance costs, business costs and income streams. Thus, LCCA can be used as an instrument per se or it can be part of the WLC. There are numerous costs associated with acquiring, operating, maintaining, and disposing of a building or building system.

With special respect to roads, costs usually fall into the following categories (WBDG 2016):

- Initial and Construction Costs;
- Fuel Costs;
- Operation, Maintenance and Repair Costs;
- Replacement Costs;
- Residual Values-Resale or Salvage Values or Disposal Costs;
- Finance Charges-Loan Interest Payments;
- Not-Monetary Benefits or Costs.

In order to compare costs that are incurred in different time during the life cycle of a project they have to be made time-equivalent. To make monetary values homogeneous with respect to the financial value of time, the LCC, LCCA and WLC methods convert them to present values by discounting them to a common point in time, usually the base date. In a formal way

$$NPV = \sum_{t=0}^{n} \frac{C_i}{(1+r)^n}$$

where

n is the time horizon
Ci are the total costs
r is the interest rate.

The interest rate used for discounting is a rate that reflects an investor's opportunity cost of money over time, while for public investment it can be assessed by considering an investment without risk.

LCC, LCA and WLC require that costs and benefits are measured in monetary terms. Multicriteria Analysis (MCA) allows to overcome this constraint, as it is capable to deal with the multiple dimensions of evaluation problems (e.g. social, cultural, ecological, technological, institutional, etc.) and with conflictual instances emerging over the entire life cycle. MCA techniques allow to combine assessment techniques with judgement methods, thus providing decision makers with a solid analytical basis for complex choices.

In the field of MCA, a broad series of different quantitative and qualitative evaluation methods has been developed (Keeney and Raiffa 1976; Nijkamp et al. 1990; Vincke 1992; Saaty 1996; Roy 1996, 2005; Bouyssou et al. 2012; Greco et al. 2016). We will focus our attention on the so-called Definite software (Janssen et al. 2000), which contains a set of multicriteria techniques for ranking problems and is able to support all decision processes, from problem definition to report generation.

In the present paper the above introduced methodology will be applied in order to compare two different type of pavement, namely the interlocking concrete blocks pavement and the bituminous conglomerate. In the following paragraph the two alternative options are described and the obtained results are reported.

3 Case Study

This section reports the results of LCCA and WLC applied for the comparison of the two above mentioned different techniques of road paving. The objective was to define a methodology to introduce into the LCC calculation the event related costs (cost of uncertain externalities) in order to assess the whole life cost of the two solutions.[1]

[1]The two options has been defined and analyzed by Locatelli F., Schicchitani S., Life Cycle Cost and Whole Life Cost of interlocking concrete block pavements: the role of event related costs and externalities, Master Degree Thesis, Academic Year 2015–2016; supervisor: prof. G. Paganin.

3.1 Life Cycle Cost

The calculation of Life Cycle Cost has considered:

– Initial costs: construction costs are taken into account, while survey and design costs are not considered reasonably assuming that they are very similar for both the paving alternatives.
– Operational costs: maintenance costs are taken into account, while running costs are not considered since the options under investigation are two road pavements.
– Disposal costs: disposal costs are taken into account and also reuse value is considered for interlocking block paving that can be reused after removal from the road.

The service life for the LCC calculation it has been assumed equal to 40 years (FHWA 2013). The FHWA (Federal Highway Administration of US Department of Transportation) recommends to carry out the analysis in a period long enough to include at least one rehabilitation activity, thus suggesting a period of 35/40 years for all the pavement projects. This work sets a pavement service life at 40 years.

The rate of the government bonds (similar to the “pavement investment” under the point of view of both starting date and duration) has been assumed as discount rate (NPRA 2005); the choice has been on bonds issued by the Italian government the 1st September 2014 and lasting 30 years at a rate of 3.25%.

Two possible applications have been considered for the LCC calculation: supermarket car park and municipal roads. This choice is based on the fact that interlocking concrete blocks paving are particularly suitable and normally used for those purposes.

The analysis has considered two possible types of soil on the basis of their bearing capacity (CBR Ratio according to ASTM D1883—16 “Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils”) which influences the design and construction of the superstructures (base course and sub base course): the two soils considered assume CBR = 3% and CBR = 10%.

Therefore, the LCC calculation has been performed for 4 different combinations:

– supermarket car park (1) CBR 3% and (2) CBR 10%;
– municipal road (3) CBR 3% and (4) CBR 10%.

In the following, only the case of municipal road will be described.

The construction cost has been calculated assuming the price list of Comune di Milano of year 2014 (Tables 1 and 2).

For what it concerns the maintenance costs, several sources (Hunter 2006; Di Mascio et al. 2010; Comune di Milano 2016; Monici 2013) have been taken into account and modified reflecting possible and reasonable adjustments on the basis of suggestions given by some skilled professionals in this field. The maintenance costs come from the following list of work activities (See Maintenance plans in Tables 3 and 4).

The results of the LCC assessment are included in the Table 5.

The results of the LCC assessment show that, over the life cycle, the operational costs may be higher than the initial capital investment leading to reconsider the

Table 1 Construction costs for the interlocking concrete paving for municipal roads (CBP.B)

Concrete block paving—CONSTRUCTION					
Layer	Thickness (cm)		Unit price	Cost (€/m^2) (t = 0)	
	CBR = 3%	CBR = 10%		CBR = 3%	CBR = 10%
Block paving	8	8	22.73 €/m^2	22.73	22.73
Laying course	4	4			
Base course (Hydraulically bound layer)	30	24	37.20 €/m^3	11.16	8.93
Geotextile			1.70 €/m^2	1.7	1.7
Sub base course (Granular mix)	32	24	20.37 €/m^3	6.52	4.89
Excavation	74	60	9.47 €/m^3	7.01	5.68
CON02				49.12	43.93

Table 2 Construction costs for the bituminous conglomerate paving for municipal roads (BIT.B)

Bitumen conglomerate—CONSTRUCTION					
Layer	Thickness (cm)		Unit price	Cost (€/m^2) (t = 0)	
	CBR = 3%	CBR = 10%		CBR = 3%	CBR = 10%
Surface course	4	4	4.80 €/m^2	4.8	4.8
Base course (Binder)	5	5	6.25 €/m^2	8.69	8.69
Road base course (Bituminous bound layer)	8	8	9.26 €/m^2	9.26	9.26
Sub base course (Granular mix)	35	15	20.37 €/m^3	7.13	7.13
Excavation	52	32	10.52 €/m^3	5.47	5.47
CON04				32.91	26.73

traditional approach to decisions that, especially for public procurement processes, are taken normally only by considering initial cost.

Table 3 Maintenance plan for interlocking concrete paving

Concrete block paving MAINTENANCE PLAN				
Intervention code	Maintenance instigator	Description	Frequency	Area affected (%)
CON01		INITIAL COSTRUCTION	t = 0	100
M02	Health and safety Aesthetics Maintaining structural integrity	CORRECTIVE MAINTENANCE Cracked/missing block replacement	Twice t = 8 t = 23	2
M04	Health and safety Aesthetics Maintaining structural integrity	CORRECTIVE MAINTENANCE Depressions/wheelpath correction	Twice t = 15 t = 30	5
M06	Intervention on underground services	Full depth relocation reusing blocks, using new laying materials and new base materials (granular mix)	Four times t = 8 t = 16 t = 24 t = 32	2
OM02	Health and safety Maintaining structural integrity	ORDINARY MAINTENANCE Joint sand restoration	Four times t = 8 t = 16 t = 24 t = 32	100
DIS02	FINAL DISPOSAL		t = 40	100

3.2 From Life Cycle Costing to Whole-Life Costing: Externalities and Events in a Municipal Road

The LCC assessment for the two types of municipal roads has been implemented with costs related to potential externalities; in this work other non-construction costs have not been considered.

The externalities considered in this work are:

1. the damages to people and/or goods, due to the lack of road maintenance. The basic hypothesis assumed is that these costs can be saved by a concrete block road compared to a bituminous conglomerate which usually suffers from poor road maintenance;
2. the externalities of pollution. The evaluation consists in the investigation of the avoided costs thanks to a photocatalytic concrete block road compared to a normal bituminous conglomerate paving.

Table 4 Maintenance plan for bituminous conglomerate paving

Bitumen conglomerate—maintenance plan				
Intervention code	Maintenance instigator	Description	Frequency	Area affected (%)
CON01		INITIAL COSTRUCTION	t = 0	100
M08	Health and safety Aesthetics Maintaining structural integrity	CORRECTIVE MAINTENANCE Reseal cracks/joints	Three times t = 4 t = 19 t = 29	5
M10	Health and safety Aesthetics Maintaining structural integrity	CORRECTIVE MAINTENANCE Patching potholes	Three times t = 4 t = 19 t = 29	5
M11	Health and safety Aesthetics Maintaining structural integrity	New surface course	Twice t = 8 t = 23	100
M13	Health and safety Aesthetics Maintaining structural integrity	New surface course and binder	Twice t = 15 t = 30	100
M15	Intervention on underground services	Full depth relocation	Four times t = 8 t = 16 t = 24 t = 32	2
DIS04	FINAL DISPOSAL		t = 40	100

Concerning the damages, the cost estimation has assumed data from the insurance field and it can be gathered from the following steps:

– research of damages statistical tables usually published on the municipality/province website together with the tender for insurance companies;
– analysis of damages statistical tables. The statistical tables of ten provinces covering damages for about five years have been considered (Annex 1). For each of the 10 provinces, damages attributable to lack of road maintenance has been high-

Table 5 LCC analysis for a service life of 40 years

CONSTRUCTION COSTS			
	€/m^2	Δ (€/m^2)	Δ (%)
CBP. B	49.12	+16.21	+49.24
BIT. B	32.91		
MAINTENANCE COSTS			
CBP. B	15.37		
BIT. B	51.65	+36.28	+207.39
DISPOSAL COSTS			
CBP. B	3.48		
BIT. B	4.28	+0.80	+23.12
LCC COSTS			
CBP. B	67.97		
BIT. B	88.84	+20.87	+27.74

lighted (potholes, surface depressions, road collapses etc.) and the reimbursement summed up in order to find a yearly average reimbursement. The yearly average reimbursement has been then divided by the surface of roads, where the maximum speed of vehicles is set to 60 km/h, therefore only provincial roads within town center that are estimated to be the 15% of total provincial road network.

For each of the 10 provinces, the annual mean reimbursement of damages related to lack of road maintenance has been divided by the surface of urban provincial roads. This value amounts to approximately 0.20 €/m^2.

The Table 6 displays the Whole Life Cost calculation, that takes into account the problem of lack of road maintenance interventions.

The difference between the two paving options stands in the addition of the costs related to lack of maintenance, that have been added to the concrete block paving as a negative value. In fact, these costs are the "avoided" costs of concrete block paving compared to the bituminous conglomerate ones, which usually suffers lack of road maintenance.

This is the explanation of the annual additional row "DAM" (connected to damages) of the annual cost for lack of road maintenance.

The table refers only to the case of CBR = 10%, since the difference with respect to the LCC does not vary dealing with the soil nature.

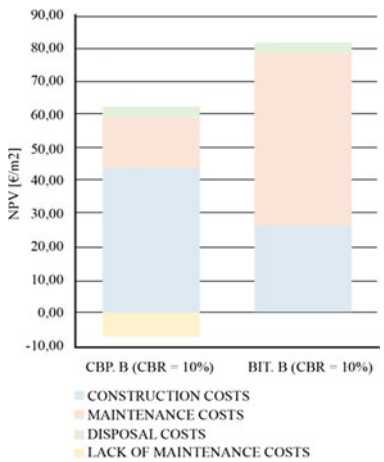
The inclusion of the event related costs in the LCC assessment shows a potential reduction in the whole life costs of the more reliable technical solution that may reduce the accidents caused by bad conditions of the road surface.

3.3 Costs Related to Pollution

In this paragraph the effectiveness of a photo catalytic block paving as alternative solution generating positive externalities is investigated, then translated in an eco-

Table 6 Municipal road pavements, actualized costs including lack of maintenance for different pavements (CBR = 10%)

CONSTRUCTION COSTS			
	€/m²	Δ (€/m²)	Δ (%)
CBP. B	43.93	+17.20	+64.33
BIT. B	26.73		
MAINTENANCE COSTS			
CBP. B	15.06		
BIT. B	51.01	+35.92	+207.39
DISPOSAL COSTS			
CBP. B	3.48		
BIT. B	4.28	+0.80	+23.12
LACK OF MAINTENANCE COSTS			
CBP. B	− 6.49		
BIT. B			
LCC COSTS			
CBP. B	55.97		
BIT. B	82.02	+26.05	+42.39



nomic value through the study of pollution reduction and finally added to the LLC evaluation.

Photocatalysis is a natural phenomenon similar to photosynthesis, where a substance called photocatalyst, through the action of natural or artificial light, starts a strong oxidation process that converts harmful organic and inorganic substances into inorganic salts such as nitrates, sulfates and calcium carbonates and leached by rainwater.

Several laboratory tests performed on concrete pavers samples showed significant reduction of pollutants (Cassar et al. 2007; Berdahl et al. 2008; Global Engineering 2004; Cassar 2005); a summary of the results is reported in Table 7.

Table 7 Average literature data for pollutant reduction due to photo catalytic cement

Pollutant	Reduction (%)
PM	47
NO_x	67
SO_x	47
Total aldehydes	64
Nitrates	74
Yeasts and mold	44

Table 8 Annual costs for NO_x and PM10 in Italy (NETCEN European Environmental Agency)

Pollutant	Annual cost in Italy (€/t)
NO_x	7100.00
PM10	1200.00

The externality connected to the pollutants reduction can be translated in an economic value by considering (Table 8): (i) the amount of roads potentially convertible into photo catalytic concrete block paving (typically roads in the so called "zone 30" where speed is limited to 30 km/h); (ii) the annual polluting emissions within ZONA 30 areas (the accounting has been done for municipality of Milano considering NO_x and PM10, those that the photocalythic concrete block may reduce more effectively) (Bedogni 2013); the annual polluting emissions reduction expressed in tonn/year. According to literature review an optimistic value of 60% reduction and a pessimistic value of 30% reduction have been assumed; annual cost per ton of pollution (the annual cost per ton in Italy has been assumed from the data published by NETCEN European Environmental Agency).

The economic value of the unitary annual emission reduction in ZONA 30 is then calculated by multiplying the annual unitary emissions reduction in ZONA 30 by the annual cost per ton in Italy and the value is then standardized to a m^2 of road (Table 9).

The LCC has been estimated again due to the fact that the photocatalytic block costs more than a normal one (30.68 €/m^2 instead of 22.73 €/m^2).

The additional row "POL" (connected to pollution) to the table is the annual savings (calculated with the method explained at the beginning of this subparagraph) that the choice of a photocatalytic concrete block paving generates. The amounts of 0.98 and 0.54 €/m^2 (each representing the costs of pollution given by the addition of NO_x and PM10 costs respectively for the optimistic and pessimistic scenario) are charged at the first year and then reported at the appropriate years using the inflation.

For simplicity, the table refers only to the case of CBR = 10% since the difference with respect to the LCC does not vary with respect to a clay or a silty soil (Table 10).

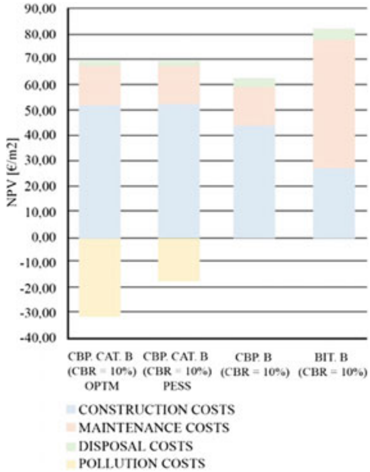
The inclusion of the pollution related costs (benefits) in the LCC assessment shows a significant reduction of the whole life cost for the solutions of paving with photo catalytic elements despite of the higher initial cost.

Table 9 Annual unitary emission reduction in ZONA 30 (€/m^2 year)

Pollutant	Annual unitary emissions reduction in ZONA 30 (t/m^2 year)		Annual cost in Italy (€/t)	Unitary annual emission reduction ZONA 30 (€/m^2 year)
NO_x	Optimistic	0.000122	7100.00	0.87
	Pessimistic	0.000061		0.43
PM10		0.000009	12,000.00	0.11

Table 10 Municipal road pavements, discounted costs including pollutions cost (CBR = 10%)

CONSTRUCTION COSTS			
	€/m^2	Δ (€/m^2)	Δ (%)
CBP. CAT. B.	51.88	+25.15	+94.09
CBP. B	43.93	+17.20	+64.33
BIT. B	26.73		
MAINTENANCE COSTS			
CBP. CAT. B.	15.33	+0.27	+1.58
CBP. B	15.06		
BIT. B	51.01	+35.92	+207.39
DISPOSAL COSTS			
CBP. CAT. B.	1.94		
CBP. B	3.48		
BIT. B	4.28	+0.80	+23.12
POLLUTION COSTS			
CBP. CAT. B.	−31.50 −17.53		
CBP. B			
BIT. B			
WLC COSTS			
CBP. CAT. B.	37.65 51.61		
CBP. B	62.47	+24.82 +10.86	+65.53 +20.47
BIT. B	82.02	+44.37 +30.41	+109.19 +54.10



3.4 *Multicriteria Analysis*

The Multicriteria Analysis (MCA) allows to analyze the problem by broadening the criteria so far involved and by the use of different measurement scales. In fact, while monetary evaluation techniques force to select for all the criteria the same scale, the MCA is based on a multidimensional analytical framework and on a standardization procedure that allows to compare and then aggregate different indicators (DCLG 2009).

The aim of the following analysis is to explore the performances of the two previous different type of pavements under the economic, social and environmental point of view. In detail, the 1. Economic dimension takes into consideration the 1.1 Initial Investment cost, the 1.2 Maintenance cost, the 1.3 Disposal value, meant as the cost for the disposal of the material at the end of life cycle and the 1.4 Safety, measured as a cost since it considers the refund for the losses suffered by drivers and streets' users. About the 2. Social dimension, it involves the 2.1 Health impact, considered as an avoided cost since it evaluates the impact of the air pollution reduction on the health by the adoption of the alternatives described, the 2.2 Aesthetic takes into consideration the flexibility of the material to replacement and its adaptability to the context, 2.3 Accessibility to the sub-services as well as the easiness of its temporary removal and the 2.4 Contribution to accident reduction given by the property of the material to not be subjected to wear and tear. The 3. Environmental dimension considers the 3.1 Pollutant emission during the production cycle and in detail it evaluates the Global Warming Potential (GWP), while the 3.2 Pollutant reduction if the material contributes to reduce PM, SO_x and NO_x in the air, 3.3 Permeability measures as the stormwater runoff reduction and 3.4 Noise emission according to the noise classification of urban road surfaces. The performances of the two alternatives have been assessed on the basis of previous analysis (see Locatelli and Scicchitani 2016), while the 3.1 Pollutant emission has been measured by comparing different Environmental Product Declarations (EPD) as well as by consulting the Oekobaudat dataset. For the 3.4 Noise emission, has been used the European project "Silence" carried on by Descornet in 2006 and in particular the state of the art "Noise classification of urban road surfaces".

The MCA has been supported by the Definite Software (Janssen et al. 2000), a Decision Support System (DSS) that allows to rank a finite number of alternatives given a specific objective and a set of criteria. Table 11 shows the impact matrix with the performances of the two alternatives in relation to the decision problem as previously defined. Different unit of measurements have been used in order to better describe each sub-criterion and the column cost/benefit underlines if the performance has to be maximized—the higher the better—or minimized—the lower the better.

In order to compare the sub-criteria, the performances have been standardized and since specific thresholds of acceptability have not been defined, the maximum standardization have been selected. Consequently, the effect scores have been divided by the maximum value of the effect and a dimensionless value is assigned, where 1 represent the best performance and 0 the worst (Table 12). The procedure used to aggregate the score standardized is a compensatory model and in particular the Weighted Sum Model (WSM):

$$A = WiXi$$

where:

A alternatives represents its suitability in the final rank;
Wi is the normalized weight of i-th objective;
Xi is the standardized score (Fishburn 1967).

Considering the criteria weight elicitation, it has been chosen a neutral scenario, by assigning to the set of criteria and sub-criteria the same weights without specifying a higher influence for one aspect rather than to another one.

4 Discussion of the Results

Figure 1 presents the final and the partial rankings obtained through the WSM. The Definite Software allows to visualize both the overall evaluation of the two alternatives and the performances with respect to the three dimensions under investigation. The most suitable alternative considering the set of criteria defined is the Concrete block pavement with an overall score of 49%, while the Bituminous conglomerate has a significant difference (13%). This evaluation is confirmed by the partial rankings where the winner alternatives keeps its first position both for the Economic Dimension (47 vs. 12%) and for the Social Dimension (75 vs. 0%). Instead for the Environmental Dimension there is a slight preference for the second classified alternative (25 vs. 27%). This result could be explained by the performances in the impact matrix (Table 11), where the Concrete block pavement scores, as an average,

Table 11 Impact matrix

				Alternatives	
Criteria	Sub-criteria	U.M.	Cost/benefit	Bituminous conglomerate	Concrete block pavement
Economic dimension	Investment cost	€/m^2	C	26.73	51.88
	Maintenance cost	€/m^2	C	51.01	15.06
	Disposal value	€/m^2	C	4.28	3.48
	Safety	€/m^2	C	6.49	0
Social Dimension	Health impact	€/m^2	B	0	0.76
	Aesthetic	Qualitative	B	Low	Medium
	Accessibility to sub-services	Qualitative	B	Low	Medium
	Contribution to the accident reduction	Binary	B	No	Yes
Environmental dimension	Pollutant emission (CO_2)	Kg CO_2 m^3	C	191.47	434.00
	Pollutant reduction	Binary	B	No	Yes
	Permeability	Qualitative	B	Medium	Low
	Noise emission	dB	C	81.30	83.20

Table 12 Standardized matrix

Criteria	Sub-criteria	Alternatives: Bituminous conglomerate	Alternatives: Concrete block pavement
Economic dimension	Investment cost	0.48	0.00
	Maintenance cost	0.00	0.70
	Disposal value	0.00	0.19
	Safety	0.00	1.00
Social dimension	Health impact	0.00	1.00
	Aesthetic	0.00	0.50
	Accessibility to sub-services	0.00	0.50
	Contribution to the accident reduction	0.00	1.00
Environmental dimension	Pollutant emission (CO_2)	0.56	0.00
	Pollutant reduction	0.00	1.00
	Permeability	0.50	0.00
	Noise emission	0.02	0.00

are higher than the Bituminous conglomerate's ones with exception, for example, of the sub-criteria 3.1 Pollutant emission, 3.3 Permeability and 3.4 Noise emission, that are part of the Environmental Dimension.

In order to test the internal consistency and the robustness of the results obtained, it has been moreover performed a sensitivity analysis (Janssen et al. 2000). In particular a "What if" analysis has been carried out, by visualizing different perspectives where it is possible to assign a higher importance to one dimension involved in the analysis. In this case it has been assigned the same influence to the level of the sub-criteria and it has been changed the weight at the level of the criteria (Economic Dimension; Social Dimension; Environmental Dimension) in order to test how much the result is sensitive to weights' changes (Fig. 2).

The analysis performed validates the result obtained, showing that the Concrete block pavement ranks as the most appropriate solution to adopt according to all the perspectives investigated. The results already obtained by performing the LCC and the WLC have confirmed this outcome and the evidence emerging by their application has been useful in the phase (Choice). In detail the LCC has allowed the evaluation of a project with a wider point of view compared with a simple initial investment estimation and the WLC has investigated the externalities associated with road surfaces. The integration of these three methodologies provides a multidimensional approach to face the decision problem and to further legitimate the final choice.

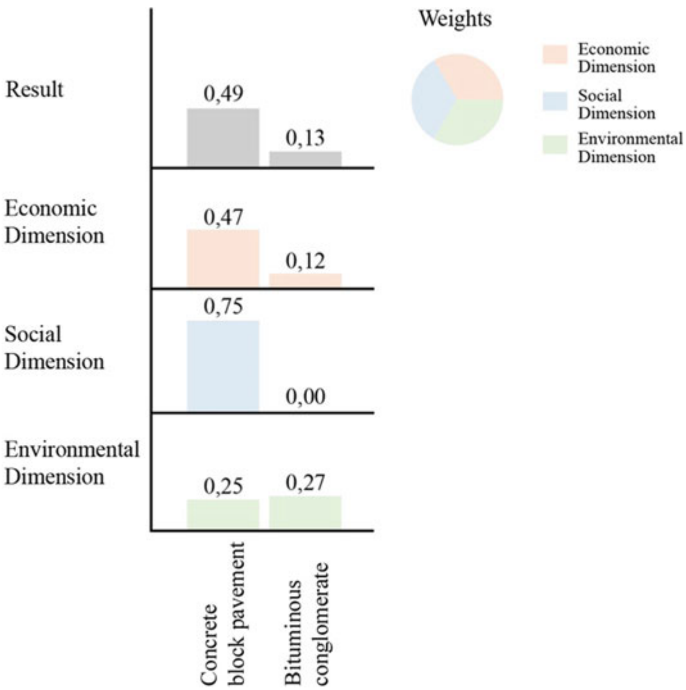


Fig. 1 Final and partial ranking

5 Conclusions and Future Research Perspectives

Road pavements have increasingly gaining importance in the last few years, given their economic and social impacts on users and environment.

Starting from an analysis of the state of the art of interlocking block pavements, the paper focuses on the impact resulting from the use of this solution as an alternative to the more widespread bituminous conglomerate.

Firstly, the Life Cycle Cost (LCC) has been estimated, thus providing a wider evaluation perspective than the initial investment estimation, since costs arising during the life cycle, from design to disposal including maintenance and operation, have been taken into account. In order to support sound decisions between the two alternatives, some of the most evident non-deterministic costs attributable to events (Event-related costs) and externalities associated with road surfaces have been introduced with respect to a Whole-Life Costing (WLC) analytical framework.

Finally Multicriteria Analysis (MCA) has been applied in order to explore advantages and criticalities expressed both in monetary and not monetary terms. MCA makes the results operational for decisions as it allows to consider the aggregate and partial scores, not only as the basis for a rank, but also as a support for exploring the decision problems and addressing choices towards a sustainable use of resources.

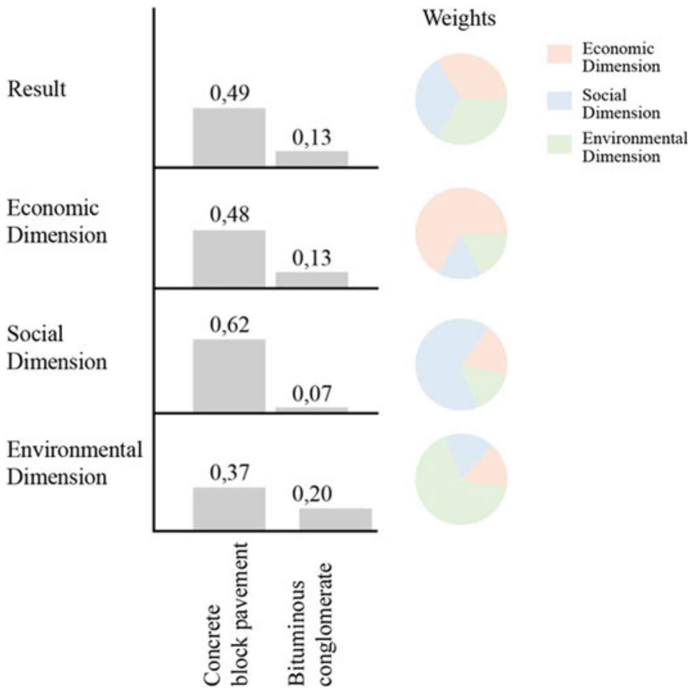


Fig. 2 “What if” analysis

With respect to the results, the LCC have shown that, despite the construction costs of the bituminous pavement are lower than the ones of the interlocking blocks, the LCC of the latter are almost 28% less. This gap grows when lack of maintenance is considered ($\Delta = 42.39\%$) and it becomes very high when the analytical perspective covers environmental and social issues, as within the WLC framework ($\Delta = 109.19\%$). This kind of evidence underlines the effectiveness of integrated evaluation approaches, based on three non-exclusive methodologies, where the use of one does not exclude the use of the others being the results strengthened. The final outcome is a trade-off among the aspects involved and a greater awareness about advantages and weakness of each alternative.

Annex 1

Example of a damages statistical table

N° protocollo	Data accadiment	Data Ricevi-nento Contraente	Data apertura sx	Luogo accadiment	Causale	Ammontare danno richiesto	Pagato/riservato
13/006057	03/08/2012		23/10/2013	LATINA	INFORTUNIO CAUSA BUCA		SS
77970/2012	29/07/2012	08/11/2012	14/11/2012	LATINA	INFORTUNIOCAUSA MARCIAPIEDE NON SEGNALATO		SS
13/00198	08/07/2012	14/12/2012	16/05/2012	LATINA	INFORTUNIO CAUSA TOMBINO ROTTo		SS
13/002680	17/05/2012	21/03/2013	16/05/2013	LATINA	INFORTUNIO CAUSA ANIMALE		SS
13/001212	01/04/2012	29/11/2012	16/05/2013	LATINA	INFORTUNIO CAUSA BUCA		SS
17721/2012	20/01/2012	08/03/202	27/11/2012	LATINA	INFORTUNIO CAUSA OLIO SULAL STRADA		€8000.00
	13/01/2012		07/11/2013	LATINA	DANNI AD UN IMMOBILE		€150.000,00
7282/2012	02/01/2012	31/01/2012	21/03/2012	FORMA	INFORTUNIO CAUSA BUCA		€20,100.00
13/006072	30/12/2011	05/09/2013	16/09/2013	LATINA	INFORTUNIO CAUSA BUCA		€18,000.00
13/001651	19/11/2011	11/02/2013	12/03/2013	LATINA	INFORTUNIO CAUSA BUCA		SS

(continued)

(continued)

N° protocollo	Data accadiment	Data Ricevi-nento Contraente	Data apertura sx	Luogo accadiment	Causale	Ammontare danno richiesto	Pagato/riservato
96150/2011	05/11/2011	16/11/2011	20/12/2011	LATINA	INFORTUNIO CAUSA CADUTA ALBERO		SS
18129/2012	15/10/2011	12/03/2012	14/03/2012	NETTUNENSE	DECESSO CAUSA CANE RANDAGIO		€250,000.00
98265/2011	13/10/2011	23/11/2011	13/01/2012	GAETA	INFORTUNIO CAUSA BUCA		€5500.00
93365/2011	10/10/2011	07/11/2011	20/12/2011	LATINA	INFORTUNIO MENTRE SCENDEVA LESCALE		SS
11161/2012	20/08/2011	09/05/2012	16/05/2012	LATINA	INFORTUNIO CAUSA DISLIVELLO STRADALE		€5500.00
878950/2011	16/08/2011	17/10/2011	07/11/2011	LATINA	INFORTUNIO CAUSA BUCA		SS
64159/2012	23/07/2011	06/04/2012	07/11/2012	APRILIA	INCIDENTESTRADALE CAUSA PRESENZA ACCUMULO TERRA		SS
66698/2011	19/07/2011	23/07/2011	08/110/2011	FONDI	DANNI ABITAZIONE		SS
43752/2011	07/07/2011	15/05/2011	20/05/2011	FORMA	DECESSO A CAUSA INCIDENTESTRADALE		€500,000.00
80317/2011	06/07/2011	21/09/2011	23/09/2011	S.P. BRACCIO ROCCA-CORGA	INFORTUNIO CAUSA ASFALTO VISCIDO		SS

(continued)

(continued)

N° protocollo	Data accadiment	Data Ricevi-nento Contraente	Data apertura sx	Luogo accadiment	Causale	Ammontare danno richiesto	Pagato/riservato
83332/2011	17/06/2011	30/09/2011	18/10/2011	LATINA	INFORTUNIO CADUTA DALLE SCALE		SS
63685/2011	05/06/2011	15/07/2011	27/09/2011	FONDI	DANNI ALLE ABITAZIONI CAUSA MANCANZA MANUTENZIONE ACQUE PIOVANE		SS
66795/2011	04/06/2011	26/07/2011	18/10/2011	BORGO PIAVE	INFORTUNIO CAUSA BUCA		€6500.00
68033/2012	30/05/2011	05/10/2012	20/11/2012	LATINA	INFORTUNIO CAUSA MASSI		€1500.00
40844/2011	23/04/2011	05/05/2011	18/05/2011	FORMA	INFORTUNIO CAUSA ASSENZA DIILLUMINAZIONE		SS
40844/2011	23/04/2011	05/05/2011	13/06/2011	FORMA	INFORTUNIO CAUSA ASSENZA DIILLUMINAZIONE EBARRIERA STRADALE		SS
7913/2011	17/04/2011	24/01/2011	23/03/2011	FONDI	INFORTUNIO CAUSA PRESENZA GATTO MORTO SULLA STRADA		€115,000.00

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N° protocollo	Data accadiment	Data Ricevi-nento Contraente	Data apertura sx	Luogo accadiment	Causale	Ammontare danno richiesto	Pagato/riservato
	16/04/2011			LATINA	APERTO SU CITAZIONE CAUSA CADUTA DALLA MOTO		€37,000.00
69125/2011	09/04/2011	01/08/2011	06/02/2012	VELLETRI	INFORTUNIO CAUSA MANTO STRADALE DISSESTATO		€59,100.00
92574/2011	02/04/2011	03/11/2011	04/01/2012	LATINA	INFORTUNIO ACCIDENTALE		SS
	30/03/2011	24/10/2012	09/11/2012	LATINA	INFORTUNIO SEGNALE NON ILLUMINATO		€1,200,000.00
21012/2012	15/03/2011	20/03/2012	17/04/2012	LATINA	DECESSO OMICIDIO COMMESSO DA AGENTE PROVINCIALE		€250,000.00
28964/2011	09/03/2011	29/03/2011	09/03/2011	CISTERNA	INFORTUNIO CAUSA GHIACCIO		€10,500.00
25529/2011	24/02/2011	15/03/2011	18/07/2011	LATINA	INFORTUNIO CAUSA SPORGENZA MARCIAPIEDE		SS

(continued)

(continued)

N° protocollo	Data accadiment	Data Ricevi-nento Contraente	Data apertura sx	Luogo accadiment	Causale	Ammontare danno richiesto	Pagato/riservato
31484/2011	23/02/2011	05/04/2011	19/04/2011	SONNINO			SS
21764/2012	26/01/2011	23/03/2012	23/05/2012	ITRI	INFORTUNIO CAUSA MANTO STRADALE DISSESTATO		SS
154912/2012	19/07/2011	01/03/2012	21/03/2012	MAENZA	INFORTUNIO CAUSA BUCA		SS
13/006891	09/01/2011	17/10/2013	23/10/2013	LATINA	DECESSO		€600,000.00
6746/2012	23/12/2011	27/01/2012	18/04/2012	SEZZE	INFORTUNIO CAUSA PRESENZA GHIACCIO		SS
2068/2011	27/12/2010	30/12/2010	18/02/2011	LATINA	DANNNI AL FABBRICATO CAUSA INFILTRAZIONI DI ACQUA		SS
28959/2011	22/11/2010	29/03/2011	11/04/2011	SEZZE	INFORTUNIO CAUSA CEDIMENTO DIUNA BANCHINA		SS

Source website of the Province of Latina, 2011–2012

References

Automobile Club d'Italia (ACI)—Istat (2017) Incidenti stradali 2017

Agenzia Mobilità Ambiente Territorio, Emissioni atmosferiche nella città di Milano 2013

Bedogni M (2013) Emissioni atmosferiche nella città di milano-periodo gennaio-giugno 2013. Technical report, AMAT-MI

Berdahl P, Akbari H (2008) Evaluation of titanium dioxide as a photocatalyst for removing air pollutants. California Energy Commission, PIER Energy—Related Environmental Research Program. CEC-500-2007-112

Bouyssou D, Jacquet-Lagrèze E, Perny P, Slowiński R, Vanderpooten D, Vincke P (2012) Aiding decisions with multiple criteria: essays in honor of Bernard Roy, vol 44. Springer Science & Business Media

Cassar L (2005) Cementitious materials and photocatalysis. Betonwerk Und Fertigteiltechnik 71(1):10

Cassar L, Beeldens A, Pimpinelli N, Guerrini GL (2007) Photocatalysis of cementitious materials. In: International RILEM symposium on photocatalysis, environment and construction materials, vol 1. RILEM, pp 131–45

Comune di Milano (2016) Listino prezzi per l'esecuzione di opere pubbliche e manutenzioni

Descornet G (2006) Noise classification of urban road surfaces. State of the Art. European Commission Dg Research

Di Mascio P, Miseri F, Moretti L (2010) Approfondimenti sulle pavimentazioni in calcestruzzo: un modello per confrontare I costi di primo impianto e manutenzione, Federcemento S.r.l

Federal Highway Administration (FHWA) (2010) Towards sustainable pavement systems. Washington, DC

Federal Highway Administration (FHWA) (2013) Reformulated Pavement Remaining Service Life Framework, Publication No. FHWA-HRT-13-038

Fishburn PC (1967) Additive utilities with incomplete product set: applications to priorities and assignments. Operations Research Society of America (ORSA), Baltimore, MD, U.S.A

Global Engineering (2004) La fotocatalisi al servizio dell'Ambiente

Greco S, Figueira J, Ehrgott M (2016) Multiple criteria decision analysis. Springer, New York

Holt A, Sullivan S, Hein DK (2011) Life cycle cost analysis of municipal pavements in Southern and Eastern Ontario. Transportation successes: let's build on them. Congress et Exhibition de l'Association des Transports du Canada. Les Success en Transports: Une Tremplin vers l'Avenir

Hunter AE (2006) Whole life cost analysis for various pavement and drainage options, INTERPAVE

Istituto Nazionale di Statistica (Istat) (2017) Incidenti stradali in Italia

Janssen R, Van Herwijnen M, Beinat E (2000) Definite for windows. A system to support decisions on a finite set of alternatives (Software and package and user manual)

Keeney RL, Raiffa H (1976) Decision analysis with multiple conflicting objectives. Wiley, New York

Lidicker J, Sathaye N, Madanat S, Horvath A (2013) Pavement resurfacing policy for minimization of life-cycle costs and greenhouse gas emissions. J Infrastruct Syst 19(2):129–137

Locatelli F, Scicchitani S Life cycle cost and whole-life cost of interlocking concrete block pavements: the role of event-related costs and externalities. School of Architecture, Urban Planning, Construction Engineering, Master degree thesis, Supervisor: G. Paganin, Academic Year 2015–2016

Monici F (2013) I costi dei pavimenti sul ciclo di vita. Pavinnova

Nassiri S, Bayat A, Skirrow R, Transportation A (2013) Integrated Road Research Facility (Irrf): An Albertan Research Initiative. In: Conference and exhibition of the transportation association of Canada-transportation: better-faster-safer, pp 1–18

Newstreet magazine. n. 9

Nijkamp P, Van den Bergh CJM, Soeteman FJ (1990) Regional sustainable development and natural resource use. The World Bank Econ Rev 4(suppl_1):153–188

NPRA (2005) Norwegian Road Projects are now Profitable. The Government Reduces the Discount Rate. NORDIC road and transport research, No 2/3
Roy B (1996) Multicriteria methodology for decision aiding, vol 12. Nonconvex optimization and its applications. Kluwer Academic Publisher, Dordrecht
Roy B (2005) Paradigms and challenges. Multiple criteria decision analysis: state of the art surveys. Springer, New York, NY, pp 3–24
Saaty TL (1996) The ANP for decision making with dependence and feedback
Torres Machi C, Pellicer E, Yepes V, Chamorro A (2017) Towards a sustainable optimization of pavement maintenance programs under budgetary restrictions. J Clean Prod 148:90–102
Vincke P (1992) Multicriteria decision AidWiley. New York
Zhang H, Lepech MD, Keoleian GA, Qian S, Li VC (2010) Dynamic life-cycle modeling of pavement overlay systems: capturing the impacts of users, construction, and roadway deterioration. J Infrastruct Syst 16(4):299–309
Wimmer W, Züst R (2003) ECODESIGN pilot: product investigation, learning and optimization tool for sustainable product Development with CD-ROM, vol 3. Springer Science & Business Media
Whole Building Design Guide (WBDG) (2016) Life-cycle cost analysis (LCCA)

Part II
Environmental Improvement Benefits and Values Creation

The Valuation of Public and Private Benefits of Green Roof Retrofit in Different Climate Conditions

Raul Berto, Carlo Antonio Stival and Paolo Rosato

Abstract Green roofs represent a suitable option for industrial buildings refurbishment, providing private and social benefits. Nowadays, in Italy green roof technology is still uncommon, because of high installation cost that drives the choice towards more traditional performing solutions, such as cool roofs (CRs). Thus, a thorough valuation of green roofs benefits in urban contexts is required to encourage their diffusion. This paper aims to valuate private and social costs and benefits generated by extensive green roofs (EGRs) compared with cool roofs in three Italian cities: Trieste, Ancona and Palermo. These contexts are characterized by different Mediterranean climate conditions (North, Centre and South Italy); moreover, residential areas overlooking industrial settlements take place in each of them, so it is possible to hypothesize a potential enhancement of landscape value in these properties, allowing to compare aesthetic benefits due to green roofs upon industrial buildings. The study has been based on literature review and on simulation of energy performances of EGR and CR alternatively considered as refurbishment solution for a reference industrial building taking place in each industrial settlement. For the social side, the externalities deriving from EGRs and CRs, such as aesthetic enhancement, biodiversity preservation and natural habitat provision, carbon reduction, air quality improvement, stormwater control, have been monetized according to available data for the cases of study. The analysis demonstrates that a private investor has a poor convenience to implement EGR rather than CR. On the other, a positive Net Present Value (NPV) derives from social cost-benefit analysis comparing EGR and CR, due to the EGR positive externalities. The valuation of the positive externalities let the calculation of economic incentives amount to promote the diffusion of green roofs in the Mediterranean area. On this basis, an annual reduction of local property tax has been considered as incentive form. Further, a sensitivity analysis with Monte Carlo simulation of both private and social benefits evaluation has been performed for each of three case studies. This technique properly evaluates the final effects on private investments in the presence of random unpredictable variables, depending either on climate conditions or on market observation, that influence their economic

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affordability. Finally, through the comparison of the three contexts, an overall discussion about of the influence of climate and urban conditions on the economic analysis has been conducted.

Keywords Green roof externalities · Cost-benefit analysis · Cash flow analysis · Industrial buildings · Mediterranean climate

1 Introduction

The technological implementation of a vegetable layer on the rooftop of existing buildings provide several benefits of private and public nature, such as aesthetic enhancement, control of stormwater run-off volume, improvement of yearly energy performances and a more comfortable indoor air conditions, mitigation of urban heat island effect, a longer lifespan of waterproofing rooftop layers (Getter and Rowe 2006; Raji et al. 2015). Extensive green roofs (EGRs) are particularly suitable for installation on existing buildings because of reduced dead loads burdening on structural system, though a limited thickness of cultivation layer can be burdened (Cascone et al. 2018).

In Italy, high construction costs and poor information about social and private benefits represent the most important cause of EGRs low diffusion (Berardi 2016). It could be encouraged in stakeholders' decisions by a higher quality information that could highlight strengths and opportunities (Brudermann and Sangkakool 2017), overcoming negative impacts of industrial settlements (Rosato et al. 2016). This research aims to evaluate social and private benefits for two alternative retrofitting solutions for existing industrial buildings located in three Italian contexts to define sustainable policies and economic measures to encourage EGRs diffusion in comparison with cool roofs (CRs).

2 Research Background

The retrofit of existing rooftops represents the more suitable action to achieve a remarkable enhancement of energy performance, a sensible target for private investors. Moreover, this intervention can enhance environmental performances in densely populated contexts. In European climates, while CRs represent a typical solution for the refurbishment of energy non-efficient buildings, GRs could balance negative effects in urban climates providing interesting performances in the management of energy consumption during the whole yearly period (Ascione et al. 2013; Porsche and Köhler 2003; Richardson et al. 2016; Shafique et al. 2018).

Compared to more traditional roofing solutions, a barrier to GRs implementation has been found in high initial installation cost; private benefits do not compensate this cost in private economic evaluation, generating and immediate value loss, confirmed by a significative net present value reduction if compared to a convention roofing system with a 40-year-long lifespan (Clark et al. 2008; Sproul et al. 2014). Anyway, previous studies show positive net savings occurring with EGR installation considering production, delivery and management phases, also considering air pollution reduction and stormwater control (Bianchini and Hewage 2012; Niu et al. 2010; Wong et al. 2003). In warm and hot climates, EGRs can perform a payback period lower than 10 years, showing an effective competitiveness (Peng and Jim 2015). In the same climate conditions, the installation of EGRs is a lower-risk investment than an intervention of intensive rooftop greening, in both cases of direct property use and property selling after installation.

Thus, the valuation of positive externalities provided by GRs, if compared to more traditional roof refurbishment solutions, and a higher reliability in terms of structural safety should be considered for monetization to consider potential economic measures capable to catch investors' interest in rooftop greening.

3 Methodology

This study uses cash flow analysis (CFA) for private evaluation and cost-benefit analysis (CBA) for public evaluation, investigating the use of incentives applied to the refurbishment of private properties that generates positive externalities according to an economic model previously tested (Berto et al. 2018). As first assumption, the model assesses the installation of an EGR, alternative to a CR solution, on the rooftop of a productive building located in EZIT industrial settlement in Trieste. Refurbished rooftop lifespan is set 40-years long (Getter et al. 2007; Porsche and Köhler 2003); during this period, appropriate maintenance operations are considered, in particular the substitution of waterproofing layer in CR solution is supposed after 20 years (Hermy et al. 2005; Oberndorfer et al. 2007; Saiz et al. 2006).

If the existing rooftop has a null remaining lifespan, refurbishment occurs at zero time. The proposed model valuates the present value of private cash flows and social benefits and costs, detailed as follows.

C_{GPcr}	present private cost of CR;
B_{Pgr}	present private benefit of GR;
B_{Pcr}	present private benefit of CR;
ΔC_{GP}	difference between C_{GPgr} and C_{GPcr};
ΔB_P	difference between B_{Pgr} and B_{Pcr};
ΔB_{PN}	net present private benefit, difference between ΔB_P and ΔC_{GP};
B_{Egr}	present social benefit of GR;
B_{Ecr}	present social benefit of CR;
ΔB_E	difference between B_{Egr} and B_{Ecr}.

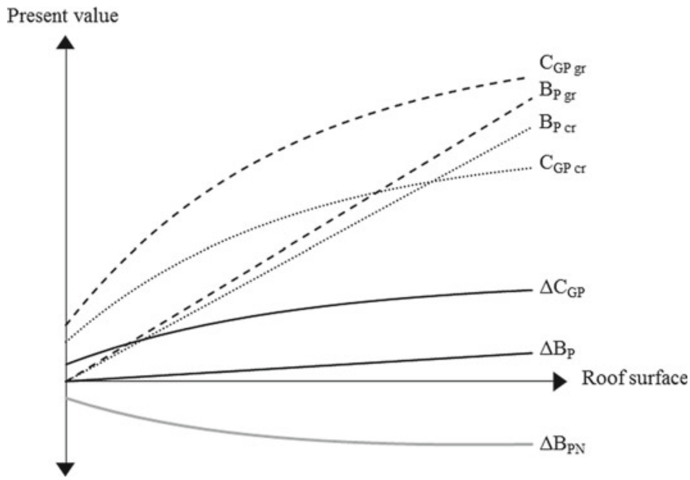

Fig. 1 Private costs and benefits of CR and EGR, with reference to rooftop surface

The present private cost (benefit) of the GR (CR), expressed alternatively as $C(B)_{GP(P)gr(cr)}$ (s_i), is defined as follows

$$C(B)_{GP(P)gr(cr)}(s_i) = \sum_{t=0}^{40} C(B)_{P(P)gr(cr)}(s_i)_t \cdot e^{-\delta \cdot t} \quad (1)$$

where δ is the instantaneous market discount rate, t represents time in years, and s_i is the GR(CR) surface. Figure 1 shows the trends of present private costs and benefits depending on the surface of the refurbished rooftop.

Present external benefits of a GR(CR), $B_{Egr(cr)}$ (s_i) related to surface area s_i are:

$$B_{Egr(cr)}(s_i) = \sum_{t=0}^{40} B_{Egr(cr)}(s_i)_t \cdot e^{-\gamma \cdot t} \quad (2)$$

where γ is the instantaneous social discount rate. Figure 2 shows the trends of social costs and benefits according to the model.

Using the functions ΔB_E and ΔB_{PN}, it is possible to define the minimum surface $s_{\min}$ for which ΔB_E is above ΔB_{PN}, as shown in Fig. 3. For green covered areas greater than $s_{\min}$, the value of positive environmental externalities is above private costs and GR is convenient from the social viewpoint. The model also allows the estimation of the economic incentives required to ensure private convenience in the adoption of EGR over CR, that is at its maximum equal to ΔB_E value and at its minimum equal to ΔB_{PN}. For a surface area smaller than $s_{\min}$, positive externalities derived by GR are not sufficient to ensure private convenience for the intervention, so the maximum value of any incentive.

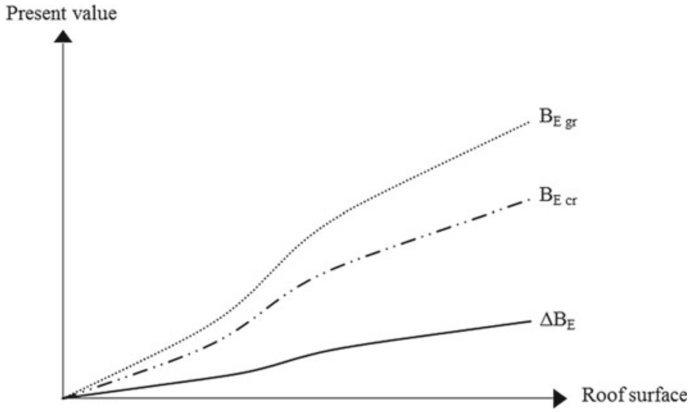

Fig. 2 Social benefits related to CR and EGR

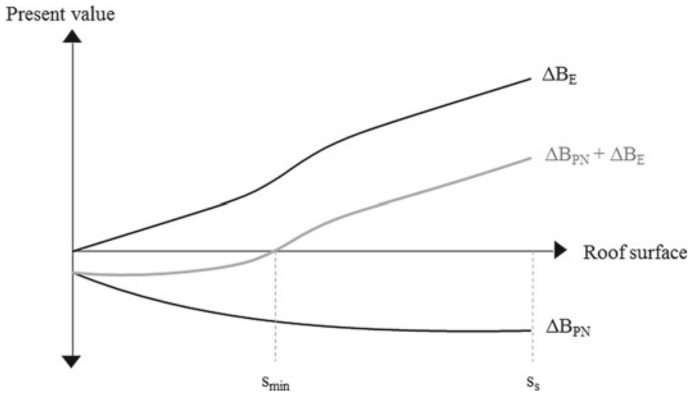

Fig. 3 Private and social benefits functions

The analysis has been conducted for three different industrial settlements in Italy: the abovementioned EZIT in Trieste, New Commercial and Industrial Port in Ancona and Brancaccio industrial area in Palermo (Fig. 4).

CFA analysis for private costs and CBA analysis for public costs and benefits can be compared with the definition of a reference building, subjected to specific climate conditions. Moreover, economic analysis conducted in these contexts reflect local policies and specific items in the local government balance sheet addressed, for example, to biodiversity preservation, sewage infrastructure management, reduction of air pollutants.

To compare CRs and EGRs effects in these climatic contexts, a reference three-storey industrial building has been studied, with reference to the thermal zone located at the upper floor. The gross area of this floor is 781 m^2, corresponding to the building footprint, with a net indoor volume equal to 2480 m^3. Rooftop surface, burdening a

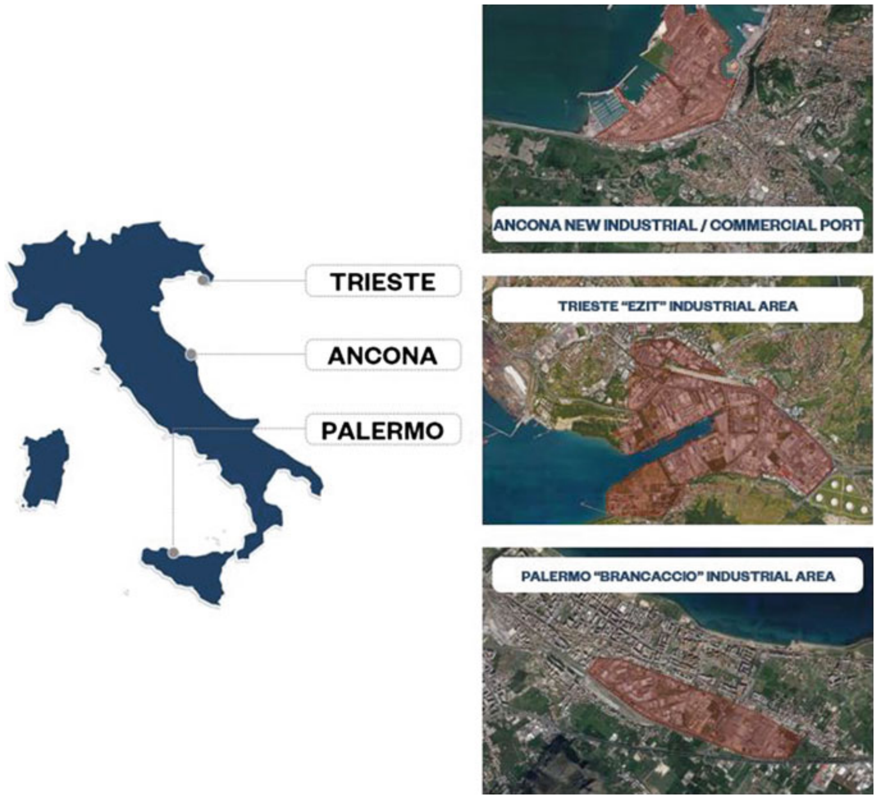

Fig. 4 Industrial settlements in which analysis has been conducted

frame structure in concrete, concur for about 60% of the whole 1300 m^2-wide zone envelope, completed by walls in insulated hollow bricks (29%) and aluminium-framed double-glazing windows (11%). The rooftop is the only technical element whose solution variates throughout analysis.

The existing flat roof has a mixed supporting layer in reinforced concrete and hollow tiles 28-cm thick, not insulted and protected by a bituminous waterproofing membrane. This solution, that has reached the end of his 40-year-long lifespan, supports both solutions for rooftop retrofit as detailed in Fig. 5: an insulated CR with reflective coating, alternative to an insulated EGR with storage element, 10-cm thick soil substrate and vegetation with *Sedum album*, *Sedum floriferum* and aromatic plants such as *Lavandula angustifolia*.

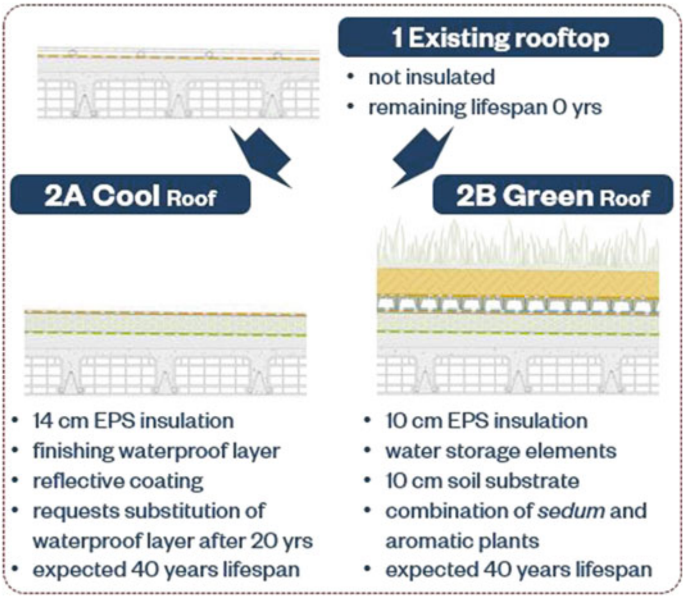

Fig. 5 Description of alternative solutions for existing rooftop refurbishment

4 Value Transfer Approach for Aesthetic Benefit Monetization

The aesthetic improvement of anthropic areas by giving a pleasant appearance to rooftop surfaces represents one of the most important benefits of GRs, not provided by CRs. A conjoint analysis experiment contextualized in Trieste asked individuals to quantify their willingness to pay (WTP) for a widespread diffusion of GRs surrounding their house (Rosato and Rotaris 2014). Accepting a 50% greening of overall rooftop visible area, WTP in Trieste ranges from 82 to 205 € per property unit area that overviews GRs.

Trieste industrial settlement is located at the bottom of a hillside upon which multi-story residential buildings take place, so it is possible to relate WTP to GR surface unit. For the purpose of this study, it is relevant to achieve WTP amount for a widespread GRs diffusion for Ancona and Palermo contexts, then the monetary value of landscape aesthetic benefit. In absence of a specific conjoint analysis available for these cities, the best way to obtain WTP at issue is the benefit transfer approach. This method needs a clear individuation of the benefit to transfer and one or more reference evaluations: in this case, WTP to view GRs and the study conducted in Trieste, respectively. According to literature (Brouwer 2000; Desvousges et al. 1992), reference study is suitable to transfer because it is similar in features to Ancona and Palermo contexts and it is based on theoretically founded methods.

The benefit transfer approach used in this study is the adjusted value transfer, since the unavailability of demand function capable to describe the value to transfer and based upon primary issues, such as socioeconomics, demographic, attitude and income level characteristics. To obtain the policy value, the study value is corrected with a coefficient k that consider the ratio between property average market values (AMV, in ordinary state of preservation) in the analyzed area in Ancona/Palermo and Trieste area ones, made available by Italian Real Estate Market Observatory:

$$WTP_{Trieste} \cdot k = WTP_{Ancona(Palermo)} \quad (3)$$

where

$$k = \frac{AMV_{Ancona(Palermo)}}{AMV_{Trieste}} \quad (4)$$

Table 1 shows the results of value transfer.

Thus, landscape aesthetic benefit has been calculated for the contexts of Trieste, Ancona and Palermo basing on the value transfer approach of WTP. The overall properties area unit facing the industrial zone EZIT in Trieste is about 62,950 m^2 wide, so the property value increase varies between 5.16 and 12.90 € millions. Rooftop surface visible from these residential properties is about 366,200 m^2, of which half is supposed to be refurbished as EGR. Thus, aesthetic improvement due to partial roof greening in Trieste varies between 27.99 and 69.97 € per EGR unit area.

Residential properties area overlooking New Industrial and Commercial Port in Ancona is about 75,588 m^2; property value increases between 6.85 and 17.13 € millions, while visible roof surface is about 299,900 m^2 and greening surface is thus 144,950 m^2. For Ancona, aesthetic benefit amount varies between 59.60 and 149.00 € per EGR unit area. Analogously, properties area facing Brancaccio industrial zone in Palermo is about 101,150 m^2; property value increases between 7.45 and 18.63 € millions, while visible roof surface is about 304,600 m^2 and greening surface is thus 152,300 m^2. It results that for Palermo context aesthetic benefit amount varies between 48.62 and 122.29 € per EGR unit area. Table 2 reports calculation results.

Value transfer concerning aesthetic benefit allows the following valuation of private costs and benefits and public benefits of refurbishment solutions. Table 3 offers a brief view of costs and benefits evaluated and their essential features. Distribution

Table 1 Results of adjusted value transfer approach for rooftop greening WTPs

City	AMV [€ mq^{-1}]	Average WTP [€ mq^{-1}]	Minimum WTP [€ mq^{-1}]	Maximum WTP [€ mq^{-1}]
Trieste	1325.00	143.50	82.00	205.00
Ancona	1525.00	165.16	94.38	235.94
Palermo	1190.00	128.88	73.65	184.11

Table 2 Calculation of aesthetic benefit values for Trieste, Ancona and Palermo contexts

City	AMV [€ mq^{-1}]	Average WTP [€ mq^{-1}]	Minimum WTP [€ mq^{-1}]	Maximum WTP [€ mq^{-1}]
Trieste	1325.00	143.50	82.00	205.00
Ancona	1525.00	165.16	94.38	235.94
Palermo	1190.00	128.88	73.65	184.11

Table 3 Description of private and public costs and benefits

Cost/benefit	Nature	Relevant solutions	Time period	Distribution
Installation	Private	CR and EGR	One time	Constant
Maintenance	Private	CR and EGR	Annuity	Constant
Energy consumption	Private	CR and EGR	Annuity	Triangular
Landscape	Public	EGR	One time	Uniform
Biodiversity preservation	Public	EGR	Annuity	Constant
Air quality	Public	EGR	Annuity	Constant
Carbon reduction	Public	CR and EGR	Annuity	Triangular
Sewage control	Public	CR and EGR	Annuity	Triangular
Infrastructure management	Public	CR and EGR	Annuity	Triangular

considers how economic values have been predicted, depending on intrinsic and random variables: by a fixed constant value, or a uniform range between minimum and maximum values, either a triangular range with a most likely value.

5 Evaluation of Private Costs and Benefits

Private costs, for both refurbishment solutions, refer to initial installation costs, annual maintenance costs and annual energy consumption costs.

Initial installation costs have been determined according to pricing lists for civil engineering products and consider, for both solutions, the removal and the disposal of existing washed gravel tiles and waterproofing membrane.

With reference to energy performances, both refurbishment solutions provide a reduction in energy supplied for heating and cooling services (Gagliano et al. 2015; Scharf and Zluwa 2017). According to a semi-stationary calculation of primary energy consumption in the thermal zone underneath the rooftop, a higher performance of EGR in achieved in summer, while for due diligence and additional insulation layer is needed (Castleton et al. 2010; D'Orazio et al. 2012). Climate data for calculation have been derived by Regional Environmental Protection Agencies of Friuli-Venezia Giulia, Marche and Sicily, while prices of natural gas and electricity derive from time series provided by Italian Authority for Electricity and Gas (AEEG).

Table 4 Average values of private costs and benefits for CR and EGR retrofit solutions

City	Installation costs [€ mq^{-1}]		Energy consumption costs [€ mq^{-1} yr^{-1}]		Maintenance costs [€ mq^{-1} yr^{-1}]	
	CR	EGR	CR	EGR	CR	EGR
Trieste	81.39	140.88	4.02	3.65	2.86	2.00
Ancona	81.39	140.88	3.70	3.65	2.86	2.00
Palermo	81.39	140.88	3.44	3.52	2.86	2.00

Finally, maintenance costs valuation has been obtained considering planned operations at different time frames. A 20-year-long lifespan has been attributed to CR solution, at whose end a re-roofing intervention has been computed to confirm water-tightness and reflection performance; on the other side, after 20 years restoration of vegetation and cultivation layer is provided in EGR solution.

Private costs are detailed in Table 4.

6 Valuation of Public Benefits

Externalities due to refurbishment solutions effects can be valuated separating EGR exclusive public benefits (detailed in Table 5) and benefits related to both solutions. Each public benefit has been valuated as lasting for overall 40-year lifespan, except for aesthetic benefit whose value has been computed two years after refurbishment, according to the approach pursued in aesthetic benefit monetization.

Biodiversity preservation and habitat provision consider the potential of attraction of EGRs replacing impervious surfaces in urban contexts; in this perspective, EGRs avoid costs for the restoration of natural areas. For each context, valuation derives from incurred costs in regional government balance sheet; as EGRs cannot be treated as natural habitats, 20% of this value has been considered appropriate.

Moreover, EGRs perform a dry deposition process of air pollutants and a secondary control of microclimate. This process provides uptake effects on pollutants

Table 5 Average values of public benefits exclusive of EGR-refurbished rooftop solution

City	Landscape aesthetic benefit [€ mq^{-1}]	Biodiversity preservation [€ mq^{-1} yr^{-1}]	Air quality improvement [€ mq^{-1} yr^{-1}]
	EGR	EGR	EGR
Trieste	48.98	3.40E-03	0.13
Ancona	104.30	1.00E-03	0.13
Palermo	85.60	7.60E-05	0.13

such as ozone, nitrogen dioxides, particulate matter PM10 and sulphur dioxide (Nowak et al. 2006; Yang et al. 2008). Considering opportune project damage costs found out in the Energy Environment Economy Model for Europe (E3ME) it is possible to estimate avoided damage costs for each pollutant (Barker and Rosendahl 2000; Rabl and Eyre 1998).

With reference to positive externalities provided by both CR and EGR solutions, the main issue to study refers to stormwater control, depending essentially on cultivation layer depth, sorption capacity and vegetation leaf area index and growth (Castiglia and Wilkinson 2016; Viola et al. 2017; Whittinghill et al. 2015). This benefit implies a reduction of stormwater volume drained to public sewage system, due to retention effect expressed mainly by cultivation layer and evapotranspiration phenomena activated by vegetation. So, on one hand this effect decreases transportation and purification treatment costs, on the other indirectly reduces the risk related to severe flood events and provides lower infrastructural management costs. For the monetization of these externalities, it can be considered that an EGR can reduce drainage flow rate by 0.5 l/m^2 per day in saturation conditions, depending on climate data about dry periods; then, it can absorb from 35 to 58% of rainfall volume (Hermy et al. 2005; Mentens et al. 2006).

Carbon reduction benefit is related, for both intervention solutions, to the reduction of energy consumption for considered energy carriers: natural gas and electricity. An appropriate value of Carbon reduction tax is detectable according to Kyoto Protocol (World Bank et al. 2016).

Urban heat island (UHI) effect has been considered an invariant effect in this study, because both refurbishing solutions provide a valuable effect on the temperature of air layer lying on rooftop outdoor surface, CR because of its high albedo and EGR because of photosynthesis process provided (Susca et al. 2011; Takebayashi and Moriyama 2007). Finally, public costs and benefits values are detailed in Table 6.

Table 6 Public costs and benefits related to CR and EGR retrofit solutions

City	Carbon reduction [€ mq^{-1} yr^{-1}]		Sewage control [€ mq^{-1} yr^{-1}]		Reduction of infrastructural costs [€ mq^{-1} yr^{-1}]	
	CR	EGR	CR	EGR	CR	EGR
Trieste	0.26	0.23	0.63E-02	2.12E-02	0.57E-02	1.70E-02
Ancona	0.23	0.23	0.98E-02	3.10E-02	0.61E-02	1.80E-02
Palermo	0.18	0.18	0.66E-02	0.82E-02	1.30E-02	3.50E-02

7 Determination of Discount Rates

CFA and CBA calculations require assumptions of congruous market and social discount rates. The latter is defined according to social time preference rate (hereafter STPR), intended as the value that society associates to current consumption with respect to the future one (HM Treasury 2003).

STPR consists of two components, the rate with which individuals relate future and current consumptions with unchanged per capita consumption ρ and a second addend related to per capita consumption growth over time that, assumed increasing, will have lower marginal utility (OXERA 2002; Ramsey 1928; Scott 1977, 1989). This effect can be quantified with the product of annual growth per capita consumption g and the elasticity of marginal utility of consumption compared to utility itself μ (Cowell and Gardiner 1999):

$$r = \rho + \mu g \tag{5}$$

Different discount rates should be used in the valuation of tangible or intangible effects, cost components and social benefits, matching the principle of time-declining discount rate (Defrancesco et al. 2014). Thus, in this analysis that considers different components of costs and benefits, occurring at different timing and time horizons as detailed in Table 3, a social discount rate variable between 3.0 and 3.5% is assumed, with reference to 31–75 year-long period and 0–30-year-long period, respectively (HM Treasury 2003), according to a triangular distribution.

Hypothesizing a similar trend, market discount rate varies between 3.5 and 6.0%, with most likely value equal to 4.0%.

8 Sensitivity Analysis Results and Discussion

In this section results of CFA and CBA analysis are shown for the three Italian contexts considered. The sensitivity analysis, based on Monte Carlo simulation method, has been performed with @Risk 7.5 software produced by Palisade Corporation.

The application of Monte Carlo method allows to simulate the effect of some variables whose behavior influences the valuation of private and public costs and benefits and, consequently, the economic affordability of the intervention. Thus, Monte Carlo method represents a valuable tool to develop an informative structure capable of matching the effects of intrinsic and external parameters related to rooftop retrofit.

In the model development, variables such as electricity and natural gas prices and private discount rate are obtained by market observation, thus they are subjected to unpredictability (Lucius 2001; Neufville 2003; Williams 1991). Then, climate conditions that affect EGR performances—such as rainfall, dry periods, outdoor air temperature and solar irradiation on the horizontal—vary throughout the reference period 1996–2015; they have been considered random variables like the previous ones, for each considered context. In Monte Carlo simulation technique, the random generation of a large number of combinations, once probability distribution curves are assigned to random variables as described in Table 3, allows to assess final effects in real estate private investments (French and Gabrielli 2004; Hoesli et al. 2006).

Sensitivity analysis has been performed by the attribution of private costs and public benefits according to peculiar time periods reported in Table 3. Over a 40-year-long period, installation costs occur once in the first annuity; moreover, landscape aesthetic benefit has been valuated once two years after EGR installation, to consider its full expression in terms of visual aspect. The other costs and benefits occur yearly and have been discounted according to the distribution of market and social discount rates, respectively.

With reference to costs and benefits, sensitivity analysis has been performed according to the following steps.

- Identification of random input variables.
- Definition of probability distribution to random variables.
- Estimate of costs and benefits distribution according to random variables.
- Simulation of private NPV probability distribution for each climate context and with different incentive policy.

Considering the difference in planned maintenance costs between CR and EGR, probabilistic CFA shows a poor convenience in adopting EGR: a negative private NPV has been found in all contexts considered (Table 7).

Conducing 10,000 simulations, the impact of uncertainty on NPV has been evaluated. Figure 6 shows the probability density function for private NPV in Trieste, Ancona and Palermo respectively, which are negative in almost all cases: as exception, Trieste context shows private NPV value positive with a very poor confidence value of 0.5%.

Regarding social viewpoint, CBA results shows a social NPV of 17,823.88 € for Trieste, of 55,151.04 € for Ancona and 39,040.42 € for Palermo. Sensitivity analysis performed for each city shows a 76.1% probability of a positive social NPV for Trieste and 99.9% for Ancona and Palermo (Fig. 7).

In Trieste context, the present value of the positive externalities provided by GR compared with CR amounts to 39.026,49 €. So, the maximum reduction on the annual municipality tax should amount to 55.35%. The minimum, those one brings the private NPV to zero, amount to 42.54%. The sensitivity analysis, adopting the

Table 7 Public costs and benefits related to CR and EGR retrofit solutions

City	Private NPV [€]	Social NPV [€]	Externalities present value [€]
Trieste	−29,741.06	17,823.88	39,026.49
Ancona	−36,441.15	55,151.04	79,309.75
Palermo	−36,976.28	39,040.42	65,541.25

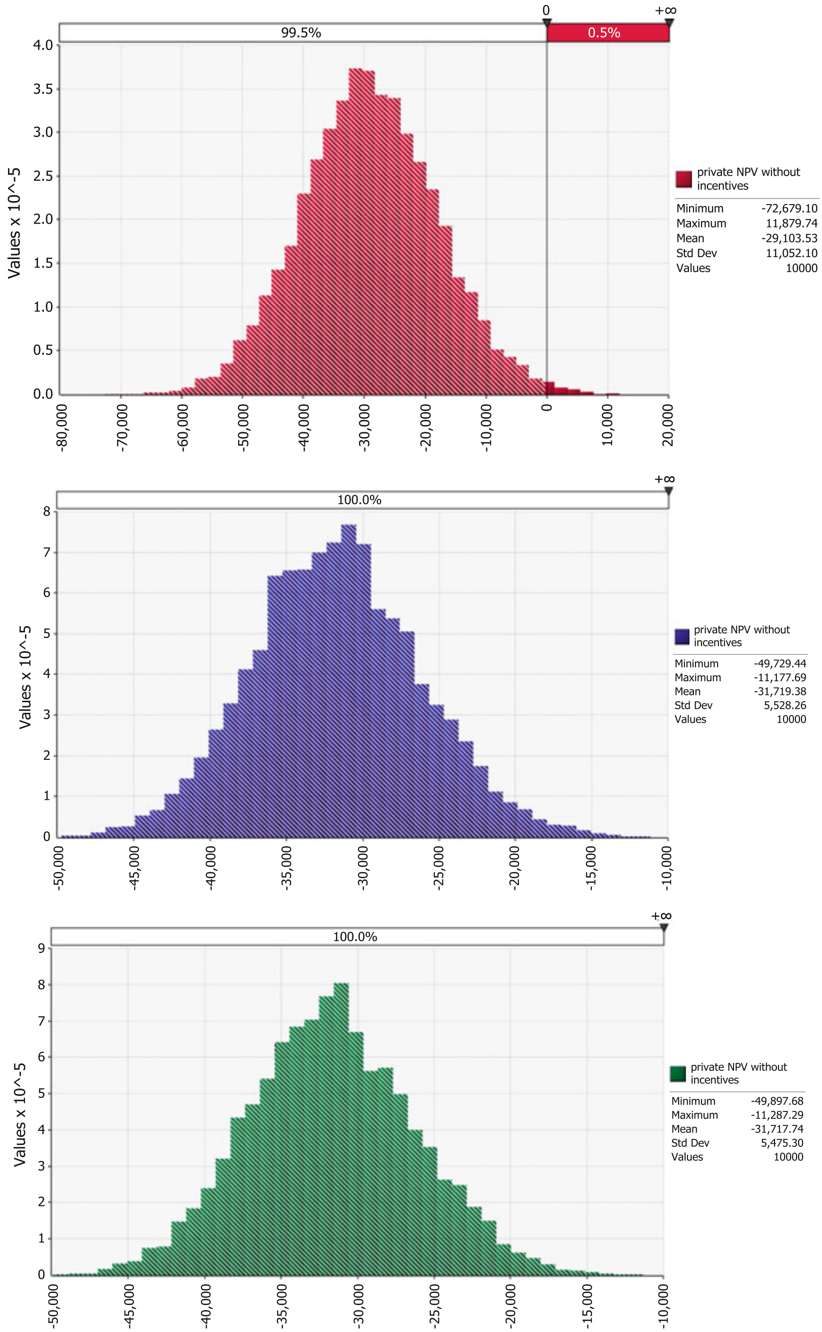

Fig. 6 Probability distribution for private NPV in Trieste, Ancona and Palermo, from the top to the bottom respectively

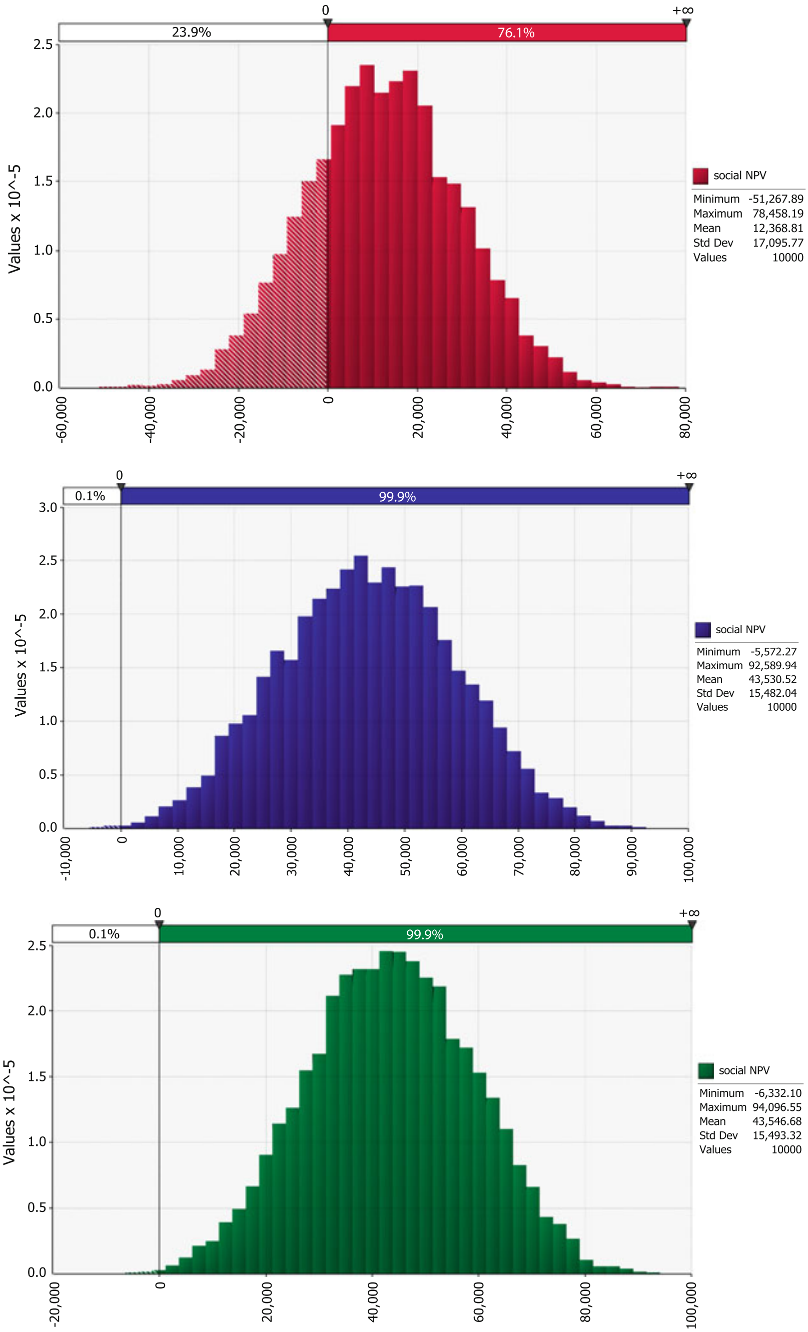

Fig. 7 Probability distribution of social NPV in Trieste, Ancona and Palermo, from the top to the bottom respectively

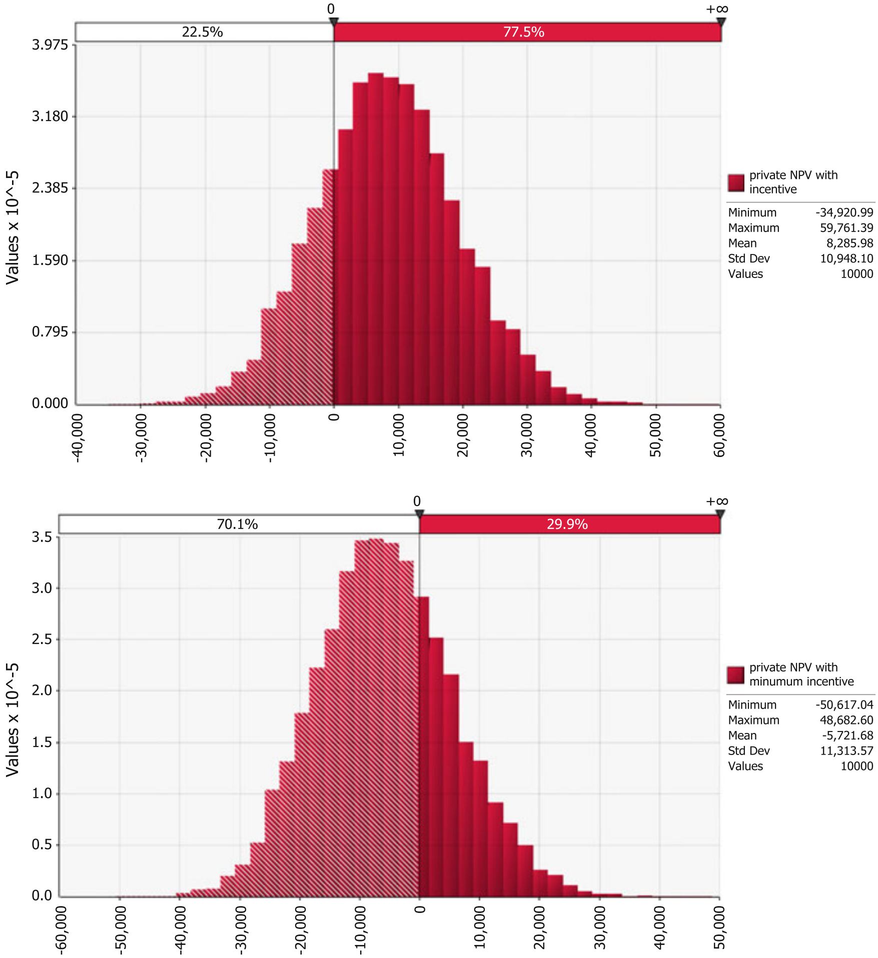

Fig. 8 Probability distribution of private NPV in Trieste, with maximum incentive (top) and minimum incentive (bottom)

maximum reduction on the annual municipality tax, shows a probability of 77.5% of a positive private NPV. Instead, adopting the minimum reduction on the annual municipality tax for Trieste, a probability of 29.9% of a positive private NPV, as reported in Fig. 8, has been obtained.

For Ancona, the present value of the positive externalities provided by GR compared with CR amounts to 79,309.75 €. The maximum reduction on the annual municipality tax should amount to 80.64%, the minimum to 37.71%. The sensitivity analysis, adopting the maximum reduction on the annual municipality tax, shows a

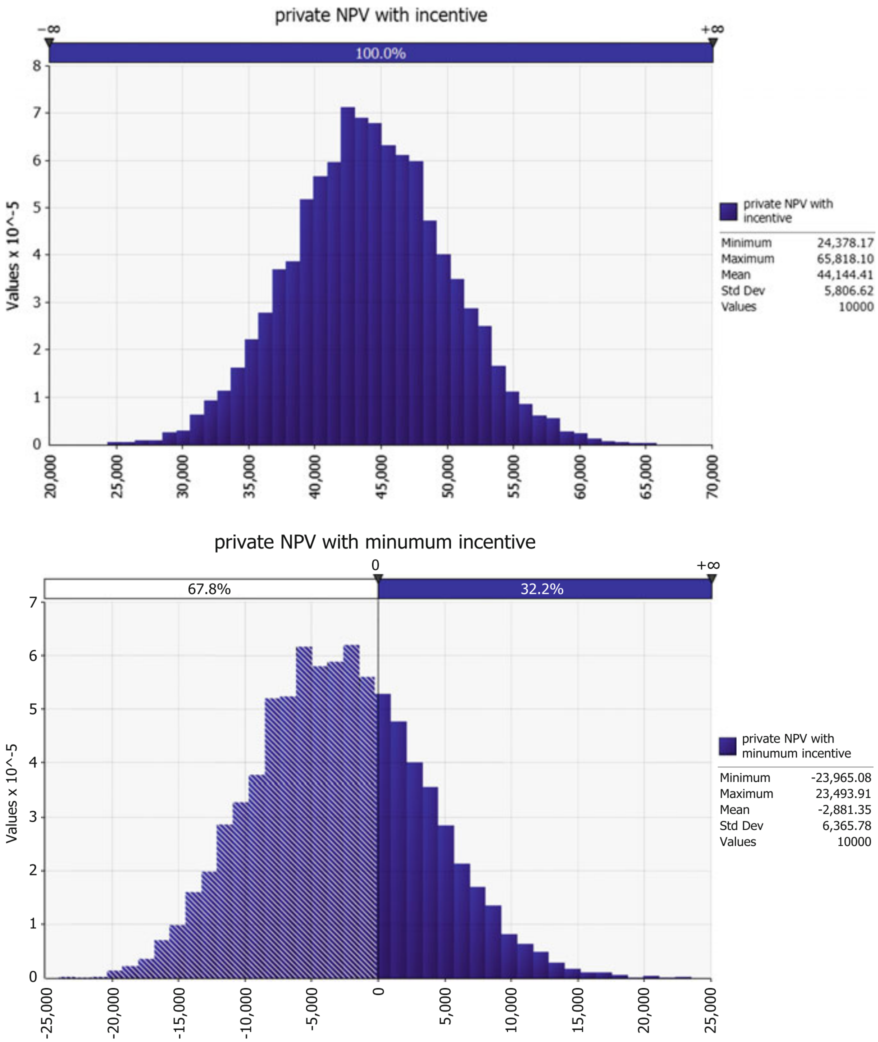

Fig. 9 Probability distribution of private NPV in Ancona, with maximum incentive (top) and minimum incentive (bottom)

probability of 100.0% of a positive private NPV, while a probability of 32.2% of a positive private NPV has been found adopting the minimum reduction on the annual municipality tax (Fig. 9).

For Palermo, the present value of the positive externalities provided by GR compared with CR amounts to 65.541,25 €. The maximum reduction on the annual municipality tax should amount to 66.64%, the minimum to 38.26%. The sensitivity analysis, adopting the maximum reduction on the annual municipality tax, shows a

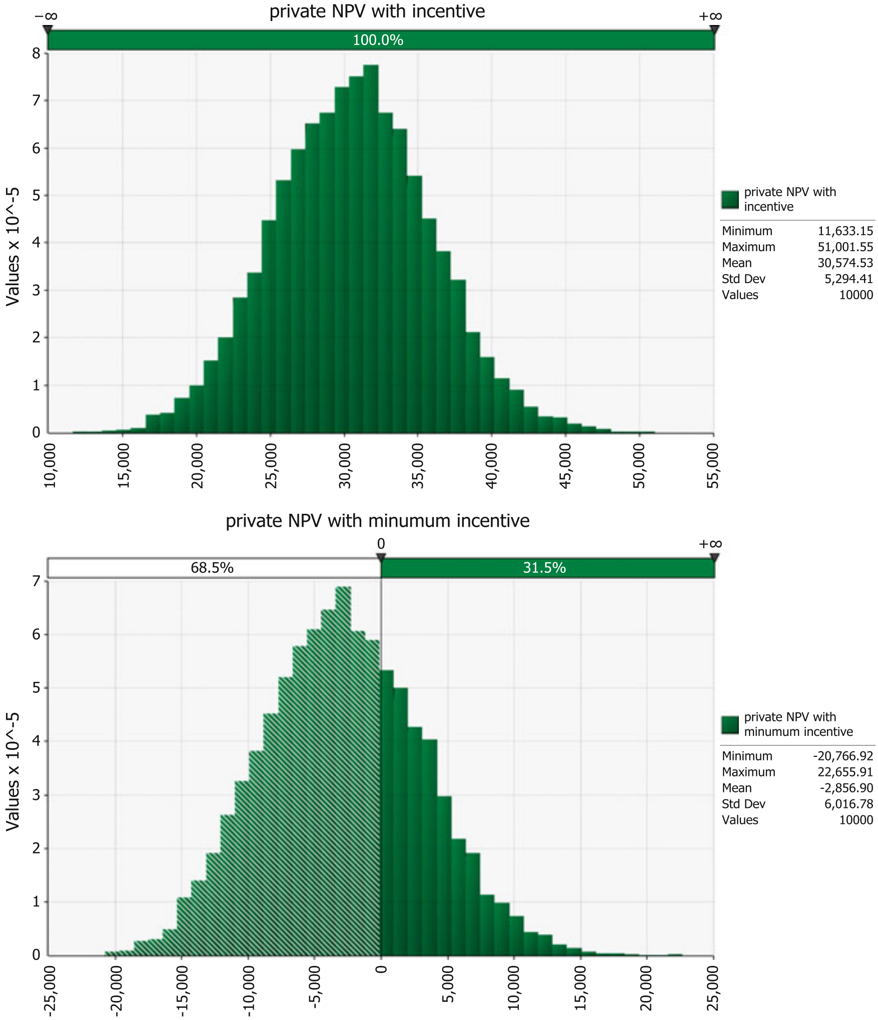

Fig. 10 Probability distribution of private NPV in Palermo, with maximum incentive (top) and minimum incentive (bottom)

probability of 100.0% of a positive private NPV, while a probability of 31.5% of a positive private NPV has been found adopting the minimum reduction on the annual municipality tax (Fig. 10).

9 Conclusions

Through CFA, the difference in costs and benefits between CR and EGR has been evaluated from the perspective of a private investor, aiming to the refurbishment of and industrial building rooftop in three different Mediterranean climate contexts: Trieste, Ancona and Palermo. Using an appropriate market discount rate NPV has been determined a very poor convenience in all three contexts. For Trieste only a 0.5% probability of positive private NPV is noticed, while in Ancona and Palermo there is zero probability of positive NPV.

CBA was performed considering the social benefits of CR and EGR, using an appropriate social discount rate. This analysis shows that for all three contexts EGR is more convenient than CR and it is possible to overcome EGR lack of economic affordability by providing local incentives related to its social benefit value. An annual reduction in local property tax rate on buildings has been considered for entire useful rooftop lifespan. Calibrating the minimum incentive as the amount for NPV equal to zero, and maximum incentive as amount of all social benefits available, probabilities of a positive private NPV equal to 29.9 and 77.5% respectively have been found for Trieste context; analogously, probabilities of 32.2 and 100% have been found for Ancona, and 31.5 and 100% for Palermo, respectively.

In all cases, climate has little influence on private benefit. The most discriminating factor in all contexts is aesthetic benefit, related to the density of residential dwellings that enjoys the sight of industrial areas refurbished by EGR solutions. Finally, rainfall conditions along the whole year represent a remarkable factor because it influences three benefits: reduction of planned maintenance costs of infrastructures, control of sewage in severe rainfall events conditions, reduction of drained stormwater volume due to evapotranspiration phenomena.

References

Ascione F, Bianco N, de' Rossi F, Turni G, Vanoli GP (2013) Green roofs in European climates. Are effective solutions for the energy savings in air-conditioning? Appl Energy 104:845–859. https://doi.org/10.1016/j.apenergy.2012.11.068

Barker T, Rosendahl KE (2000) Ancillary benefits of GHG mitigation in Europe: SO_2, NO_x and PM10 reductions from policies to meet Kyoto targets using the E3ME model and ExternE valuations. In: Organization for Economic Co-operation and Development (ed) Ancillary benefits and costs of GreenHouse Gas mitigation. Washington: Organization for Economic Co-operation and Development, pp 413–450. https://doi.org/10.1787/9789264188129-en

Berardi U (2016) The outdoor microclimate benefits and energy saving resulting from green roofs retrofits. Energy Build 121:217–229. https://doi.org/10.1016/j.enbuild.2016.03.021

Berto R, Stival CA, Rosato P (2018) Enhancing the environmental performance of industrial settlements: an economic evaluation of extensive green roof competitiveness. Build Environ 127. https://doi.org/10.1016/j.buildenv.2017.10.032

Bianchini F, Hewage K (2012) Probabilistic social cost-benefit analysis for green roofs: a lifecycle approach. Build Environ 58:152–162. https://doi.org/10.1016/j.buildenv.2012.07.005

Brouwer R (2000) Environmental value transfer: state of the art and future prospects. Ecol Econ 32(1):137–152. https://doi.org/10.1016/S0921-8009(99)00070-1
Brudermann T, Sangkakool T (2017) Green roofs in temperate climate cities in Europe—an analysis of key decision factors. Urban For Urban Greening 21:224–234. https://doi.org/10.1016/j.ufug.2016.12.008
Cascone S, Catania F, Gagliano A, Sciuto G (2018) A comprehensive study on green roof performance for retrofitting existing buildings. Build Environ 136(March):227–239. https://doi.org/10.1016/j.buildenv.2018.03.052
Castiglia R, Wilkinson S (2016) Landscape and urban planning modelling green roof stormwater response for different soil depths. Landscape Urban Plan 153:170–179. https://doi.org/10.1016/j.landurbplan.2016.05.007
Castleton HF, Stovin V, Beck SBM, Davison JB (2010) Green roofs: building energy savings and the potential for retrofit. Energy Build 42(10):1582–1591. https://doi.org/10.1016/j.enbuild.2010.05.004
Clark C, Adriaens P, Talbot FB (2008) Green roof valuation: a probabilistic economic analysis of environmental benefits. Environ Sci Technol 42(6):2155–2161. https://doi.org/10.1021/es0706652
Cowell F, Gardiner K (1999) Welfare Weights. STICERD, London School of Economics. Retrieved from http://eprints.lse.ac.uk/id/eprint/4270
D'Orazio M, Di Perna C, Di Giuseppe E (2012) Green roof yearly performance: a case study in a highly insulated building under temperate climate. Energy Build 55:439–451. https://doi.org/10.1016/j.enbuild.2012.09.009
Defrancesco E, Gatto P, Rosato P (2014) A "component-based" approach to discounting for natural resource damage assessment. Ecol Econ 99:1–9. https://doi.org/10.1016/j.ecolecon.2013.12.017
Desvousges WH, Naughton MC, Parsons GR (1992) Benefit transfer: conceptual problems in estimating water quality benefits using existing studies. Water Resour Res 28(3):675–683. https://doi.org/10.1029/91WR02592
French N, Gabrielli L (2004) The uncertainty of valuation. J Property Investment Financ. https://doi.org/10.1108/14635780410569470
Gagliano A, Detommaso M, Nocera F, Evola G (2015) A multi-criteria methodology for comparing the energy and environmental behavior of cool, green and traditional roofs. Build Environ 90:71–81. https://doi.org/10.1016/j.buildenv.2015.02.043
Getter KL, Rowe DB (2006) The role of extensive green roofs in sustainable development. HortScience 41(5):1276–1285. https://doi.org/10.17776/csj.30292
Getter KL, Rowe DB, Andresen JA (2007) Quantifying the effect of slope on extensive green roof stormwater retention. Ecol Eng 31(4):225–231. https://doi.org/10.1016/j.ecoleng.2007.06.004
Hermy M, Schauvliege M, Tijskens G (2005) Groenbeheer: Een verhaal met toekomst (Green government: a story with future). Ministerie van de Vlaamse Gemeenschap. Afdeling Bos en Groen, Bruxelles
HM Treasury (2003) The green book: appraisal and evaluation in central government. Evaluation, (October 2002), 118. http://greenbook.treasury.gov.uk/index.htm
Hoesli M, Jani E, Bender A (2006) Monte Carlo simulations for real estate valuation. J Property Investment Financ. https://doi.org/10.1108/14635780610655076
Lucius DI (2001) Real options in real estate development. J Property Investment Financ. https://doi.org/10.1108/14635780110365370
Mentens J, Raes D, Hermy M (2006) Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landscape Urban Plan 77(3):217–226. https://doi.org/10.1016/j.landurbplan.2005.02.010
Neufville R (2003) Real options: dealing with uncertainty in systems planning and design. Integr Assess. https://doi.org/10.1076/iaij.4.1.26.16461
Niu H, Clark C, Zhou J, Adriaens P (2010) Scaling of economic benefits from green roof implementation in Washington, DC. Environ Sci Technol 44(11):4302–4308. https://doi.org/10.1021/es902456x

Nowak DJ, Crane DE, Stevens JC (2006) Air pollution removal by urban trees and shrubs in the United States. Urban For Urban Greening 4(3–4):115–123. https://doi.org/10.1016/j.ufug.2006.01.007

Oberndorfer E, Lundholm J, Bass B, Coffman RR, Doshi H, Dunnett N, Rowe B (2007) Green roofs as urban ecosystems: ecological structures, functions, and services. Bioscience 57(10):823–833. https://doi.org/10.1641/B571005

OXERA (2002) A social time preference rate for use in long-term discounting. London, UK. Retrieved from http://www.oxera.com/Latest-Thinking/Publications/Reports/2002/A-social-time-preference-for-use-in-long-term-disc.aspx

Peng LLH, Jim CY (2015) Economic evaluation of green-roof environmental benefits in the context of climate change: the case of Hong Kong. Urban For Urban Greening 14(3):554–561. https://doi.org/10.1016/j.ufug.2015.05.006

Porsche U, Köhler M (2003) Life cycle costs of green roofs—a comparison of Germany, USA, and Brazil. RIO 3—World Climate & Energy Event, (December), 1–5. https://doi.org/10.1007/s00158-009-0416-y

Rabl A, Eyre N (1998) An estimate of regional and global O_3 damage from precursor NO(x) and VOC emissions. Environ Int 24(8):835–850. https://doi.org/10.1016/S0160-4120(98)00053-1

Raji B, Tenpierik MJ, Van Den Dobbelsteen A (2015) The impact of greening systems on building energy performance: a literature review. Renew Sustain Energy Rev 45:610–623. https://doi.org/10.1016/j.rser.2015.02.011

Ramsey FP (1928) A mathematical theory of saving. The Econ J 38(152):543–559. Retrieved from http://www.jstor.org/stable/2224098

Richardson M, Kumar P, William R, Goodwell A, Stillwell AS, Le PVV (2016) An environmental cost-benefit analysis of alternative green roofing strategies. Ecol Eng 95:1–9. https://doi.org/10.1016/j.ecoleng.2016.06.091

Rosato P, Rotaris L (2014) La scarsa diffusione delle coperture verdi in Italia: bassa disponibilità a pagare o poca informazione? (The poor diffusion of green roofs in Italy: low willingness to pay or little information?). Valori e Valutazioni 13(13):1–10

Rosato P, Valcovich E, Stival CA, Berto R, Cechet G (2016) Horizontal extensive green roofs in existing buildings. Part two—economic features. Valori e Valutazioni 16(16):3–24

Saiz S, Kennedy C, Bass B, Pressnail K (2006) Comparative life cycle assessment of standard and green roofs. Environ Sci Technol 40(13):4312–4316. https://doi.org/10.1021/Es0517522

Scharf B, Zluwa I (2017) Case study investigation of the building physical properties of seven different green roof systems. Energy Build 151:564–573. https://doi.org/10.1016/j.enbuild.2017.06.050

Scott MF (1977) Test rate of discount and changes in base-level income in United-Kingdom. Econ J 87(346):219–241. https://doi.org/10.2307/2232083

Scott MF (1989) A new view of economic growth. Clarendon Paperbacks, Oxford, UK. https://doi.org/10.1093/0198287429.001.0001

Shafique M, Kim R, Rafiq M (2018) Green roof benefits, opportunities and challenges—a review. Renew Sustain Energy Rev 90(March):757–773. https://doi.org/10.1016/j.rser.2018.04.006

Sproul J, Wan MP, Mandel BH, Rosenfeld AH (2014) Economic comparison of white, green, and black flat roofs in the United States. Energy Build 71:20–27. https://doi.org/10.1016/j.enbuild.2013.11.058

Susca T, Gaffin SR, Dell'Osso GR (2011) Positive effects of vegetation: urban heat island and green roofs. Environ Pollut 159(8–9):2119–2126. https://doi.org/10.1016/j.envpol.2011.03.007

Takebayashi H, Moriyama M (2007) Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. Build Environ 42(8):2971–2979. https://doi.org/10.1016/j.buildenv.2006.06.017

Viola F, Hellies M, Deidda R (2017) Retention performance of green roofs in representative climates worldwide. J Hydrol 553:763–772. https://doi.org/10.1016/j.jhydrol.2017.08.033

Whittinghill LJ, Rowe DB, Andresen JA, Cregg BM (2015) Comparison of stormwater runoff from sedum, native prairie, and vegetable producing green roofs. Urban Ecosyst 18(1):13–29. https://doi.org/10.1007/s11252-014-0386-8

Williams JT (1991) Real estate development as an option. J Real Estate Financ Econ. https://doi.org/10.1007/BF00173124

Wong NH, Tay SF, Wong R, Ong CL, Sia A (2003) Life cycle cost analysis of rooftop gardens in Singapore. Build Environ 38(3):499–509. https://doi.org/10.1016/S0360-1323(02)00131-2

World Bank, Ecofys, Vivid Economics (2016) State and trends of carbon pricing. (World Bank, Ed.), Washington, DC: World Bank, vol 88284. Washington. https://doi.org/10.1596/978-1-4648-1001-5

Yang J, Yu Q, Gong P (2008) Quantifying air pollution removal by green roofs in Chicago. Atmos Environ 42(31):7266–7273. https://doi.org/10.1016/j.atmosenv.2008.07.003

Energy Efficiency Choices and Residential Sector: Observable Behaviors and Valuation Models

Marta Bottero, Marina Bravi, Federico Dell'Anna and Carlos Marmolejo-Duarte

Abstract Over the last decade, households' preferences about energy efficiency measures in the residential sector have been the focus of a growing body research employing models based on revealed and stated preferences. Analysis of households' energy consumption and demand elasticities were carried out before with the intent to forecast the potential of energy efficiency programs, but the recent concerns about climate change have drawn attention to the causes of this problem. As a result, the residential and renewable energy sectors have become strategic for the human being's future. Different retrofit measures and technical solutions are now available for the new buildings, but the existing residential stock is more difficult to improve. More specifically, this implies the investment decision of heterogeneous groups of homeowners and landlords who differ in terms of the characteristics of their assets, their financial possibilities and time preferences. Valuation models have helped to forecast the demand of both market and public goods. Based on different approaches and theories, these applications have opened new avenues of research, but leaving some questions unanswered. This work tries to take stock of a debate that is still open by comparing experiments based on revealed and stated preferences in this specific field.

Keywords Stated preference · Revealed preference · Energy efficiency · Individual behavior

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1 Introduction

Measures implemented to improve energy efficiency are now recognized as a means of reducing greenhouse gas emissions, improving the procurement security, cutting down import costs, and creating a system less exposed to risks and volatility that global economic growth inevitably causes. In this direction, the real estate assets play a fundamental role, involving different economic sectors, from raw materials and technical installations to goods and services related to domestic supplies (Dell'Anna et al. 2019). Furthermore, facing the key challenge of fighting climate change while increasing the energy sector sustainability and maintaining economic growth will not be achieved without buildings energy efficiency. After all, the virtual supply of energy saved from a higher level of efficiency could generate multiple benefits to governments, businesses, and households, providing at the same time a market opportunity for a wide range of sectors (Becchio et al. 2018; Barthelmes et al. 2016).

Despite this trend, the immaterial nature of energy and its interweaving with everyday life make it difficult to observe and interpret, with the necessary scientific strictness, family choices and individual behaviors that are closely related to the sector. In this direction, the work intends to propose a reflection, also starting from previous experiments (Marmolejo-Duarte and Bravi 2017; Bottero et al. 2019), on the possibilities of observing—and evaluating—households' choices related to energy saving, taking into account the role that a correct information plays in determining them. Although a reasonably large literature surveys various potential market failure in energy efficiency investment (Allcott and Greenstone 2013; Gerarden et al. 2015), few efforts have been directed specifically on information programs. In fact, the intangible resources of communication appear to be an essential item to make the material resource of the energy works better and determining individual choices that are consistent to the social well-being (Becchio et al. 2018).

Furthermore, the analysis of user behavior directly involved in relevant public policies—such as energy policy—has recently attracted the attention of scholars and policy-makers (Sousa Lourenço et al. 2016). It has been recognized that the increase in competition does not always offer an effective advantage to the consumers. Often, individual choices rely on a limited number of heuristics that sometimes lead to reasonable judgments, and sometimes involve severe and systematic errors generating contradictory behaviors (Kahneman and Tversky 1984; Gilovich et al. 2002; Peón et al. 2017).

How can valuation approaches to individual choices take this matter into account? How can these experiments be used profitably, also in order to limit the buildings energy consumption? This work aims to answer these questions by proposing a reasoning about approaches based on revealed and stated preferences. For this purpose, in Sect. 2 the problem of energy consumption and families' choices related to the residential sector is analyzed, especially from the market—revealed preferences—point of view. Instead, Sect. 3 shows how a stated preferences approach based on the method of choice experiment could be employed to better understand the decision-making process and improve knowledge in this field; for this purpose, a brief summary of the relevant literature is recalled. Conclusions follow.

2 Energy Efficiency Choices Starting from Revealed Preferences Analysis

Changes from traditional energy production systems to low carbon technologies imply a shift in investments and not necessarily an increase in them, as well as a change in market dynamics. The reduction of greenhouse gas emissions does not imply horizontal cuts in spending as the different role that each socio-economic sector can play in the process of changing is recognized. The residential and tertiary sectors are those from which to expect, in the short term, the best results in terms of energy savings. Particularly, the interventions on the existing building stock appear to be strategic from this point of view.

The European Union has set some important principles on the buildings energy efficiency (GU, 2010, L 153/13) with the Energy Performance of Building Directive recast (EPBD recast). However, the lack of a common definition and evaluation of NZEBs (Nearly Zero Energy Building) by the Member States has caused some difficulties and has slowed down the process of efficiency and energy savings (Bottero et al. 2018a). This led, recently, to the revision of the EPBD (European Commission 2016) emphasizing the urgent need to reduce greenhouse gas emissions by involving all sectors, including the residential one.

In fact, despite the constant increase in the renewable sources penetration, it is necessary to reduce the amount of energy required to satisfy individuals and households consumption. The building stock consumes approximately 40% of gross primary energy, since it includes both the residential and services sectors. The European real estate assets are indeed old; most of the buildings were built before the implementation of the energy consumption standards and, in particular for the Mediterranean countries, the breakdown by construction period is as follows: 37%, 49% and 14%, respectively for the period before 1960, between 1961 and 1990 and between 1991 and 2010 (BPIE 2011). Therefore, the interventions on the existing stock are important because the new buildings represent less than 1% per annum.

Given the urgency of stopping the anthropogenic environmental and energy impact, a substantial reform of a wide range of domestic energy behaviors is required in addition to other measures. In this perspective, consumers represent one of the main actors able to influence the energy transaction towards a post-carbon society (Fabi et al. 2017; Becchio et al. 2019). On the one hand, the adoption of measures disseminating sustainable energy sources and technologies, the installation of appliances bringing down the electric load as well as actions reducing the thermal demand through the building envelope efficiency, represent solutions purely related to new investments. On the other, the focus is shifting more and more towards the effects derived from the change in user behavior, with a lowered energy demand matching a supply coming from renewable sources. In this perspective, several kinds of research have been developed with the aim of investigating the factors that influence the public acceptability of energy policies (Steg et al. 2015), the adoption of renewable energy resources by the final users (Barthelmes et al. 2017), and the introduction of energy-efficient technologies in the private sector. It seems that inclusion in decision making leads individuals and families to more easily accept energy policies and changes in energy system, especially if their interests are taken into account (Perlaviciute and Steg 2014). In this regard, it is necessary to clarify why there are still very low percentages of investments to improve energy efficiency.

The analysis of revealed preferences shows the presence of many barriers, including the investment size and the difficulty in forecasting the expected results. With regard to financial barriers, the amount of the investment is considered one of the main limitations to proceed, despite the economic return due to energy savings and the trend of rising in energy prices. The pay-back period is still another problem because, according to the single stakeholder, its acceptability could change. A substantial risk aversion to this kind of investment has also been demonstrated (Newell and Siikamki 2015). Besides, the choice to invest is faced to the competition with other types of goods bearing a status symbol and social prestige. In this direction, the perception and values that real estate assets represent make it difficult to generalize the policies goals. Tax incentives are not enough because they produce fragmentation of interventions, rather than achieving economies of scale with greater efficiency and effectiveness.

Moreover, energy expenditure implies a series of secondary phenomena, including split incentive, in which the investor is not the beneficiary of the intervention –landlord versus tenant or homeowner –, and rebound effect (Schleich et al. 2014), in which greater consumption offsets the energy saved by increasing efficiency. In this context, methods based on revealed preferences have not always been capable of entirely capturing user preferences by observing market behavior.

Many studies have tried to infer information on consumer preferences through the Hedonic Price Method (HPM), by observing real estate sales (Freeman et al. 2003). HPM is based on Lancaster's theory (1966) according to which people give value to a bundle of goods attributes. This approach allows to estimate costs and benefits associated to the structural and locational attributes that consumers believe are important when they buy a home. In light of this, a family maximizes its utility by simultaneously moving along each marginal price schedule, where this last can be interpreted as a household's willingness to pay for a unit of each attribute. HPM is generally used for environmental valuation purposes—parks and different kind of amenities—but, in recent years, a flourishing literature on energy efficiency demand has been developed. In fact, since 2008, Member States have been obliged by the European Union to indicate for each building, built, sold or rented, the Energy Performance Certificate (EPC) that describes the energy performance.

Some studies have shown that buildings with high energy performance level are appreciated compared to the others (Bonifaci and Copiello 2015; Bottero et al. 2018), although, other applications have found a null impact of EPC ranking on prices (Olaussen et al. 2017) or only little on some market segments (Fregonara et al. 2017; Marmolejo-Duarte and Chen 2019). This latter finding interestingly coincides with opinion-based research, that has found that EPC ranking has a negligible impact on the housing market (Pascuas et al. 2017). It has also been demonstrated by Olaussen et al. (2017) that energy efficiency attributes can incorrectly absorb the impact on prices by other unobserved variables, such as structural ones, producing a spurious correlation between EPC and other attributes.

Anyway, according to some studies, energy label appears to have achieved significant savings by inducing energy efficiency and increasing information transparency (Howarth et al. 2000; Webber et al. 2000). Furthermore, the results suggest as other incentives—such as green loans, subsidies and tax reductions—can promote energy savings encouraging real estate developers to offer building characterized by advanced green features (Gillingham et al. 2009; Buso et al. 2017; Napoli et al. 2017; D'Alpaos and Bragolusi 2018).

3 Stated Preferences and Energy Efficiency: How Does a Choice Experiment Could Be Modeled?

Since human choice processes have been analyzed by different disciplines, there is not a unique theoretical framework to refer to. Ben-Akiva et al. (2002) depicted the state of the art of Predictive Choice Experiments (PCE) in relation to the more general field of human behavior analysis and they showed the differences, but also the fruitful exchanges occurred between the two. In fact, the research goals are different—prevision and regularity *vs*. deconstruction and heterogeneity—but this does not mean that various methodologies could not work together for the solution of empirical problems. The common objective is still today the individual choice process modelling in a variety of situations and applications.

As widely recognized, in the PCE, the Random Utility Maximization (RUM) model is the main referring framework. From the narrowest formulation (Marschak 1960; McFadden 1974, 2001) until today, the evolution of this theory has taken advantage from a progressive hybridization, so much to identify another generation of models with a new label, that of Hybrid Choice Models (HCM). The latter have tried to solve many issues arising from the experimentation: (a) presence of heterogeneity across decision-makers due to different attitudes and perceptions (Greene et al. 2006); (b) choice state-dependence (Viscusi and Huber 2012); (c) latent constructs and cognitive biases (Hensher and Greene 2010) (d) information processing (Denstadli et al. 2012); (e) time preferences in presence of risk and uncertainty (Glenk and Colombo 2013; Lundhede et al. 2015).

For the reasons explained before, it is particularly interesting to focus on information availability in the consumer choice process, first of all by comparing real and hypothetical markets. Some aspects of this problem are often confused. For example, one would be led to believe that, while in a real markets information is transparent and accessible, in a simulated one—as in a choice experiment—de facto this cannot be. On the contrary, it has been widely demonstrated that consumers adapt the decision-making process to the available quantity of information each time they make a choice, real or hypothetical (Payne et al. 1993; Lacetera et al. 2012). From this perspective, potential sources of behavioral biases could cause: unobserved costs or overstated benefits, ignored product attributes or use of inappropriate discount rates in presence of risk and uncertainty.

Especially when the decision involves time preferences, the available information becomes a strategic item. Moreover, the profitability of energy efficiency investments depends fundamentally on the rate at which individuals discount future energy savings related to the initial investment; but individual discount rates exhibit considerable heterogeneity in experimental studies with time preferences elicitation (Newell and Siikamki 2015). In this sense, product or service choices may not minimize present value costs. Gerarden et al. (2015) outline that consumers may be inattentive to energy costs when purchasing products, but such lack of attention is not necessarily irrational. Bounded rationality could inhibit from properly balancing benefits and costs when comparing products or services where energy consuming is involved.

Furthermore, information availability is directly related to the selection bias; in other words, due to human limited attention, memory and processing capacities, individuals make decisions based on subsets of information that are easily and immediately available (Peón et al. 2017). This behavior determines an important collateral effect that has been tested in the PCE: the regret effect. Individual thinks «I would not want to regret not choosing or done… something», rather than maximizing the expected utility. Coherently, regret is defined as what one experiences when a non-chosen alternative performs better than a chosen one, taking into account one or more attributes. Boeri and Longo (2017) show that Random Regret Minimization (RRM) model explains the respondents' choices better than RUM, indicating that regret is an important choice paradigm for renewable energy programs (Chorus 2010). In other words, the authors suggest that bounded rationality leads individuals to choose options that minimize their possible losses when considering energy saving.

3.1 Modelling Choice Experiments

In this Section a more specific comparison of choice experiments in the field of buildings energy efficiency is recalled with the intent to clarify how some of the issues referred to above could be managed. One of the first experiment in this sector was probably that of Cameron (1985) who employed data collected by a national survey on energy consumption. Analysis of households' energy consumption and demand elasticities were carried out also before to forecast the potential of energy efficiency programs (Li and Just 2018), but Cameron took on a choice model showing the demand sensitivity to changes in investment costs, energy prices and income.

A significant increasing of the relevant literature occurs only in the first decade of the 2000s, when greenhouse effect on environment and climate becomes more evident. Scholars probably consider the valuation models based on stated preferences more manageable, flexible and suitable for describing consumers hypothetical choices. Sadler's work (2003) is often cited as a good example of these first studies; she conducted two choice experiments among more than 600 owners of single family homes across Canada. In one of the two, respondents were asked to choose between a renovation that does not include energy efficiency retrofits and one that does it with only two alternatives with three attributes and two levels each. The results show that energy-efficient renovations are preferred compared to those without energy retrofits. Later, Banfi et al. (2008) use a choice experiment to evaluate the willingness to pay for energy-saving measures in Switzerland's residential buildings. These interventions include ventilation system and insulation of windows and facades; also in this case, the results suggest that the benefits of energy saving attributes are significantly considered by the consumers. While showing that a preference for this kind of investment does matter, these early applications do not go much further; the models employed are basically standard, like the Multinomial Logit Model (MLM) with fixed effects. Other possibilities will be experimented later.

Kwak et al. (2010) estimate the willingness to pay for air-conditioning and heating considering three main attributes: windows, facade, and ventilation. More specifically, they test the hypothesis that energy efficiency choices would be nested. The Nested Logit Model (NLM) relaxes the so-called IIA (Independence of Irrelevant Alternatives) assumption—also known as binary independence—organizing the alternatives into groups and allowing for correlations among them. A little later, Achtnicht (2011) conducts a choice experiment concerning energy retrofits for existing houses in Germany; the respondents have to choose between a modern heating system or an improved thermal insulation for their home. In this case, a Mixed Logit Model is employed and the investment payback period is included, but removing the related uncertainty. Rouvinen and Matero (2013) examine how different attributes of heating systems affect homeowners' choice following renovations when preferences heterogeneity is considered; a Random Parameters Logit (RPL) model allows to relax the IIA assumption identifying the random characteristics and taking under control consumers heterogeneity. Similarly, Bottero et al. (2019) opt for a RPL model to estimate the residents' willingness to pay for buildings energy retrofit of an urban district in Italy. By aggregating costs and willingness to pay for the entire district, the presence of a potential for improving the energy efficiency is verified with a variation related to the kind of investment: windows substitution or facades insulation.

More specifically and about information availability in households' decision-making, a large number of experiments cannot be found in this field. A certain attention is concentrated on the attributes selection process and the choice sets creation as well as the inclusion of information related to the greenhouse effect and the consequences of fossil energies consumption in general. Less work has been devoted to verifying the presence or absence of eventual biases able to influence the individual behavior. For example, Philips (2012) presents the results of a choice experiment used to investigate the preferences of landlords and tenants for insulation and heating retrofit in New Zeland. The first are willing to pay more for a heating appliance than any other option; on the contrary, the second have a low willingness to pay for heating substitution and would prefer under-floor insulation. Accordingly, a poor information may be a reason why many landlords are not willing to pay market prices for energy efficiency upgrades. About that, Michelsen and Madlener (2012) analyze the influence of the preferences for specific attributes of residential heating system on the homeowners' adoption decision in Germany. They found there are different drivers, especially from sociodemographic and spatial point of view. Particularly important is the difference between newly and existing buildings.

Some studies consider reasons and motivations that encourage homeowners to carry out building energy retrofits as well as barriers against such investments. For example, Achtnicht and Madlener (2014) directly investigate the reasons for and against building energy retrofits in Germany, but also apply a choice experiment involving different measures. Even though the most homeowners wait until single building elements are approaching the end of their useful life, before considering options for renovation or replacement, it seems they consider whether or not the additional costs for energy efficiency retrofit is affordable and profitable. Besides, the incentive effect of expert recommendations appears to be significant.

More recently, some authors have outlined that the decision to retrofit should go beyond mere cost-benefit considerations and include other aspects as, for example, increase in indoor comfort. By means of a choice experiment, different thermal energy-saving measures in residential buildings have been investigated taking into account the individuals' environmental concerns (Galassi and Madlener 2017). This last seems to be important in explaining consumers' heterogeneity. That the concerns about the environment and climate change are increasing in public opinion is however a fact (Alberini et al. 2018), and today the demand for transparent information about costs and benefits of energy saving measures could require urgent answers. Starting from the analysis of the literature, Table 1 summaries the main estimation models that have been used for the development of choice experiment method (Soeckai et al. 2018).

4 Conclusions

Buildings energy efficiency is clearly a strategic sector to mitigate the climate change effects that are becoming devastating and irreversible. In the last decades, scholars have given a large contribution to the knowledge of consumers' behavior, also in uncertain conditions as those characterizing the energy consumption. It was demonstrated that information availability and environmental concerns are important to drive families' investment decision towards more efficient products. At the same

Table 1 Main estimation framework and econometric analysis models

Estimation framework	Random utility maximization (Marschak 1960; McFadden 1974, 2001; Borchers et al. 2007)
	Random Regret Minimization (Chorus 2010; Chorus et al. 2014; Boeri and Longo 2017)
	Hybrid Choice Models (Ben-Akiva et al. 2002)
Econometric analysis model	Multinomial Logit Model (Banfi et al. 2008; Andrews and Krogmann 2009)
	Mixed Multinomial Logit Model (Achtnicht 2011)
	Nested Logit Model (Kwak et al. 2010; Ma and Burton 2013)
	Random Parameter Logit (Rouvinen and Matero 2013; Ward et al. 2011)
	Latent class (Janssen et al. 2017; Rhead et al. 2018)
	Scale adjusted latent class (Magidson and Vermunt 2007; Islam 2014)
	Heteroskedastic Multinomial Logit (Swait and Adamowicz 1996)
	Generalised Multinomial Logit (Fiebig et al. 2010)

time, the existent real estate assets need stronger and aimed policies able to overcome the fragmentation of single private initiatives.

The state of the art of revealed and stated preferences analysis in this specific field shows research advancing but also the incapacity to translate findings in practical advice for the policy-makers. Besides, econometric models based on inferential analysis bring with them the problem of the validity of the results under sampling conditions. Usually, with stated preferences, respondents sampling requires more effort and resources, in front of smaller samples, than revealed preferences. These last are investigated through more extensive surveys, generally at the national level. What should probably be tested is the possibility of integrating directly observable consumer behavior with choice experiments. This has already been attempted but not in this specific sector. For example, the analysis of the investment choices already made by the families could identify their status quo and allow, through an interview based on a choice experiment, to keep heterogeneity under control. As well as panel data could help to understand how it is possible to increase sensitivity and sustainable behavior in energy consumption.

Although estimates of willingness to pay captured through studies based on revealed and stated preferences should be considered with caution, they could provide very important indications for the policy maker. Considering low-cost energy efficiency solutions, identified through a cost-optimal approach, can help to define the strategies to be adopted or to be subsidized by government subsidies. Or, when energy policies for reducing energy consumption include an expensive cost, energy measures combined with awareness campaigns, could provide a low-cost solution. Further developments may include hybrid models for defining future energy scenarios for the city. Actually, in the urban field analysis they are limited and little explored. Indeed, attention is shifting more and more towards energy issues at the district and city scale. In this context, starting from the consumers' current behaviors captured by revealed preferences methods, future scenarios can be designed using the stated preferences by the consumers involved. In this case the analysis of user behavior becomes of considerable importance. Moreover, in a vision of a sustainable city, the buildings cover only a part of the causes that can be mitigated to achieve the energy and environmental objectives to which the Member States must refer. In this direction, integrated energy savings strategies capable of involving different sectors could achieve greater benefits for the whole community.

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References

Achtnicht M (2011) Do environmental benefits matter? Evidence from a choice experiment among house owners in Germany. Ecol Econ 70:2191–2200

Achtnicht M, Madlener R (2014) Factors influencing German house owners' preferences on energy retrofits. Energy Policy 68:254–263

Alberini A, Bigano A, Ščasný M, Zvěřinová I (2018) Preferences for Energy Efficiency vs. Renewables: What Is the Willingness to Pay to Reduce CO_2 Emissions? Ecol Econ 144:171–185

Allcott H, Greenstone M (2013) Is there an energy efficiency gap? In: Energy efficiency. Elsevier, pp 133–161

Andrews CJ, Krogmann U (2009) Explaining the adoption of energy-efficient technologies in U.S. commercial buildings. Energy Build 41:287–294

Banfi S, Farsi M, Filippini M, Jakob M (2008) Willingness to pay for energy-saving measures in residential buildings. Energy Econ 30:503–516

Barthelmes VM, Becchio C, Bottero M, Corgnati SP (2016) Cost-optimal analysis for the definition of energy design strategies: the case of a Nearly-Zero Energy Building. Valori e valutazioni 21:61–76

Barthelmes VM, Becchio C, Fabi V, Corgnati SP (2017) Occupant behaviour lifestyles and effects on building energy use: investigation on high and low performing building features. Energy Procedia 140:93–101

Becchio C, Bertoncini M, Boggio A et al (2018) The Impact of Users' Lifestyle in Zero-Energy and Emission Buildings: an Application of Cost-Benefit Analysis. In: New Metropolitan Perspectives. Springer International Publishing, pp 123–131

Becchio C, Bottero MC, Corgnati SP, Dell'Anna F (2018) Decision making for sustainable urban energy planning: an integrated evaluation framework of alternative solutions for a NZED (Net Zero-Energy District) in Turin. Land Use Policy 78:803–817

Ben-Akiva M, Mcfadden D, Train K et al (2002) Hybrid choice models: progress and challenges. Mark Lett 13:163–175

Boeri M, Longo A (2017) The importance of regret minimization in the choice for renewable energy programmes: evidence from a discrete choice experiment. Energy Econ 63:253–260

Bonifaci P, Copiello S (2015) Real estate market and building energy performance: data for a mass appraisal approach. Data Br

Borchers AM, Duke JM, Parsons GR (2007) Does willingness to pay for green energy differ by source? Energy Policy 35:3327–3334

Bottero MC, Bravi M, Cavana G, Dell'Anna F (2019, Forthcoming) Energy retrofit and investment decisions: individuals' preferences valuation through a Choice Experiment. Geoing Ambient e Mineraria

Bottero M, D'Alpaos C, Dell'Anna F (2018a) Boosting Investments in Buildings Energy Retrofit: the Role of Incentives. In: New Metropolitan Perspectives. Springer International Publishing, pp 593–600

Bottero MC, Bravi M, Dell'Anna F, Mondini G (2018b) Valuing building energy efficient through Hedonic Prices Method: are spatial effects relevant? Valori e Valutazioni 21:27–40

BPIE (Buildings Performance Institute Europe) (2011) Europe's buildings under the micro-scope: a country-by-country review of the energy performance of Europe's buildings. http://bpie.eu/publication/europes-buildings-under-the-microscope/

Buso T, Dell'Anna F, Becchio C, Bottero M, Corgnati S (2017) Of comfort and cost: examining indoor comfort conditions and guests' valuations in Italian hotel rooms. Energy Res Soc Sci 32:94–111

Cameron TA (1985) A nested logit model of energy conservation activity by owners of existing single family dwellings. Rev Econ Stat 67(2):205–211

Chorus C, van Cranenburgh S, Dekker T (2014) Random regret minimization for consumer choice modeling: assessment of empirical evidence. J Bus Res 67:2428–2436

Chorus CG (2010) A new model of Random Regret Minimization. Eur J Transp Infrastruct Res 10(2):181–196

D'Alpaos C, Bragolusi P (2018) Multicriteria prioritization of policy instruments in buildings energy retrofit. Valori e Valutazioni 21:15–25

Dell'Anna F, Vergerio G, Corgnati S, Mondini G (2019) A new price list for retrofit intervention evaluation on some archetypical buildings. Valori e Valutazioni 22:3–17

Denstadli JM, Lines R, de Dios Ortúzar J (2012) Information processing in choice-based conjoint experiments. Eur J Mark 46:422–446

European Commission (2016) Accelerating Clean Energy in Buildings. COM 2016 860 final Annex 1

Fabi V, Di Nicoli MV, Spigliantini G, Corgnati SP (2017) Insights on pro-environmental behavior towards post-carbon society. Energy Procedia 134:462–469

Fiebig DG, Keane MP, Louviere J, Wasi N (2010) The generalized multinomial logit model: accounting for scale and coefficient heterogeneity. Market Sci 29:393–421

Freeman AM III, Herriges JA, Kling CL (2003) The measurement of environmental and resource values: theory and methods. Resources for the Future, Routledge, Washington DC

Fregonara E, Rolando D, Semeraro P (2017) Energy performance certificates in the Turin real estate market. J Eur Real Estate Res 10(2):149–169

Galassi V, Madlener R (2017) The role of environmental concern and comfort expectations in energy retrofit decisions. Ecol Econ 141:53–65

Gerarden T, Newell RG, Stavins RN (2015) Deconstructing the energy efficiency gap: conceptual frameworks and evidence. Am Econ Rev 105(5):183–186

Gillingham K, Newell RG, Palmer K (2009) Energy efficiency economics and policy. Discussion Paper RFF DP 09-13, Resource for the Future, Washington DC

Gilovich T, Griffin D, Kahneman D (2002) Euristic and biases: the psychology of intuitive judgement. Cambridge University Press, Cambridge UK

Glenk K, Colombo S (2013) Modelling outcome-related risk in choice experiments. Aust J Agric Resour Econ 57:559–578

Greene WH, Hensher DA, Rose J (2006) Accounting for heterogeneity in the variance of unobserved effects in mixed logit models. Transp Res Part B Methodol. 40B(1):75–92

Hensher DA, Greene WH (2010) Non-attendance and dual processing of common-metric attributes in choice analysis: a latent class specification. Empir Econ. 39:413–426

Howarth R, Haddad BM, Paton B (2000) The economics of energy efficiency: insights from voluntary participation programs. Energy Policy 28:477–486

Islam T (2014) Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data. Energy Policy 65:340–350

Janssen EM, Marshall DA, Hauber AB, Bridges JFP (2017) Improving the quality of discrete-choice experiments in health: how can we assess validity and reliability? Expert Rev Pharmacoeconomics Outcomes Res 17:531–542

Kahneman D, Tversky A (1984) Choices, values, and frames. Am Psychol 399:341–350

Kwak S-Y, Yoo S-H, Kwak S-J (2010) Valuing energy-saving measures in residential buildings: a choice experiment study. Energy Policy 38:673–677

Lacetera N, Pope DG, Sydnor JR (2012) Heuristic thinking and limited attention in the car market. Am Econ Rev 102:2206–2236

Li J, Just RE (2018) Modeling household energy consumption and adoption of energy efficient technology. Energy Econ 72:404–415

Lundhede T, Jacobsen JB, Hanley N et al (2015) Incorporating outcome uncertainty and prior outcome beliefs in stated preferences. Land Econ 911(2):296–316

Ma C, Burton MP (2013) A nested logit model of green electricity consumption in Western Australia (No. 1784-2016-141890)

Magidson J, Vermunt J. (2007) Removing the scale factor confound in multinomial logit choice models to obtain better estimates of preference. 2007 Sawtooth software conference, Santa Rosa (CA), 17–19 Oct 2007

Marmolejo-Duarte C, Bravi M (2017) Does the energy label (EL) matter in the residential market? A stated preference analysis in Barcelona. Buildings 7:53

Marmolejo-Duarte C, Chen A (2019) The uneven price impact of energy efficiency ratings on housing segments. Implications for public policy and private markets. Sustainability 11:372

Marschak J (1960) Binary choice constraints on random utility indicators. In: Arrow K (ed) Stanford symposium on mathematical methods in the social sciences. Stanford University Press, Stanford, CA, pp 312–329

McFadden D (1974) Conditional logit analysis of qualitative choice behavior. In: Paul Zarembka (ed) Frontiers in econometrics. Academic Press, New York, pp 105–142

McFadden D (2001) Economic Choices. Am Econ Rev 91:351–378

Michelsen CC, Madlener R (2012) Homeowners' preferences for adopting innovative residential heating systems: a discrete choice analysis for Germany. Energy Econ 34:1271–1283

Napoli G, Gabrielli L, Barbaro S (2017) The efficiency of the incentives for the public buildings' energy retrofit. The case of the Italian Regions of the "Objective Convergence". Valori e valutazioni 18:25–39

Newell RG, Siikamki J (2015) Individual time preferences and energy efficiency. Am Econ Rev 105(5):196–200

Olaussen JO, Oust A, Solstad JT (2017) Energy performance certificates—Informing the informed or the indifferent? Energy Policy 111:246–254

Pascuas RP, Paoletti G, Lollini R (2017) Impact and reliability of EPCs in the real estate market. Energy Procedia 140:102–114

Payne JW, Bettman JR, Johnson EJ (1993) The adaptive decision maker. Cambridge University Press, New York, NY

Peón D, Antelo M, Calvo-Silvosa A (2017) An inclusive taxonomy of behavioral biases. Eur J Gov Econ 6:24–58

Perlaviciute G, Steg L (2014) Contextual and psychological factors shaping evaluations and acceptability of energy alternatives: integrated review and research agenda. Renew Sustain Energy Rev 35:361–381

Phillips Y (2012) Landlords versus tenants: Information asymmetry and mismatched preferences for home energy efficiency. Energy Policy 45:112–121

Rhead R, Elliot M, Upham P (2018) Using latent class analysis to produce a typology of environmental concern in the UK. Soc Sci Res 74:210–222

Rouvinen S, Matero J (2013) Stated preferences of Finnish private homeowners for residential heating systems: a discrete choice experiment. Biomass Bioenerg 57:22–32

Sadler M (2003) Applying stated choice modeling to a hybrid energy economy model. Report to Natural Resources Canada, Simon Fraser University
Schleich J, Mills B, Dütschke E (2014) A brighter future? Quantifying the rebound effect in energy efficient lighting. Energy Policy 72:35–42
Soekhai V, de Bekker-Grob EW, Ellis AR, Vass CM (2018) Discrete choice experiments in health economics: past, present and future. PharmacoEconomics 37:201–226
Sousa Lourenço J, Ciriolo E, Rafael Almeida S, Troussard X (2016) Behavioural in-sights applied to policy: European report 2016. JRC EUR 27726 EN. https://publications.europa.eu/en/publication-detail/-/publication/eb1f5ea2-d3ae-11e5-a4b5-01aa75ed71a1/language-en
Steg L, Perlaviciute G, van der Werff E (2015) Understanding the human dimensions of a sustainable energy transition. Front Psychol 6
Swait J, Adamowicz W (1996) The effect of choice environment and task demands on consumer behavior: discriminating between contribution and confusion. University of Alberta Libraries
Viscusi WK, Huber J (2012) Reference-dependent valuations of risk: why willingness-to-accept exceeds willingness-to-pay. J Risk Uncertain 44:19–44
Ward DO, Clark CD, Jensen KL et al (2011) Factors influencing willingness-to-pay for the ENERGY STAR® label. Energy Policy 39:1450–1458
Webber CA, Brown RE, Koomey J (2000) Savings estimates for the Energy Star® voluntary labeling program. Energy Policy 28:1137–1149

Comparative and Evaluative Economic Analysis of Ground Mounted Photovoltaic Plants

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Abstract Energy produced from renewable sources has assumed an increasingly central role, thanks to the investments in renewable energy and the agreements reached during the last Conferences of the Parties. This paper deals with the economic-estimative evaluation of two photovoltaic plants with similar peak power and geographic position located precisely in the areas of Mandatoriccio and Campana (Calabria, South Italy). The evaluation method used is the Discounted Cash Flow (DCF), a financial procedure that allows to simulate the entire life cycle of the photovoltaic system, from the acquisition date. This method has been implemented by applying an experimental combination of the Build up Approach and the analytical method based on the ascending and descending influences that act on the specific risks related to photovoltaic investment. This paper also highlights the importance of the energy potentially produced by the photovoltaic plants to obtain a very objective estimation value. For this purpose, the annual energy production was estimated using the simplified Siegel method. Thus it was possible to compare Siegel data with real ones supplied by their managers, to carry out a comparative estimative analysis of the two photovoltaic plants covered by our article.

Keywords DCF · Siegel method · Photovoltaic plant

1 Introduction

The first studies on the evaluation of photovoltaic systems were theoretically developed by Webb and Harris (Harris 1984; Webb 1980) in the early 1980s. They indicated the income capitalization approach as the most suitable evaluation method, by taking into account that these systems generate cash flows during their life.

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In the new millennium, there was an exponential growth of the photovoltaic market with the installation of numerous photovoltaic systems on the roofs of residential, retail and office buildings, but also on the ground. According to a study conducted by the Lawrence Berkeley National Laboratory (Hoen et al. 2011) and set in California, the houses provided with photovoltaic systems and sold in the period from 2001 to 2009 have a greater market value compared to those newly construction and provided with a photovoltaic system.

Nowadays, since the market value of properties is strongly influenced by the presence of photovoltaic systems, the Appraisal Institute has tried to provide guidelines for the evaluation of green homes with the publication of a book (Simmons 2010) by analyzing the technical-economic characteristics that influence their value. In the Photovoltaic Specialists Conference held in Tampa (Florida) on 21 June 2013, the authors Klise, Johnson and Adomatis discussed on all the factors that influence the market value of the photovoltaic systems: the feed-in-tariff contribution, the maintenance conditions, the aesthetics, the obsolescence, the correct functioning and the produced energy (Klise et al. 2013a).

The authors also analyzed the main evaluation methods approved by the International Valuation Standards (IVS), such as market approach, cost approach and income approach, in order to understand which allows to attain the most truthful evaluations. The use of the cost approach is not recommended because it takes into account only the physical depreciation of the system without considering the feed-in-tariff contribution. At the current state of the photovoltaic market, it is not possible to use the market approach due to the difficulties of finding a suitable number of comparable data belonging to the same market segment. The most suitable evaluation procedure for photovoltaic systems is DCF, because it considers the revenues produced during their life cycle. In 2012, Sandia National Laboratories developed an evaluation tool with the purpose of standardizing the appraisal of photovoltaic systems. This tool uses DCF to determine the market value of the system and it is divided into different sections: the energy produced, the calculation of the discounting rate, the electricity tariffs, operation and maintenance (Klise et al. 2013b).

This paper deals with the economic-estimative evaluation of two photovoltaic plants located in South Italy. The purpose of the paper is to evaluate in an objective way the market value of the ground mounted photovoltaic plants by using the DCF. Thus this method was implemented by combining the Build up Approach and the analytical method that uses the ascending and descending influences. Moreover the study takes into account of the risks related to the photovoltaic investment and which allow to calculate the discount rate. In fact, the percentage incidences of the ascending and descending influences are determined considering the factors that contribute to the formation of the risks.

The paper also highlights the importance of the evaluation of the energy potentially produced by the photovoltaic plants for estimating an objective market value. So the annual energy production has been estimated using the simplified Siegel method.

2 Methodology

The appraisal of the value of the two photovoltaic plants has been conducted using DCF due to the difficulty of finding comparable data belonging to the same market segment. This evaluation method allows to simulate the entire life cycle of the systems considering that their main feature is to generate income during their life (Hasan et al. 2016; Foracci 2009). The energy potentially produced by the system has a great importance to evaluate the incoming cash flows, which derive from government incentives (Campoccia et al. 2014), if present, and the sale of produced energy, considering inflation and deflation of electricity. This method is always applicable even in countries where feed-in-tariff contribution for photovoltaic systems are no longer provided. This study also carries out the evaluation of the energy potentially produced by the system by using the simplified Siegel method.

The choice of using the DCF is very crucial and it depends on the data belonging to the subject's market segment. For the evaluation of photovoltaic systems, DCF is presented in the following form:

$$V = \sum_{t=1}^{n} \frac{(R_t - S_t)}{(1+k)^t} - \frac{V_f}{(1+k)^s}, \tag{1}$$

with:

- R_t expected annual revenues (€/year);
- S_t expected annual operating expenses (€/year);
- k discount rate;
- V_f final output value (€);
- n investment time horizon (years);
- s year in which the system has to be dismantled (year);
- t generic year (year).

According to formula (1), the current value of the photovoltaic system is obtained by the difference between the sum of the discounted cash flows and the final exit value. The expected annual revenues are related to the energy produced by the system during its operation period. They are divided into fixed revenues, which derive from government incentives if present, and in variable revenues deriving from the sale of produced energy. The outgoing cash flows coincide with operating expenses that are divided into fixed costs, variable expenses and extraordinary maintenance expenses.

The determination of the discount rate is a crucial point of DCF, because even small percentage variations reflect significantly on the value of the asset.

In our study, due to the difficulty of finding comparable data, the discount rate has been determined by combining the Build up Approach with the analytical method based on ascending and descending influences that act, with a positive or negative sign respectively, on the specific risks of the factors related to the photovoltaic investment (Salvo et al. 2017; Forte et al. 1974). The percentage incidences of the ascending and descending influences are determined considering the factors that contribute to the formation of the risks, such as: geographic position of the system, nominal power of the system, photovoltaic cells material, the age of the system, inclination and orientation of the panels, feed-in-tariff contribution, etc.

The formula for determining the discount rate is the following:

$$K = K_f + PR, \tag{2}$$

where:

K discount rate;
K_f risk-free rate;
PR risk premium.

The risk premium can be written according to the following formula:

$$\begin{aligned} \mathrm{PR} &= \sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{R_i} = \sum_{\mathrm{i}=1}^{\mathrm{m}} \left(\mathrm{R_{tmedio}} + \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{A_i} - \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{D_i} \right) \\ &= R_{tmedio} + \sum_{i=1}^{n} A_i - \sum_{i=1}^{n} D_i, \end{aligned} \tag{3}$$

with:

R_i generic risk related to photovoltaic investment;
R_{tmedio} average rate of the real estate investment;
A_i ascending influences;
D_i descending influences.

The risks associated with photovoltaic investment are:

- **context risk** (R_{cont}), related to the geographic position of the photovoltaic system and the presence of shading areas caused by natural obstacles on the site or by the inclination of the panels;
- **endogenous risk** (R_{end}), related to the technical characteristics of the photovoltaic system and the purchase prices of electricity;
- **financial risk** (R_{fin}), linked to the specific investment;
- **system risk** (R_{sist}), linked to changes in the regulatory and fiscal framework;
- **insurable risk** (R_{ass}), linked to the possibility that exogenous events of particular gravity, such as thefts and natural disasters, can cause damage to the modules;
- **property risk management** (R_{gest}), related to the system management.

An average theoretical risk is quantitatively determined for each risk (Table 1) by taking into account of the data provided us by some private equity funds which invest in photovoltaic plants.

The ascending and descending influences are determined for each risk considering all the circumstances that influence photovoltaic investments. Each of the Tables 2, 3, 4, 5, 6 and 7 consider one the risk factors associated with photovoltaic investment.

Table 1 Risk factors of the photovoltaic investment

Typology of risk	Range (%)	$R_{taverage}$ (%)
Context risk	0.25–2.50	1.38
Endogenous risk	0.30–2.00	1.15
Financial risk	0.50–1.50	1.00
System risk	0.50–2.00	1.25
Insurable risk	0.20–1.00	0.60
Property risk management	0.20–1.00	0.60
Total		5.98

Table 2 Ascending and descending influences for the context risk

Risk typology	Factors	Ascending influences (+) and descending influences (−)
Context risk (R_{cont})	Geographical location of the system	
	South Italy	−(1.10 ÷ 1.20)%
	Centre Italy	−(0.60 ÷ 0.80)%
	North Italy	−(0.20 ÷ 0.35)%
	Presence of the shadow areas	+(0.15 ÷ 0.40)%

Table 3 Ascending and descending influences for the endogenous risk

Risk typology	Factors	Ascending influences (+) and descending influences (−)
Endogenous risk (R_{end})	Nominal power of the system (kW)	
	Small size (P < 100 kW)	+0.30%
	Medium size (100 kW ≤ P ≤ 1000 kW)	−(0.20 ÷ 0.40)%
	Large size (P > 1000 kW)	−(0.50 ÷ 1.00)%
	Solar cell material	
	Monocrystalline silicon	−0.25%
	Polycrystalline silicon	−0.20%
	Amorphous silicon	−0.05%
	Age of the system	+(0.15 ÷ 0.30)%
	Tilt and orientation of the panels	±0.10%

Table 4 Ascending and descending influences for the financial risk

Risk typology	Factors	Ascending influences (+) and descending influences (−)
Financial risk (R_{fin})	Feed-in-tariff contribution	
	I feed-in-tariff contribution	−0.45%
	II feed-in-tariff contribution	−0.35%
	III feed-in-tariff contribution	−0.30%
	IV feed-in-tariff contribution	−0.20%
	V feed-in-tariff contribution	−0.10%
	None feed-in-tariff contribution	+0.30%

Table 5 Ascending and descending influences for the system risk

Risk typology	Factors	Ascending influences (+) and descending influences (−)
System risk (R_{sist})	Quotes of the investment returns in the photovoltaic	±0.50%

Table 6 Ascending and descending influences for the insurable risk

Risk typology	Factors	Ascending influences (+) and descending influences (−)
Insurable risk (R_{ass})	Power of the system	+(0.10 ÷ 0.35)%
	Disaster risk	+(0 ÷ 0.20)%
	Theft risk	+(0.10 ÷ 0.40)%

Table 7 Ascending and descending influences for property risk management

Risk typology	Factors	Ascending influences (+) and descending influences (−)
Property risk management (R_{gest})	Repairs	
	Periodical	−0.30%
	Non periodic	+(0.50 ÷ 2.00)%
	Reliability of the SGR	±0.25%

2.1 *Evaluation of the Energy Produced by the Photovoltaic Systems Using Siegel Method*

The energy potentially produced by a photovoltaic system per year depends on the annual solar irradiation, which varies according to geographic position (Castillo et al. 2016) and hours of daylight in the different months of the year. Other influential factors on energy production are: angle of inclination of the panels on the horizontal plane (tilt), their orientation in relation to the south (azimuth), efficiency of the single photovoltaic module and the efficiency of the whole photovoltaic system (Mehleri et al. 2010; Kacira et al. 2004; Hussein et al. 2004).

The evaluation of the produced energy is a very important step because the return of the investment is directly linked to the amount of kWh of energy produced by the plants (Mondol et al. 2007). Therefore, the annual energy production has been estimated using the simplified Siegel method (Siegel et al. 1981; Mazzeo et al. 2015). This method allows to evaluate the monthly average daily efficiency of a photovoltaic system, which is influenced by the monthly average daily values of the external air temperature and the incident solar radiation (4). The formula used to calculate the monthly average daily efficiency is the following:

$$\bar{\eta} = \eta_R \cdot \left[1 - \beta \cdot \left(\overline{T_a} - T_R\right) - \frac{\beta \cdot (\overline{\tau\alpha}) \cdot V \cdot \overline{\overline{E}}}{n \cdot U_c}\right], \tag{4}$$

where:

- $\bar{\eta}$ monthly average daily efficiency;
- η_R efficiency at reference temperature T_R and solar radiation of 1000 W/m^2;
- β slope of photovoltaic array;
- $\overline{T_a}$ external air temperature;
- n number of hours per day;
- $\overline{\tau\alpha}$ medium module transmittance-absorptance product;
- U_c overall thermal loss coefficient;
- V dimensionless function of the sunset angle, the monthly average daily clearness index and the ratio of the monthly average daily total radiation on the array to that on a horizontal surface;
- $\bar{E}$ incident solar radiation;
- T_R reference temperature.

It is possible to calculate the monthly average daily electrical energy supplied by the photovoltaic system through the use of the following formula:

$$\bar{E}_e = \bar{\eta} \cdot \eta_{BOS} \cdot A \cdot \bar{E}, \tag{5}$$

where:

- $\bar{E}_e$ monthly average daily electrical energy supplied by the photovoltaic system;
- $\bar{\eta}$ monthly average daily efficiency;
- A area of the photovoltaic field;
- $\bar{E}$ incident solar radiation;
- η_{BOS} BOS (Balance of System) efficiency.

It must be considered that the evaluated energy virtually produced by the system will decrease during its operation period due to the loss of efficiency and the possible failures that entail the production block. Losses are indicated with the parameter

Balance of System (B.O.S.) that varies from 15 to 25% for medium and large photovoltaic systems. By contrast, the efficiency is given by the ratio between the actual energy fed into the grid and the energy produced by the panels. It can vary for medium and large installations from 75 to 85%. In our study, we have hypothesized that the annual production of energy undergoes a decrease due to faults and malfunctions equal to 2% per year constant and the decay of energy performance equal to 0.9% per year.

3 Case Study

This study treats the appraisal of two ground mounted photovoltaic plants located in Campana and Mandatoriccio (Calabria, South Italy). The plant located in Campana has a peak power of 997.92 kW_p, while the other has a peak power of 977.50 kW_p. Both systems benefit from IV feed-in-tariff contribution for a period of 20 years (Table 8).

Table 8 Main features of the photovoltaic plants located in Campana and Mandatoriccio

Main features	Photovoltaic plant in Campana	Photovoltaic plant in Mandatoriccio
Peak power	997.92 kW_p	977.50 kW_p
Latitude	39.431450	39.474927
Longitude	16.811425	16.842094
Date entered into operation	21/12/2012	28/06/2012
Photovoltaic module technology	Polycrystalline silicon	Monocrystalline silicon
Mounting position	Ground	Ground
Total number of modules	4158	3910
Tilt	28°	28°
Azimuth	0°	0°
Efficiency index (%)	75	75
Losses (%)	25	25
Feed-in-tariff	IV—0.222 €/kWh	IV—0.2235 €/kWh
Annual potentially producible energy	1,190,000 kWh	1,240,000 kWh

3.1 Evaluation of Photovoltaic Systems Using the Simplified Siegel Method

The annual energy production of both plants is calculated using the simplified Siegel method (4) and (5). The annual energy produced by the system located in Campana is equal to 1,365,775.50 kWh, while the value for the other system is 1,365,775.46 kWh (Table 9).

After evaluating the energy potentially produced by the systems, it is possible to determine the incoming cash flows considering the government incentives and the sale of energy in the free market (Table 10). This evaluation also considers the performance decay of photovoltaic modules performance mainly due to their physical obsolescence (Table 11).

The expenditure cash flows are given by the sum of fixed costs, variable costs and extraordinary maintenance costs (Table 12). Both plants are not subject to the payment of the single municipal tax (IMU).

The expected cash flows are determined by the difference in revenues and expenditures (Table 13).

The discount rate is determined with the Build up Approach (2) implemented with the ascending and descending influences (Tables 1, 2, 3, 4, 5, 6 and 7). The following risks are calculated with the theory of ascending and descending influences (Table 14).

Table 9 Performance of the photovoltaic plants in Campana and Mandatoriccio

	Photovoltaic plant in Campana	Photovoltaic plant in Mandatoriccio
Month	$\overline{E_e}$ (kWh)	$\overline{E_e}$ (kWh)
Jan.	76,141.80	72,734.49
Feb.	87,480.30	83,530.19
Mar.	110,465.00	105,338.40
Apr.	123,594.00	117,686.93
May.	131,249.50	124,743.20
Jun.	136,767.10	129,755.26
Jul.	146,760.10	139,129.20
Aug.	147,026.10	139,493.51
Sept.	123,519.80	117,469.08
Oct.	115,252.90	109,816.63
Nov.	85,611.40	81,713.17
Dec.	81,907.50	78,257.63
Annual produced energy	1,365,775.50	1,299,667.70

Table 10 Incoming cash flow of the photovoltaic plant located in Campana

Year	Production taken from the reference date (kWh/year)	IV feed-in-tariff (€/kWh)	Projections of sales prices (€/kWh)	Total revenues (€)
2017	418,561.92	0.222	0.0614	€118,635.16
2018	1,272,072.37	0.222	0.0609	€359,862.69
2019	1,258,821.62	0.222	0.0604	€355,433.96
2020	1,245,570.87	0.222	0.0598	€351,019.55
2021	1,232,320.11	0.222	0.0593	€346,619.46
2022	1,219,069.36	0.222	0.0587	€342,233.69
2023	1,205,818.60	0.222	0.0582	€337,862.24
2024	1,192,567.85	0.222	0.0577	€333,505.10
2025	1,179,317.10	0.222	0.0571	€329,162.29
2026	1,166,066.34	0.222	0.0566	€324,833.79
2027	1,152,815.59	0.222	0.0560	€320,19.62
2028	1,139,564.84	0.222	0.0555	€316,219.76
2029	1,126,314.08	0.222	0.0550	€311,934.22
2030	1,113,063.33	0.222	0.0544	€307,663.00
2031	1,099,812.57	0.222	0.0539	€303,406.10
2032	933,974.17	0.222	0.0533	€257,151.50

Table 11 Incoming cash flow of the photovoltaic plant located in Mandatoriccio

Year	Production taken from the reference date (kWh/year)	IV feed-in-tariff (€/kWh)	Projections of sales prices (€/kWh)	Total revenues (€)
2017	307,641.60	0.235	0.0614	€91,195.78
2018	1,210,500.10	0.235	0.0609	€358,180.72
2019	1,197,890.72	0.235	0.0604	€353,802.43
2020	1,185,281.35	0.235	0.0598	€349,437.77
2021	1,172,671.97	0.235	0.0593	€345,086.73
2022	1,160,062.59	0.235	0.0587	€340,749.32
2023	1,147,453.22	0.235	0.0582	€336,425.54
2024	1,134,843.84	0.235	0.0577	€332,115.38
2025	1,122,234.47	0.235	0.0571	€327,818.85
2026	1,109,625.09	0.235	0.0566	€323,535.95

(continued)

Table 11 (continued)

Year	Production taken from the reference date (kWh/year)	IV feed-in-tariff (€/kWh)	Projections of sales prices (€/kWh)	Total revenues (€)
2027	1,097,015.71	0.235	0.0560	€319,266.67
2028	1,084,406.34	0.235	0.0555	€315,011.02
2029	1,071,796.96	0.235	0.0550	€310,768.99
2030	1,059,187.59	0.235	0.0544	€306,540.59
2031	1,046,578.21	0.235	0.0539	€302,325.82
2032	494,045.24	0.235	0.0533	€142,448.27

Table 12 Expenditure cash flow of the photovoltaic plants located in Campana and Mandatoriccio

	Photovoltaic plant in Campana			Photovoltaic plant in Mandatoriccio		
Year	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)
2017	€1,213.33	€20,238.93	€21,452.27	€1,213.33	€20,238.93	€21,452.27
2018	€3,749.20	€62,234.72	€65,983.92	€3,749.20	€62,234.72	€65,983.92
2019	€3,861.68	€62,234.72	€66,096.40	€3,861.68	€62,234.72	€66,096.40
2020	€3,977.53	€63,790.59	€67,768.11	€3,977.53	€63,790.59	€67,768.11
2021	€4,096.85	€65,385.35	€69,482.20	€4,096.85	€65,385.35	€69,482.20
2022	€4,219.76	€67,019.99	€71,239.74	€4,219.76	€67,019.99	€71,239.74
2023	€4,346.35	€68,695.49	€73,041.84	€4,346.35	€68,695.49	€73,041.84
2024	€4,476.74	€70,412.87	€74,889.61	€4,476.74	€70,412.87	€74,889.61
2025	€4,611.04	€72,173.20	€76,784.24	€4,611.04	€72,173.20	€76,784.24
2026	€4,749.37	€73,977.53	€78,726.90	€4,749.37	€73,977.53	€78,726.90
2027	€4,891.86	€75,826.96	€80,718.82	€4,891.86	€75,826.96	€80,718.82
2028	€5,038.61	€77,722.64	€82,761.25	€5,038.61	€77,722.64	€82,761.25
2029	€5,189.77	€79,665.70	€84,855.47	€5,189.77	€79,665.70	€84,855.47
2030	€5,345.46	€81,657.35	€87,002.81	€5,345.46	€81,657.35	€87,002.81
2031	€5,505.83	€83,698.78	€89,204.61	€5,505.83	€83,698.78	€89,204.61
2032	€5,671.00	€85,791.25	€91,462.25	€5,671.00	€85,791.25	€91,462.25

Table 13 Expected cash flow of the photovoltaic plants located in Campana and Mandatoriccio

	Photovoltaic plant in Campana	Photovoltaic plant in Mandatoriccio
Year	Expected cash flows (€)	Expected cash flows (€)
2017	€97,182.89	€69,743.51
2018	€293,878.77	€292,196.80
2019	€289,337.57	€287,706.03
2020	€283,251.44	€281,669.65
2021	€277,137.26	€275,604.53
2022	€270,993.94	€269,509.58
2023	€264,820.40	€263,383.70
2024	€258,615.49	€257,225.77
2025	€252,378.05	€251,034.61
2026	€246,106.89	€244,809.05
2027	€239,800.80	€238,547.85
2028	€233,458.51	€232,249.77
2029	€227,078.75	€225,913.52
2030	€220,660.19	€219,537.78
2031	€214,201.50	€213,121.21
2032	€165,689.25	€50,986.02

Table 14 Risks calculated with the influences theory for the plants located in Campana and Mandatoriccio

Risk typology	$R_{taverage}$ (%)	Ascending influences (+)	Descending influences (−)
Context risk	1.38	–	−1.10%
Endogenous risk	1.15	–	−0.45%
Financial risk	1.00	–	−0.20%
Risk system	1.25	–	−0.50%
Insurable risk	0.60	0.30%	–
Property risk management	0.60	–	−0.50%
$\boldsymbol{PR = \sum_{i=1}^{n} R_i}$			3.53%

The calculated risks coincide for both system, because they have similar technical characteristics and similar geographical position. The discounting rate (Table 15) is obtained using Eq. (2).

The market value of the systems is determined through Eq. (1) after calculating the discount rate. The final exit value of Eq. (1) is considered null, because the dismantling of the modules is not at the expense of the purchaser (Tables 16 and 17).

Table 15 Discount rate

Risk free rate—German Bund at 10 years	Risk premium	Total
0.371%	3.53%	3.901%

Table 16 Discounted cash flow of the photovoltaic plant located in Campana

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2017	€97,182.89	0.962454644	€93,534.12
2018	€293,878.77	0.926318942	€272,225.47
2019	€289,337.57	0.891539968	€257,956.00
2020	€283,251.44	0.858066783	€243,048.65
2021	€277,137.26	0.82585036	€228,873.90
2022	€270,993.94	0.794843515	€215,397.78
2023	€264,820.40	0.765000832	€202,587.83
2024	€258,615.49	0.736278604	€190,413.05
2025	€252,378.05	0.708634762	€178,843.86
2026	€246,106.89	0.682028818	€167,851.99
2027	€239,800.80	0.656421803	€157,410.47
2028	€233,458.51	0.631776213	€147,493.53
2029	€227,078.75	0.608055951	€138,076.58
2030	€220,660.19	0.585226274	€129,136.14
2031	€214,201.50	0.563253745	€120,649.79
2032	€165,689.25	0.542106183	€89,821.17
Market value (V)			€2,833,320.36

Table 17 Discounted cash flow of the photovoltaic plant located in Mandatoriccio

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2017	€69,743.51	0.962454644	€67,124.97
2018	€292,196.80	0.926318942	€270,667.43
2019	€287,706.03	0.891539968	€256,501.43
2020	€281,669.65	0.858066783	€241,691.37
2021	€275,604.53	0.82585036	€227,608.10
2022	€269,509.58	0.794843515	€214,217.94
2023	€263,383.70	0.765000832	€201,488.75
2024	€257,225.77	0.736278604	€189,389.83
2025	€251,034.61	0.708634762	€177,891.85
2026	€244,809.05	0.682028818	€166,966.83
2027	€238,547.85	0.656421803	€156,588.01

(continued)

Table 17 (continued)

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2028	€232,249.77	0.631776213	€146,729.88
2029	€225,913.52	0.608055951	€137,368.06
2030	€219,537.78	0.585226274	€128,479.28
2031	€213,121.21	0.563253745	€120,041.32
2032	€50,986.02	0.542106183	€27,639.84
Market value (V)			€2,730,394.88

3.2 *Evaluation of Photovoltaic Systems Through the Provided Real Data*

The incomes generated by photovoltaic systems are calculated considering the energy data actually produced. The photovoltaic system located in Campana produced 1,455,000 kWh in 2016, while the one located in Mandatoriccio produced 1,350,000 kWh in 2016. Revenues from incentives and the sale of energy are shown in Tables 18 and 19.

Table 18 Incoming cash flow of the photovoltaic plant located in Campana

Year	Production taken from the reference date (kWh/year)	IV feed-in-tariff (€/kWh)	Projections of sales prices (€/kWh)	Total revenues (€)
2017	1,338,797.76	0.222	0.0614	€114,594.79
2018	1,324,851.95	0.222	0.0609	€378,738.96
2019	1,310,906.14	0.222	0.0604	€374,077.92
2020	1,296,960.33	0.222	0.0598	€369,431.96
2021	1,283,014.52	0.222	0.0593	€364,801.07
2022	1,269,068.71	0.222	0.0587	€360,185.24
2023	1,255,122.90	0.222	0.0582	€355,584.49
2024	1,241,177.09	0.222	0.0577	€350,998.81
2025	1,227,231.28	0.222	0.0571	€346,428.19
2026	1,213,285.47	0.222	0.0566	€341,872.65
2027	1,199,339.66	0.222	0.0560	€337,332.18
2028	1,185,393.85	0.222	0.0555	€332,806.78
2029	1,171,448.04	0.222	0.0550	€328,296.44
2030	1,157,502.23	0.222	0.0544	€323,801.18
2031	1,143,556.42	0.222	0.0539	€319,320.99
2032	1,338,797.76	0.222	0.0533	€314,855.87

Table 19 Incoming cash flow of the photovoltaic plant located in Mandatoriccio

Year	Production taken from the reference date (kWh/year)	IV feed-in-tariff (€/kWh)	Projections of sales prices (€/kWh)	Total revenues (€)
2017	291,260.39	0.235	0.0614	€86,339.81
2018	1,221,438.65	0.235	0.0609	€361,417.37
2019	1,208,715.33	0.235	0.0604	€356,999.52
2020	1,195,992.01	0.235	0.0598	€352,595.42
2021	1,183,268.69	0.235	0.0593	€348,205.07
2022	1,170,545.37	0.235	0.0587	€343,828.47
2023	1,157,822.05	0.235	0.0582	€339,465.61
2024	1,145,098.73	0.235	0.0577	€335,116.51
2025	1,132,375.41	0.235	0.0571	€330,781.15
2026	1,119,652.09	0.235	0.0566	€326,459.54
2027	1,106,928.77	0.235	0.0560	€322,151.69
2028	1,094,205.45	0.235	0.0555	€317,857.58
2029	1,081,482.13	0.235	0.0550	€313,577.22
2030	1,068,758.81	0.235	0.0544	€309,310.61
2031	1,056,035.50	0.235	0.0539	€305,057.75
2032	538,000.16	0.235	0.0533	€155,121.81

The tables below show the operating costs of the system and the expected cash flows (Tables 20 and 21).

Table 20 Expenditure cash flow of the photovoltaic plants located in Campana and Mandatoriccio

	Photovoltaic plant in Campana			Photovoltaic plant in Mandatoriccio		
Year	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)
2017	€1,213.33	€20,238.93	€21,452.27	€1,213.33	€20,238.93	€21,452.27
2018	€3,749.20	€62,234.72	€65,983.92	€3,749.20	€62,234.72	€65,983.92
2019	€3,861.68	€62,234.72	€66,096.40	€3,861.68	€62,234.72	€66,096.40
2020	€3,977.53	€63,790.59	€67,768.11	€3,977.53	€63,790.59	€67,768.11
2021	€4,096.85	€65,385.35	€69,482.20	€4,096.85	€65,385.35	€69,482.20
2022	€4,219.76	€67,019.99	€71,239.74	€4,219.76	€67,019.99	€71,239.74
2023	€4,346.35	€68,695.49	€73,041.84	€4,346.35	€68,695.49	€73,041.84

(continued)

Table 20 (continued)

	Photovoltaic plant in Campana			Photovoltaic plant in Mandatoriccio		
Year	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)	Insurance policy (€)	Expenditure for administration, maintenance and utilities (€)	Total expenditure (€)
2024	€4,476.74	€70,412.87	€74,889.61	€4,476.74	€70,412.87	€74,889.61
2025	€4,611.04	€72,173.20	€76,784.24	€4,611.04	€72,173.20	€76,784.24
2026	€4,749.37	€73,977.53	€78,726.90	€4,749.37	€73,977.53	€78,726.90
2027	€4,891.86	€75,826.96	€80,718.82	€4,891.86	€75,826.96	€80,718.82
2028	€5,038.61	€77,722.64	€82,761.25	€5,038.61	€77,722.64	€82,761.25
2029	€5,189.77	€79,665.70	€84,855.47	€5,189.77	€79,665.70	€84,855.47
2030	€5,345.46	€81,657.35	€87,002.81	€5,345.46	€81,657.35	€87,002.81
2031	€5,505.83	€83,698.78	€89,204.61	€5,505.83	€83,698.78	€89.204,61
2032	€5,671.00	€85,791.25	€91,462.25	€5,671.00	€85,791.25	€91,462.25

Table 21 Expected cash flow of the photovoltaic plants located in Campana and Mandatoriccio

	Photovoltaic plant in Campana	Photovoltaic plant in Mandatoriccio
Year	Expected cash flows (€)	Expected cash flows (€)
2017	€93,142.52	€64,887.55
2018	€312,755.04	€295,433.45
2019	€307,981.53	€290,903.13
2020	€301,663.85	€284,827.31
2021	€295,318.86	€278,722.86
2022	€288,945.50	€272,588.72
2023	€282,542.65	€266,423.78
2024	€276,109.19	€260,226.89
2025	€269,643.95	€253,996.91
2026	€263,145.75	€247,732.64
2027	€256,613.36	€241,432.87
2028	€250,045.53	€235,096.33
2029	€243,440.97	€228,721.75
2030	€236,798.37	€222,307.80
2031	€230,116.38	€215,853.14
2032	€223,393.62	€63,659.56

The value of the discounting rate is the same for the two appraisal cases above (Tables 18 and 19). The market value of the systems is shown in Tables 22 and 23.

Table 22 Discounted cash flow of the photovoltaic plant located in Campana

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2017	€93,142.52	0.962454644	€89,645.45
2018	€312,755.04	0.926318942	€289,710.92
2019	€307,981.53	0.891539968	€274,577.84
2020	€301,663.85	0.858066783	€258,847.73
2021	€295,318.86	0.82585036	€243,889.19
2022	€288,945.50	0.794843515	€229,666.46
2023	€282,542.65	0.765000832	€216,145.36
2024	€276,109.19	0.736278604	€203,293.29
2025	€269,643.95	0.708634762	€191,079.08
2026	€263,145.75	0.682028818	€179,472.99
2027	€256,613.36	0.656421803	€168,446.60
2028	€250,045.53	0.631776213	€157,972.82
2029	€243,440.97	0.608055951	€148,025.73
2030	€236,798.37	0.585226274	€138,580.63
2031	€230,116.38	0.563253745	€129,613.92
2032	€223,393.62	0.542106183	€121,103.06
Market value (V)			€3,040,071.06

Table 23 Discounted cash flow of the photovoltaic plant located in Mandatoriccio

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2017	€64,887.55	0.962454644	€62,451.32
2018	€295,433.45	0.926318942	€273,665.61
2019	€290,903.13	0.891539968	€259,351.77
2020	€284,827.31	0.858066783	€244,400.85
2021	€278,722.86	0.82585036	€230,183.38
2022	€272,588.72	0.794843515	€216,665.38
2023	€266,423.78	0.765000832	€203,814.41
2024	€260,226.89	0.736278604	€191,599.49
2025	€253,996.91	0.708634762	€179,991.04
2026	€247,732.64	0.682028818	€168,960.80

(continued)

Table 23 (continued)

Year	Expected cash flow (€)	Discounting coefficient (€)	Discounted cash flow (€)
2027	€241,432.87	0.656421803	€158,481.80
2028	€235,096.33	0.631776213	€148,528.27
2029	€228,721.75	0.608055951	€139,075.62
2030	€222,307.80	0.585226274	€130,100.37
2031	€215,853.14	0.563253745	€121,580.09
2032	€63,659.56	0.542106183	€34,510.24
Market value (V)			€2,763,360.43

4 Conclusions

Energy produced from renewable sources has an increasingly central role, thanks to the increase in investments made in world renewable energy markets and to policies against climate change. By analyzing the literature on the evaluation of photovoltaic systems, it resulted that the most suitable evaluation procedure for photovoltaic systems is DCF because it takes into account of the incomes generated during their life cycle. The aim of our study consisted in implementing the evaluation of the discount rate by combining the Build up Approach and the analytical method that uses the ascending and descending influences. The determination of discount rate is a crucial point of DCF, because even small percentage variations reflect significantly on the value of the asset. The ascending and descending influences act with a positive or negative sign respectively on the specific risks of the factors related to the photovoltaic investment. Moreover, the paper highlight the importance of the evaluation of the energy potentially produced by the photovoltaic plants because it directly influences the incoming cash flows. So the annual energy production has been estimated using the simplified Siegel method.

The present study compares the data provided by the Siegel method with real data of energy produced by two photovoltaic plants located in Campana and Mandatoriccio (Calabria, South Italy) and consequently the appraisal values obtained considering the estimated energy with Siegel data and real data. By comparing the results obtained, it can notice as the results provided by the Siegel method are very close to the results obtained by the real data. So the use of the simplified Siegel method and the combination of Build up Approach with the analytical method, that uses the ascending and descending influences, allow to get an objective market value of the photovoltaic plants evaluated.

References

Campoccia A, Dusonchet L, Telaretti E, Zizzo G (2014) An analysis of feed-in-tariff for solar PV in six representative countries of the European Union. Solar Energy (107):530–542

Castillo CP, Silva FB, Lavalle C (2016) An assessment of the regional potential for solar power generation in EU-28. Energy Policy 86–99

Foracci A (2009) Residential system investment appraisal subsequent to the new supporting photovoltaic economic mechanism in Italy. Renew Sustain Energy Rev 13:2710–2715

Forte C, Dè Rossi B (1974) Principi di economia ed estimo (Etaslibri), 1974, Milano, pp 144–154

Harris J. (1984) The value of solar energy: Chic, patriotism and economic rationality. Real Estate Apprais Anal 5–7

Hasan M, Zhang M, Wu W, Langrish TAG (2016) Discounted cash flow analysis of greenhouse-type solar kilns. Renew Energy 95:404–412

Hoen B, Wiser R, Cappers P, Thayer M (2011) An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California, Ernest Orlando Berkeley National Laboratory, LBNL-4476E. Available online: http://emp.lbl.gov/sites/all/files/lbnl-4476e.pdf. Accessed 19 Nov 2017

Hussein HMS, Hamad GE, El-Ghetany HH (2004) Performance evaluation of photovoltaic modules at different tilt angles and orientations. Energy Convers Manag 2441–2452

Kacira M, Simsek M, Babur Y, Demirkol S (2004) Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey. Renew Energy 1265–1275

Klise GT, Johnson JL, Adomatis SK (2013a) Standardizing appraisals for PV installations. In: IEEE 39th photovoltaic specialists conference (PVSC), Available online: http://energy.sandia.gov/wp-content/gallery/uploads/SAND2013-5239C.pdf. Accessed 22 Nov 2017

Klise GT, Johnson JL, Adomatis SK (2013b) Valuation of solar photovoltaic systems using a discounted cash flow approach. Apprais J 18:316–331

Mazzeo D, Matera N, Bevilacqua P, Arcuri N (2015) Energy and economic analysis of solar photovoltaic systems located at the University of Calabria. Int J Heat Technol 33(4):41–50

Mehleri ED, Zervas PL, Sarimveis H, Palyvos JA, Markatos NC (2010) Determination of the optimal tilt angle and orientation for solar photovoltaic arrays. Renew Energy, 2468–2475

Mondol JD, Yohanis YG, Norton B (2007) The impact of array inclination and orientation on the performance of a grid-connected photovoltaic system. Renew Energy 118–140

Salvo F, Ciuna M, De Ruggiero M, Marchianò S (2017) Economic Valuation of ground mounted photovoltaic systems. Buildings 2(2)

Siegel MD, Klein SA, Beckman WA (1981) A simplified method for estimating the monthly-average performance of photovoltaic systems. Sol Energy 26:413–418

Simmons AF (2010) An introduction to green home. Chicago, IL, USA, Appraisal Institute. ISBN 978-1-935328-09-4

Webb JR (1980) The influence of solar Energy systems on the value of dwellings: theory versus practice. Real Estate Apprais Anal 4–6

Eco-system Services and Integrated Urban Planning. A Multi-criteria Assessment Framework for Ecosystem Urban Forestry Projects

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Abstract In the world the cities development must take place through urban sustainable interventions. This aims at promoting city economic growth, protecting citizens health and safeguarding natural and environmental components. In this perspective, forestry initiatives, raise the environmental, social and cultural quality level, as well as the income capacity of territory urban portions in joint manner. These are multiple benefits, noted as eco-systemic services, which provide regulation, support and recreational activities for population. However, the urban interventions including, also and not only, forestry—definable as Ecosystem Integrated Forestry Projects (EIFP)—are less considered as one of the main action modalities to apply within urbanized areas. This is due to the complexity both to jointly evaluate eco-system services produced by EIFP, both to develop initiatives in urban areas and provide services considering not only specific dimensional standards, but also the multidimensional effects that single initiative generates within urban context of reference. Thus, an economic evaluation methodology is defined according to multi-criteria logic based on the system of functional relationships between objectives, targets and performance indicators. The proposed methodology helps to define logical-mathematical models able to answer different evaluation questions related to EIFP. The construction of such

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models can be made using Linear Programming algorithms as tools for expressing functional relations between elements characterizing the problem to be solved.

Keywords Sustainable development · Land use · Economic evaluation · Urban forestry projects · Multi-criteria decision analysis · Operational research

1 Introduction

The phenomena on rapid climate change, exponential demographic growth, migration and concentration of the population in urban areas that are more and more extensive and unequal each other (*Urban Sprawl*) have determined the progressive reduction of the environmental and natural system's factors of many states (Scovronick et al. 2017). In particular, the urbanization and expansion phenomena of the cities have returned over time territorial structures characterized by the ever wider occupation of originally agricultural, natural or semi-natural surfaces for the realization of artificial coverings (buildings, infrastructures, etc.) (Eigenbrod et al. 2011). This has produced effects on the urban quality level not only ecological-environmental, but also economic-productive and socio-cultural type (Torre et al. 2017).

At the same time, the use of urban planning models based on design methodologies of functional zoning subjected to quantitative constraints has produced a territory with areas inside the same city conurbation with specific morphological, environmental, functional, productive, socio-cultural features.

In front of this, the need to implement intervention strategies that consider jointly economic growth, protection of existing natural and environmental resources and safeguarding the population well-being in optic to promote sustainable territory development within urban and extra-urban areas is recognized (Jabareen 2006; Farr 2012).

According to European Environment Agency (EEA), the soil resource must be considered as an integrated system (*land system*) made of biophysical and human land subsystems (EEA 2018). Based on this point of view, the components of land use and land cover (EC 2007) are elements of same process of landscape transformation. This unified vision of the land defines alternative ways of using it through an integrated territory planning in relation to ecosystem services produced by natural element.

Since the early years of 21st century, initiatives developed at international level, such as the Millennium Ecosystem Assessment (MEA) in 2005, and European level, such as The Economics of Ecosystems and Biodiversity (TEEB) in 2010, focused on eco-system services assessment (MEA 2005; TEEB 2010), also with reference to urban forestry initiatives (Seppelt et al. 2011; Boerema et al. 2016). The main types of eco-system services are related to the production of Regulating (Climate Regulation, Flood Regulation, Water Purification), Cultural (Aesthetic, Educational, Recreational, Cultural Heritage), Provisioning (Food, Fresh-water, Wood and Fiber) and Supporting (Soil Formation, Primary Production) activities.

The United Nations (UN) Global Agenda for Sustainable Development (2015) describes 17 Sustainable Development Goals (SDG) that UN member states have agreed to pursue by 2030 in order to implement government policies for ensuring environmental, economic and social sustainability of the territory (UN 2015). On the basis of these SDG, in particular the one about land degradation (SDG15), and the aim of the European Biodiversity Strategy 2020 (EC 2011) to maintain and restore ecosystems with their services, the EEA in its report *Land systems at European level* (EEA 2018) assesses the state of land systems, the trade-offs resulting from policy decisions and the impacts of observed changes.

Since the last decade of 21st century, intervention models based on Ecosystems Management (Alberti and Waddell 2000) have been applied within urban policies of many European cities in order to «[…] impact [on] human activities from production of food, fiber and foorage to protection and restoration of ecosystem» (Williams et al. 1997). The use of these models involves the execution of actions for an ecologically sustainable management of natural resources (*Nature Based Solutions*), even when present or/and included in the consolidated fabrics of the city (Kabisch et al. 2016). From some examples of Nature Based Solutions in Europe (Maes and Jacobs 2017) it can see how the sustainable management and use of existing natural capital allows multiple benefits in an integrated manner with reference both to the citizens health and the socio-economic development of territory (Verburg et al. 2013). The effects generated by interventions involving the protection and/or inclusion of «[…] all trees in the urban area, inclusive of individual street trees and clusters of park trees, and peri-urban forests extend to the outer metropolitan area» (Urban Forestry) (Endreny 2018) correspond to the production of Eco-system Services (ES) that «[…] establish a balance between human and ecological values […] for the wellbeing of human societies» (Bell et al. 2005; Díaz et al. 2015).

In relation to international classification on ES, the Food and Agriculture Organization (FAO) has identified 10 Key Issues to express what goods and services are produced by forestry initiatives according to eco-systemic logic (FAO 2016). Some Key-Issues concern biodiversity, bio-physical and ecological targets of the environment (Ecological Targets); others economic (Structure-Strengthenin Targets) and socio-cultural (Recreational Targets) ones (Yahdjian et al. 2015). In urban forestry interventions the primacy of a target type is function of both economic, social and environmental objective to be pursued (MEA 2005), and the urban scale of interest (single building, city block in which local urban streets fall, urban neighborhoods often to be redeveloped) (Goméz-Baggethun and Barton 2013).

In this context, in Italy a debate has been developing around the need to incorporate eco-system services production (Micelli 2004; Agrimi 2013; D'Onofrio and Trusiani 2017) within regulatory instruments related to the determination and sizing of urban services (public parks, parking lots, collective services) designed still in 2019 in a quantitative way according to urban planning standards specified in the 1968 Ministerial Decree n°1444, that favorite the monofunctional, land use. The need to consider in qualitative and multifunctional terms the effects that such urban services can produce over time if they are defined and evaluated within an integrated strategic land use planning is increasingly recognizing. In particular, considering the functional relationships among the type of service and the characteristics of the urban intervention area is possible to favorite the territory transformation in an integrated sustainable manner. So, each private and/or public areas to be redeveloped will be evaluated in terms of eco-systemic effects that each alternative design solution produces on the territory.

On the basis of Target type and corresponding Key Issues, it is possible to encourage the creation of interventions, definable as Eco-system Integrated Projects based on principles of urban forestry (EIFP), realized on completely or partially free and/or degraded urban areas (Guarini et al. 2018).

Although the *focus* on such initiatives is progressively growing, mayors, planners and other urban decision-makers are often unaware of the crucial economic, social and environmental benefits that EIFP can provide. They often place a low priority on inclusion of forests elements in urban fabrics. Therefore, budgetary resources are allocated in different way to other civic areas—such as health, welfare and safety—for the interest to consider only the immediate consequences of financial nature, or to separate the environmental aspects from the corresponding repercussions of economic and social type.

In order to produce multiple effects on territory with EIFP, it is useful to use Integrative Ecosystem Assessment Frameworks (De Groot et al. 2010). They are about «[…] a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors, in relation to specified ecosystem management objectives.» (Levin et al. 2009). The IEAF methodology consists of: (i) identifying ecosystem goals related to safeguarding the population well-being, the economic development of the territory and the protection of existing natural components; (ii) defining of targets to be pursued according to objective to be achieved and the eco-systemic service type produced; (iii) using of specific indicators in order to measure quantitatively and/or qualitatively the effects deriving from the eco-systems The use of IEAF is useful for solving problems regarding sustainable land use planning (Daily et al. 2009; Baró et al. 2016), natural resources management (Tallis and Polasky 2009) and biodiversity conservation (Chan et al. 2011). This also with evaluative methodologies and techniques based on multi-criteria logics with which to express the multidimensional character of initiatives including forestry (Wilson and Howarth 2002).

From these premises, the work aim is to provide a methodology through which to evaluate the eco-system services that the realization of EIFP can produce in urban contexts. The use of this methodology allows to solve some evaluation problems linked to initiatives developed according to eco-systemic logics on the basis of appropriate evaluation criteria and specific performance indicators chosen according to the objective to be pursued.

Below, are illustrated in the Section: (Sect. 2) the criteria and corresponding main indicators used in the case of urban forestry interventions (Sect. 2.1) and the multicriteria evaluation techniques most often used to solve some evaluation problems concerning forestry (Sect. 2.2); (Sect. 3) the evaluation methodology for interventions in urban areas that include forestation (Sect. 3.1) and an example of optimization model built according to integrated eco-systemic logics (Sect. 3.2); (Sect. 4) the conclusions and the potential for the future applications of the proposed model.

2 Materials and Methods

2.1 Urban Forestry Projects. Criteria Classes and Indicator Sets

On the basis of the considerations in Sect. 1, the paper objective is to define an evaluation methodology for projects realized according to eco-systemic logics and including forestation. The execution of EIFP in un-built and/or decommissioned areas in more or less densely built urban context allows, on the one hand, to raise their quality level, on the other, to reach a more homogeneous level of services among various parts of the city's articulation favoring the integration of the natural and built environment with a view to unitary territory development. This is possible considering socio-cultural (e.g. by improving the psycho-physical citizens well-being), ecological-environmental (e.g. by improving air quality) and economic-financial (e.g. by increasing the market value of properties in reference context) point of view.

In order to express the multi-dimensional character of these initiatives, the use of multiple representative indicators of environmental, social and economic type is required. For this purpose, the indicators most commonly considered in urban forestry interventions can be utilize in order to measure the effects that such initiatives generate on the territory, and then proceed to the selection of those most appropriate in function of specific evaluation case to be solved. Finally, the values of the selected indicators can be aggregated to each other, so as to obtain an evaluation index, definable Total Eco-systemic Value (TEV), representative of the project's ability to pursue multiple objectives in an eco-systemic integrated key.

With a view to integrated urban planning, urban renewal and/or regeneration initiatives, that are conducted through forestation, pursue targets relative to: psycho-physical citizens wellbeing, safeguard of natural and environmental components, economic, social-cultural development of the area (Van Elegem et al. 2002). According to the Target type to be achieved and the eco-system service, Key Issues to be considered during the design phase are identified (Fig. 1).

The achievement degree for the aforementioned objectives can be expressed with appropriate evaluation criteria and performance indicators useful for quantitative and qualitative surveying of the ecosystem services that urban forestry interventions produces.

From the cases study known in the literature (Clark et al. 1997; De Groot et al. 2010; Dobbs et al. 2011; Kenney et al. 2011; Barron et al. 2016), some Criteria Classes can be identified (Fig. 2e), such as specific performance Indicators (Fig. 2f) which include morphological, urban, social, economic and environmental parameters, able

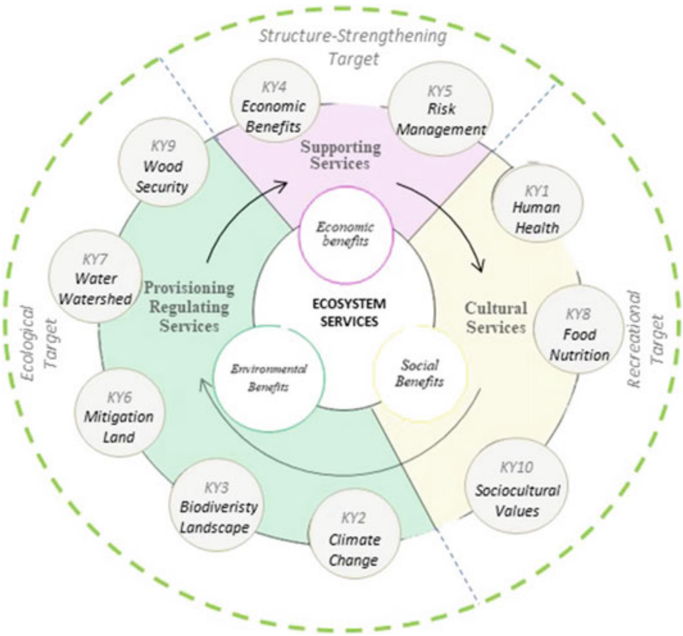

Fig. 1 Ecosystem services, targets and key issues

to define *ex-ante* and *ex-post* the reference context according to an eco-systemic, and not, point of view proper of forestry projects. Based on the general objectives to be pursued (Fig. 2a) and specific Sustainability Development Goals defined in the respect of natural and socio-economic intervention area characteristics (Fig. 2b), it is possible to establish the indicator type to be considered in the evaluation phase, always in the respect of the Targets (Fig. 2d) and Key Issues (Fig. 2c).

The selection of indicators to be used in evaluation phase depends on the problem type to be solved, which, in the case of forestry, may concern, for example, selection cases between different management options of urban forestry, ordering of design alternatives in function of predetermined targets to be achieved, and optimization solutions about financial evaluation issues (e.g. for the allocation of monetary resources between projects) and strategic territory planning actions (e.g. for the selection of urban areas that are best suited to the forestation).

These problems related to various kinds decisional fields can be solved by using evaluation methodologies based on multi-criteria logics able to consider in the decision-making phase the multiple aspects of EIFP in joint manner.

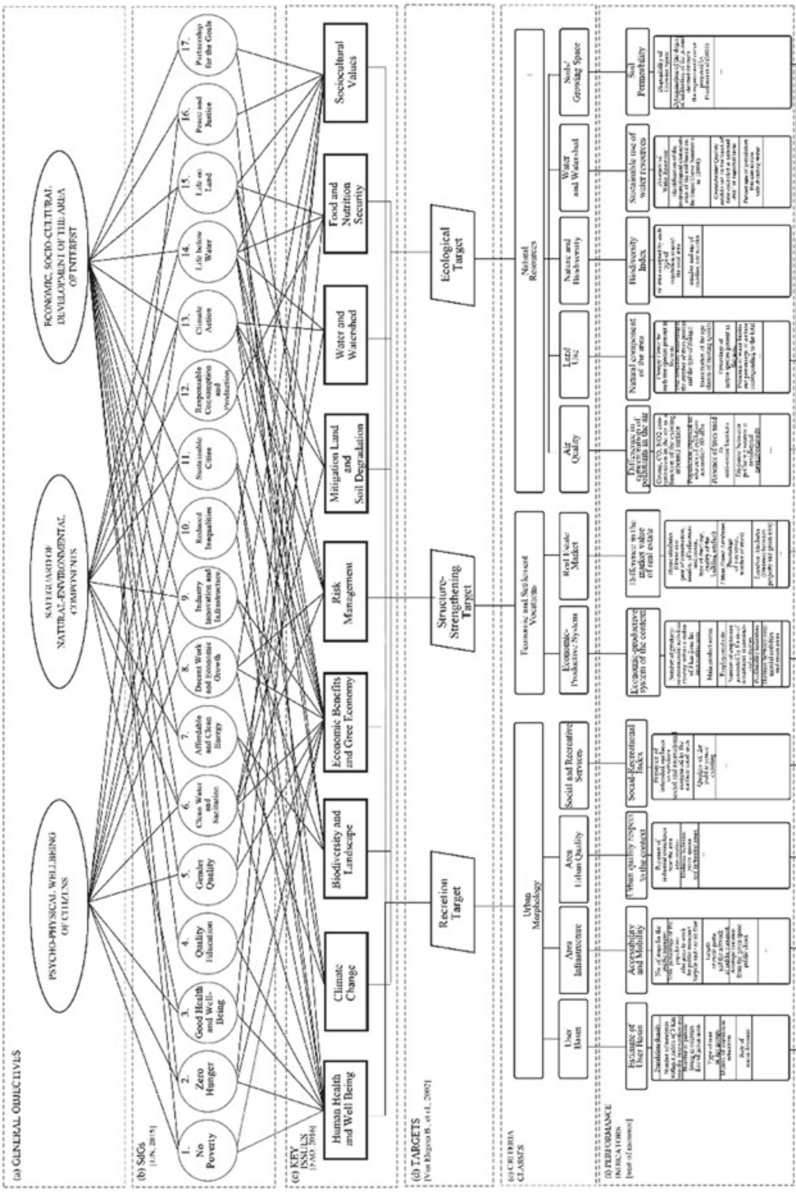

Fig. 2 Logical-functional relations system for the evaluation of ecosystem integrated forestry projects

2.2 *Multi-criteria Assessment Tools for Urban Forestry Projects*

The use of multi-criteria evaluation methodologies allows to consider environmental, social and cultural aspects separately or in combination with the financial one. This can be done through the use of appropriate assessment techniques that make it possible to carry out integrated assessments by making references both to the morphological characteristics of urban context, and to the effects generated on the territory according to the evaluation question to be solved (Varma et al. 2000; Sheppard and Meitner 2005; Diaz-Balteiro and Romero 2008).

Considering case studies known in the literature in which some of the most widespread multicriteria analysis tools have been applied (Ishizaka and Nemery 2013), in order to solve evaluation problems related to urban forestry projects it can be used: (i) the Analytic Hierarchy Processes (AHP) for the selection between different management options of urban forestry (Van Elegem et al. 2002; Wolfslehner et al. 2005; Stirn 2006); (ii) Tecniques for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Opricovic et al. 2004; Chee et al. 2007); (iii) Goal Programming (Walker 1985) in order to rank design alternatives in consideration of ideal solution to pursue; (iv) optimization algorithms of the Operational Research (OR) useful for answering, for example, questions of financial type about distribution of monetary resources available among alternative investment projects (Guarini et al. 2018; Nesticò et al. 2019).

Among the multi-criteria tools, the ones of the OR allow to solve evaluation problems through logical-mathematical paradigms able to provide an optimal solution to the posed question. In particular, it is possible to solve many evaluation problems also referred to EFIP by structuring multi-objective optimization mathematical models based on Linear Programming (LP) principles both Continuous (CLP) and Discrete (DLP) type (Vercellis 2008). Specifically, the CLP can solve different cases. Some of these regard the definition of the amount of monetary resources to be distributed between forestry interventions in the respect of an available budget (Guarini et al. 2018); others the selection of urban areas that are better suited to forestation (Nesticò et al. 2019); others the creation of the best investment projects portfolio assessed through urban sustainability criteria (Nesticò and Sica 2017), and still the multi-site land-use allocation solved also using GIS tools (Aerts et al. 2003).

In general, linear programming models, both continuous and discrete type, can be implemented through specific mathematical programming tools, such as, for example, MatLab, A Mathematical Programming Language (AMPL), Excel, Lingo, Lindo. The selection of the software to be used depends on the number of parameters and constraint conditions characterizing the evaluation problem. Specifically, the AMPL software corresponds to a mathematical language used to describe and solve optimization problems (Schoen 2006), in particular scheduling ones (Dolan and Mosé 2002). This language is well suited to modelling decision-making cases related to urban renewal projects developed according to eco-systemic logics (Bagstad et al. 2013; Nesticò and Sica 2017).

3 An Evaluation Protocol for EIFP

3.1 Linear Programming as Tool for the Definition of the Evaluation Methodology for EIFP

The methodology proposed in order to evaluate the effects produced by EIFP on the territory is developed using linear programming principles of the OR. Thanks to them it is possible to express the relationships between elements characterizing the evaluation problem through linear mathematical expressions of simple algebraic construction.

According to an evaluation function f of the type:

$$f : D \rightarrow R \tag{1}$$

to each alternative of the Decision Domain (D) is associated a summary indicator (Total Value) that is image of the data characterizing the aspect of the decision problem that is examined. Depending on the evaluation function, the selection criteria (Ci) and the corresponding performance indicators (Ii) may differ (Vercellis 2008). In particular, the index corresponding to the Total Value, which may be either of a monetary nature or of another species, is a function of the Goal j-*th* (Gj) to be achieved and the parameters characterizing the evaluation case.

Specifically to EIFP, each project identifies an alternative Di, whose characteristics are expressed with criteria (Ci) detected through appropriate performance indicators (Ii). Each indicator expresses unequivocally economic, social and environmental aspects of the i-*th* area both before and after the intervention including forestation. The parameters belong to the economic, social and environmental territory system are elements to be defined according to the aims connected to the evaluation problem to solve. From the linear combination of the each indicator's values, the Total Eco-systemic Value (TEV) *ex-ante* (TEV_{in}) and *ex-post* (TEV_{fin}) to the realization of initiatives carried out according to the EIFP model is obtained. This index expresses the eco-systemic component of the area subjected to EIFP, and not only the converted soil obtained considering in the design phase specific dimensional standards in correspondence of each type of service to be realized. The use of this index qualifies urban design in an integrated ecosystem view (Integrated Ecosystem Design). It defines a modus operandi that combines the services generated by forestation and the standardized transformation processes of land use based on the use of dimensional parameters referring to the type of urban service to be achieved (Not Ecosystem Design).

As in Fig. 3, the design levels developed in an eco-systemic key, and not, produce different increments of overall eco-systemic value. This according to the ability to operate in urban areas with initiatives re-including forestation as element to support the production of services useful for the integrated development of urban reference context.

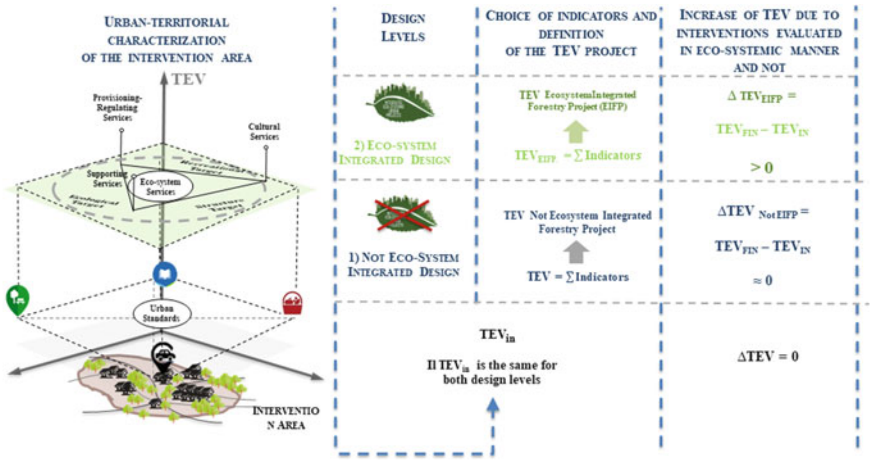

Fig. 3 Levels of integrated eco-system urban planning. Increases in total ecosystem value due to EIFP

The difference ΔTEV_i between TEV_{i_fin} and TEV_{i_in} estimates the increase of the eco-system value of the area following the intervention re-including forestation.

On the basis of ΔTEV_i regarding i-*th* area, such that:

$$\max \sum i\Delta\ TEV_i = \max \sum i\ \Delta \left(TEV_{i\_fin} - TEV_{i\_in}\right) \tag{2}$$

the TEV_{i_fin} can be:

(i) obtained through a mathematical formulation of the type:

$$TEV_{i\_fin} = TEV_{i\_in} + \Delta TEV_i \tag{3}$$

(ii) correspond to a known reference parameter (PARAMETER) assumed as target to be reached through EIFP.

In particular:

- in (i), the determination of the final eco-system value obtained with EIFP is function of the increase value (ΔTEV_i) measured in corresponding to each representative performance indicator related to the service type in exame;
- in (ii), the final eco-system value is taken as reference parameter (target) to be achieved. This is useful, for example, when it is necessary to ensure the achievement of a given value of TEV_{i_in} for all the areas on which can realize EFIP, also in order to establish an equitable distribution of available financial resources among alternative projects of same type.

The terms (TEV_{i_fin}), (TEV_{i_in}), (ΔTEV_i) are also elements for the structuring of linear algebraic expressions that allow to characterize the system to be solved. Such relationships can express suitable constraint conditions (φ_m), established according to evaluation problem and constraint type.

Thus, the writing of linear algebraic expressions, in which the elements characterizing the problem to be solved are placed in polynomial relation between them, allows to structure evaluation models based on multi-criteria logics referred to EIFP using linear mathematical systems of the type:

$$\begin{cases} TEV_{in/fin} = f(Ci, Ii) \\ \max \sum_{i=1}^{n} \Delta TEV_i = \Delta(TEV_{fin} - TEV_{in}) \\ \varphi_m \leq \geq PARAMETER \end{cases} \tag{4}$$

3.2 *Evaluation Protocol for EIFP. an Optimization Model for Integrated Sustainable Urban Development*

Using linear algebraic expressions such as those in (4), it is possible to define evaluative models for EIFP in view of both design and urban planning in order to limit the size of the land for a specific community service, but also to orient the process of determination and dimensioning urban services on the basis of the increase of the Total Eco-Systemic Value obtained thanks to projects including forestation.

In fact, on the basis of system (4), it is possible to formalize multiple and different mathematical models in which the objective function (that can be a maximization and/ or minimization function), and the constraints of various nature (technical-design, economic-financial, socio-cultural, ecological-environmental) depend on the evaluation problem type to be solved.

In general, the structuring of these models cut through the:

1. identification of the sustainability objectives to be pursued, and definition of the corresponding evaluation criteria in compliance with the Targets and the eco-systemic service produced;
2. selection of indicators for each criterion according to the assessed evaluation question, and estimate of each indicator through quantitative and/or qualitative measurement systems;
3. writing of logical-mathematical relations between elements that define the evaluation problem, and definition of multi-criteria evaluation model;
4. implementation of the evaluation model through the use of mathematical programming software, and analysis of the results.

As regards the identification of the objective (point 1), it can be specifically environmental (for example, the decrease in the carbon dioxide production in atmosphere), economic-financial (for example, the increase in the urban rent of specific territory portions), as well as social type (for example, the improvement of psycho-physical population wellbeing), or it can regard all these aspects in optic of integrated multidimensional urban transformation (see Sect. 1).

In order to quantify the achievement of the prefixed objective type, it is necessary to identify criteria and corresponding indicators (point 2) that allow to measure the degree of objective achievement with respect to the *ex-ante status* that define the intervention area before the execution of EIFP (see Sect. 2.1).

The indicators and criteria considered are, then, elements for the structuring of evaluation models (point 3) referring to EIFP based on the ΔTEV_i obtained as a result of initiatives including forestation (see Sect. 3.1). Pursuing equalizing logics useful for standardizing the distribution of value, expressed in terms of eco-systemic services, between urban areas with different TEV_{i_in}, the increase in value of the i-*th* area following EIFP can be compared to that of other intervention areas formalizing a linear mathematical expression of type:

$$TEV_{(i-1)\_in} + \Delta TEV_{(i-1)} = TEV_{i\_in} + \Delta TEV_i = TEV_{(i+1)\_in} + \Delta TEV_{(i+1)} \quad (5)$$

in which the TEV_{fin} of the i-*th* area assumes the same value to be reached through EIFP in each intervention area.

This *modus operandi* in eco-systemic key can also support the decision-making systems concerning the optimal allocation of financial resources (ε_i) among alternative projects in accordance with budget available. This correspond to writing a linear constraint of the type:

$$\sum \varepsilon_i C_i \le BUDGET \quad (6)$$

in which the investment cost C_i of the i-*th* project is related to the available Budget.

In addition to constraint expressions (5) and (6), there may be further technical-design conditions to be taken into account in the planning phase of specific urban areas. For example, some constraints (like the inequality number 7) can express the limit of the available land amount (b_{ij}) relative to the i-*th* area to be allocated to j-*th* service (x_{ij}) obtained after EIFP.

$$x_{ij} \le b_{ij} \quad (7)$$

Others, however, may concern, for example, the relationship between the amount of available land in the i-*th* area to be allocated to the j-*th* type service (x_{ij}) and the users number (a_j) beneficiaries of the service produced by EIFP. This condition can be expressed through a mathematical expression of the type:

$$\sum i \sum j\, a_j\, x_{ij} \le B_i \quad (8)$$

where B_i represents the total i-*th* area to be redeveloped with EIFP.

On the basis of the problem to be solved, the constraint relations [(5), (6), (7), (8)] can be combined jointly or severally within a single mathematical system of the type:

$$\begin{cases} \max \sum_{\mathrm{i}} \Delta \mathrm{TEV_i} \cdot \varepsilon_{\mathrm{i}} \\ \mathrm{TEV_{(i-1)\_fin}} = \mathrm{TEV_{i\_fin}} = \mathrm{TEV_{(i+1)\_fin}} \\ \sum_{\mathrm{i}} \mathrm{C_i} \cdot \varepsilon_{\mathrm{i}} \leq \mathrm{BUDGET} \\ \mathrm{x}_{ij} \leq b_{ij} \\ \sum_i \sum_j a_j \bar{x}_{ij} \leq B_i \end{cases} \tag{9}$$

In this way, it is possible to define mathematical models supporting the decisions useful for orienting urban planning and design towards principles aimed at the integrated eco-sustainable development of the city.

The implementation of the evaluation model will take place through the use of mathematical software programming that solve the specific evaluation problem (point 4).

4 Conclusions

An integrated vision between natural and built environment define alternative action strategies respect to the common ways of land use based on standardized intervention practices aimed to consider financial, social, cultural and environmental factors useful for territory development. Against to such a manner to operate in the city, the interventions based on eco-systemic logics, which also include urban forestry (EIFP), create transformation processes able to produce eco-systemic services on the territory.

The multidimensional character of the EIFP invites the use of evaluation models with which can consider the plurality of the effects produced by this type of interventions during the planning of settlement initiatives, especially in respect of the morphological-urban characteristics of the reference context. Only the use of evaluation protocols based on multi-criteria analysis allow to structure evaluation models for EIFP established according to the objective to be pursued in the context of integrated sustainable urban development. The steps that define the structure of the evaluation protocol for EIFP can be to help especially for the technicians—but not only—who must support Public Administration in the choice of planning solutions for territory portions within urban and/or extra-urban areas preferring eco-systemic logics. As well, these steps can lead the structuring phase of logical-operative models able to answer specific evaluation questions related to EIFP. The use of such models makes it possible to carry out evaluations in favour of an integrated urban planning, as well as to improve the transparency of choices also through the use of operational tools in which different constraints and generic objectives of the problem to be solved are expressed with the mathematical syllogisms of linear programming proper of the Operational Research.

In this perspective, new research developments may initially concern the study and definition of the relationships between elements regarding socio-cultural and economic-productive system of examined urban context, and the effects produced by the presence of natural elements. This integrated manner to urban land use in eco-systemic view support the realization of intervention practices valuated according to its consequently eco-systemic value increase. A further point for new study concerns the choice and use of the mathematical programming techniques most suited to solving the considered evaluation problem, and the applicability limits deriving from their use.

References

Aerts Jeroen CJH, Eisinger E, Heuvelink GBM et al (2003) Using linear integer programming for multi-site land-use allocation. Geogr Anal 35(2):148–169

Agrimi M (2013) Significato e ruolo della “foresta urbana” nella gestione territoriale in Italia. L’Italia Forestale e Montana 68(1):11–23

Alberti M, Waddell P (2000) An integrated urban development and ecological simulation model. Integr Assess 1(3):215–227

Bagstad KJ, Semmens DJ, Waage S et al (2013) A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosyst Serv 5:27–39

Baró F, Palomo I, Zulian G et al (2016) Mapping ecosystem service capacity, flow and demand for landscape and urban planning: a case study in the Barcelona metropolitan region. Land Use Policy 57:405–417. https://doi.org/10.1016/j.landusepol.2016.06.006

Barron S, Sheppard SRJ, Condon PM (2016) Urban forest indicators for planning and designing future forests. Forests 7:208

Bell S, Blom D, Rautamäki M et al (2005) Design of urban forests. In: Konijnendijk C, Nilssom K, Randrup T, Schipperijn L (eds) Urban forest and trees. Berlin, Springer

Boerema A, Rebelo AJ, Bodi MB et al (2016) Are ecosystem services adequately quantified? J Appl Ecol 54(2):358–370. https://doi.org/10.1111/1365-2664.12696

Chan KM, Hoshizaki L, Klinkenberg B (2011) Ecosystem services in conservation planning: targeted benefits vs. co-benefits or costs? PLoS One 6(9):e24378. https://doi.org/10.1371/journal.pone.0024378

Chee M, Shyu J, Tzeng GH et al (2007) Comparison among three analytical methods for knowledge communities group-decision analysis. Expert Syst Appl 33(4):1011–1024

Clark JR, Matheny NP, Cross G et al (1997) A model of urban forest sustainability. J Arboric 23:17–30

D’Onofrio R, Trusiani E (2017) Città, salute e benessere: Nuovi percorsi per l’urbanistica. Franco Angeli

Daily GC, Polasky S, Goldstein J et al (2009) Ecosystem services in decision making: time to deliver. Front Ecol Environ 7(1):21–28. https://doi.org/10.1890/080025

De Groot RS, Alkemade R, Braat L et al (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol Complex 7:260–272

Díaz S, Demissew S, Carabias J et al (2015) The IPBES conceptual framework-connecting nature and people. Curr Opin Environ Sustain 14:1–16

Diaz-Balteiro L, Romero C (2008) Making forestry decisions with multiple criteria: a review and an assessment. Forest Ecol Manag 255:3222–3241

Dobbs C, Escobedo FJ, Zipperer WC (2011) A framework for developing urban forest ecosystem services and goods indicators. Landsc Urban Plan 99:196–206

Dolan E, Moré JJ (2002) Benchmarking optimization software with performance profiles. Math Program 91(2):201–213

Eigenbrod F, Bell VA, Davies HN et al (2011) The impact of projected increases in urbanization on ecosystem services. Proc R Soc Lond B: Biol Sci 278(1722):3201–3208

Endreny TA (2018) Strategically growing the urban forest will improve our world. Nat Commun 9(1):1160

European Commission (EC) (2007) Directive 2007/2/EC […] establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Available online https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0002&from=EN. Last access 28 March 2019

European Commission (EC) (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM(2011) 244 final. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0244:FIN:EN:pdf. Last access 28 Mar 2019

European Environment Agency (EEA) (2018) Land system at European level—analytical assessment framework European, Briefing no. 10/2018. Available online https://www.eea.europa.eu/publications/land-system-at-european-level. Last access 28 March 2019

FAO (2016) Guidelines on urban and peri-urban forestry. Forestry Paper 178

Farr D (2012) Sustainable urbanism: urban design with nature. Wiley, Hoboken, NJ

Goméz-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecol Econ 86:235–245

Guarini MR, Nesticò A, Morano P, Sica F (2018) A multicriteria economic analysis model for urban Forestry projects. In: International symposium on new metropolitan perspectives. Springer, Cham, pp 564–571. https://doi.org/10.1007/978-3-319-92099-363

Ishizaka A, Nemery P (2013) Multi-criteria decision analysis: methods and software. Wiley, Hoboken, NJ, USA

Jabareen YR (2006) Sustainable urban forms: their typologies, models, and concepts. J Plann Educ Res 26(1):38–52

Kabisch N, Frantzeskaki N, Pauleit S et al (2016) Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecol Soc 21(2):39

Kenney WA, Van Wassenaer PJ, Satel AL (2011) Criteria and indicators for strategic urban forest planning and management. Arboric Urban Forest 37:108–117

Levin PS, Fogarty MJ, Murawski SA et al (2009) Integrated ecosystem assessments: developing the scientific basis for eco-system management of the ocean. PLoS Biol 7(1):e1000014

Maes J, Jacobs S (2017) Nature-based solutions for Europe's sustainable development. Conserv Lett 10(1):121–124

MEA (2005) Ecosystems and human Well-being: current State and trends. Island Press, Washington, DC

Micelli E (2004) Nuovi strumenti per la gestione dei piani urbanistici: un'interpretazione economico-estimativa. Scienze regionali 2/2004

Nesticò A, Guarini MR, Morano P, Sica F (2019) An economic analysis algorithm for urban forestry projects. Sustainability 11(2):314. https://doi.org/10.3390/su11020314

Nesticò A, Sica F (2017) The sustainability of urban renewal projects: a model for economic multi-criteria analysis. J Prop Invest Financ 35(4):397–409. https://doi.org/10.1108/JPIF-01-2017-0003

Opricovic S, Tzeng GH (2004) Extended VIKOR method in comparison with outranking methods. Eur J Oper Res 178:514–529

Schoen F (2006) Modelli di ottimizzazione per le decisioni. Società Editrice Esculapio, Bologna, Italia

Scovronick N et al (2017) Impact of population growth and population ethics on climate change mitigation policy. Proc Natl Acad Sci 114(46):12338–12343

Seppelt R, Dormann CF, Eppink FV et al (2011) A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. J Appl Ecol 48:630–636. https://doi.org/10.1111/j.1365-2664.2010.01952.x

Sheppard SR, Meitner M (2005) Using multi-criteria analysis and visualization for sustainable forest management planning with stakeholders groups. For Ecol Manage 207:171–187

Stirn LZ (2006) Integrating the fuzzy analytic hierarchy process with dynamic programming approach for determining the optimal forest management decisions. Ecol Model 194:296–305

Tallis H, Polasky S (2009) Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. Ann N Y Acad Sci 1162:265–283. https://doi.org/10.1111/j.1749-6632.2009.04152.x

TEEB (2010) The economics of ecosystems and biodiversity ecological and economic foundations (ed: Kumar P). Earthscan, London and Washington

Torre CM, Morano P, Tajani F (2017) Saving soil for sustainable land use. Sustainability 9(3):350. https://doi.org/10.3390/su9030350

Union Nations (2015) Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1. http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/70/1

Van Elegem B, Embo T, Lust N (2002) A methodology to select the best locations for new urban forests using multicriteria analysis. Forestry 75(1):13–23

Varma VK, Ferguson I, Wild I (2000) Decision support system for the sustainable forest management. For Ecol Manage 128(1):49–55

Verburg PH, Erb KH, Mertz O et al (2013) Land system science: between global challenges and local realities. Curr Opin Environ Sustain. Human Settlements and Industrial Systems 5(5):433–437

Vercellis C (2008) Ottimizzazione, Teoria, metodi e applicazioni. The McGraw-Hill Companies, Milano

Walker HD (1985) An alternative approach to goal programming. Can J Forest Res 15:319–325

Williams JE, Wood CA, Dombeck MP (1997) Watershed restoration: principles and practices. American Fisheries Society, Bethesda, MD

Wilson MA, Howarth RB (2002) Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. Ecol Econ 41(3):431–443

Wolfslehner B, Vacik H, Lexer MJ (2005) Application of the analytic network process in multicriteria analysis of sustainable forest management. For Ecol Manage 207:157–170

Yahdjian L, Sala OE, Havstad KM (2015) Rangeland ecosystem services: shifting focus from supply to reconciling supply and demand. Front Ecol Environ 13:44–51. https://doi.org/10.1890/140156

Innovation of Off-Site Constructions: Benefits for Developers and the Community in an Italian Case Study

Alessia Mangialardo and Ezio Micelli

Abstract The search for new tools to regenerate existing cities in an economically and environmentally sustainable way is at the heart of a lively debate at national and international level. The collective agenda is focused on the search for innovative production processes that guarantee at the same time durable, economic and minimum consumption of environmental resources interventions. This objective can be pursued by adopting the new paradigm of industrialization capable of capturing variety and efficiency through the use of new technologies. The aim of the research is to investigate, through a qualitative analysis of an Italian case study of a hotel construction process, what are the benefits and costs both of a private nature—for the construction companies and any developers—and of a public nature—related to the community—linked to an off-site project. The case study analyzed highlights how, compared to traditional construction procedures on site, the off-site construction is able to reduce by more than half the costs and timing of design and implementation. Finally, off-site construction helps to reduce the waste of resources and gives the possibility of disassembling and reusing construction components in other places and the reuse of materials in line with other industrial sectors and according to the principles of the circular economy.

Keywords Retrofit · Pre-fab construction · Off-site construction · Construction industry · Circular economy

1 Introduction

The search for new tools to regenerate existing cities in a sustainable way is at the centre of a lively debate at national and international level. The collective agenda is focused to find innovative production processes that guarantee both sustainable

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and economic interventions with minimum consumption of environmental resources. While these purposes are known and officially recognised in urban policies, the construction industry does not seem to be ready for such challenges. The evident decline in the construction sector's performance in terms of productivity, delivery certainty, skills shortages and data transparency necessitate radical innovation (ANCE 2018). This objective can be pursued by industrialising the design phases, the construction process and the entire life cycle of the work, transferring the main site activities to the factory, adopting the new paradigm of industrialisation capable of capturing variety and efficiency through the use of new technologies.

The purpose of the paper is to investigate, through the qualitative analysis of an Italian case study of a patented construction system to build modular hotels, what are the benefits both of a private nature—for the construction companies and any developers—and of a public nature—referred to the community—linked to an off-site project. Numerous national and international examples have shown that off-site construction processes can considerably reduce project and construction costs and the possibility of making design errors or mistakes during construction.

While in some European countries, such as the United Kingdom, the Netherlands, Sweden and Finland, off-site construction has become an established practice—adopted mainly by governments for the construction of social or public housing—in the Italian peninsula this production system has not yet fully established (Ganiron and Almarwae 2014; Mangialardo and Micelli 2018a, b; Vernikos et al. 2013). There are many reasons for this. The first one can be attributed to the substantial drop—by more than 36% in ten years (ANCE 2018)—in investment in construction. This negative economic situation is attributable to the economic crisis that has hit the country since 2008 with the consequence of a drastic decrease in investment and research in innovation. Furthermore, the construction sector has not been able to grasp the needs of a demand that has profoundly changed its investment choices and its spending capacity: it is necessary to identify building interventions at lower prices with greater attention linked to the sustainability of the interventions.

Nevertheless, the lack of knowledge of product quality and the lack of confidence in a poorly publicised construction system are the reasons of a low affirmation of off-site construction practices in Italy. Finally, the Italian construction industry is characterized by a completely different supply chain compared to other types of industries, which makes the innovation production process more complex. The plurality of players operating in the sector, both on the demand and on the supply side, often cause overlapping responsibilities and failures. These actors operate individually and hardly work at an integrated level in order to achieve common and shared purposes. The final aim is to pursue immediate speculative objectives rather than to achieve long term benefits improving costs and construction times. As the numerous international cases show, off-site construction are able to respond to many needs: interventions are faster, economically and environmentally sustainable and qualitatively better than on site processes and durable over time.

The paper is divided into four parts. The first identifies the benefits of off-site construction by comparing it with the traditional production system. The second part presents the Italian case study. The third, thanks to the elements that emerged from the case study, interprets and highlights some aspects of off-site construction that have been little explored by the scientific the literature of the sector and, finally, the conclusions summaries the results and outline the future developments of the research

2 The Renovation of the Construction Industry Through off Site Processes

Dang and Low (2015) define the construction sector as an economic activity that involves the entire construction process from the production of raw materials to the manufacture of construction components, providing professional services such as design and project management and the execution of works in situ. From this point of view, the construction sector is an economic activity that intersects all economic sectors starting from the primary one, for the extraction of building materials, to the secondary one, for the processing of raw materials and the realization of building elements, and finally the tertiary sector because it provides management, design, control and consulting services for the entire building intervention.

From the industrial and productive point of view, there are clear gaps that have led to an exponential drop in productivity compared to other industrial sectors. Even today, a building that employ traditional construction technologies is built with the same principles of the last century: examining only the automotive sector one should ask oneself how much would cost vehicles today if they were produced with the same techniques of a century ago (Mangialardo and Micelli 2018a, b; Boyd et al. 2013).

Nevertheless, in recent decades some construction companies have started an industrialisation process that has led to test innovative construction methods: off-site construction has become a valid alternative to the traditional onsite construction process. Off-site construction is based on the industrialisation of the production of building components, which are transferred to the site and assembled very quickly.

Based on the degree of off-site work, off-site construction is divided into four types (Kamali and Hewage 2016). The first concerns the under-assembly of small-scale components, such as windows or precast concrete blocks. The second type concerns non-volumetric components that are assembled in the factory, such as building cladding panels. The third type involves the off-site construction of entire volumetric units that are transferred to the construction site and assembled directly. Among these, bathroom cells are frequently used. The last type is represented by the entirely modular construction: the building components are produced and assembled in the factory. The finished modules are transferred to the site and assembled directly generating in a short time the complete building.

The benefits of an off-site approach to the construction sector are known in the literature (Boyd et al. 2013; Court et al. 2009; Fan et al. 2017; Goulding et al. 2015; Mangialardo and Micelli 2018a, b; Roy et al. 2003; Sparksman et al. 1999)

Table 1 The benefits of off-site construction

Categories	Benefits
Time	– Increased speed in the construction process
	– Fast tracking
	– Increased certainty in delivery times
Costs	– Less qualified labour
	– Lower maintenance costs
	– Lower cost of professionals
	– Fewer variants in progress
Production process	– Use of controlled production facilities
	– Economies of scale
	– Possibility of transporting building components even to distant locations
	– Increased transparency
	– Increased productivity
	– Skill in transporting components required
Respect for the environment	– Reduction of dust, GHG emissions and noise
	– Less waste of raw materials
	– Recycling and reuse of waste materials

Elaboration of the authors

and depend on the different level of prefabrication. Nevertheless, many benefits are common to all types of off-site construction (see Table 1).

With regard to the timing of the construction of a building, the speed of execution of the works is reduced by more than half compared to the use of onsite processes (Boyd et al. 2013). This is due not only to a considerable simplification of the construction process thanks to the industrialisation of the technologies used, but also thanks to the failure of interrupting construction on site due to the adverse climate. Furthermore, the fast tracking of the components together with the possibility of combining different types of work (hydraulic, electrical, plant engineering, etc.) without the need to wait for a professional to continue the work, allows a significant time saving. As a result, there is greater certainty related to delivery times. Ballard and Howell, authors of empirical observations regarding the assignment of weekly operations in a construction process, state that in on-site construction processes the probability of time deviations due to high waste of time and resources is equal to 40% of cases. On the contrary, in off-site construction, more than 90% of cases are on time (Boyd et al. 2013; Mangialardo and Micelli 2018a, b).

On the cost front, there are considerable savings that can range from 7% (Boyd et al. 2013) to 30% (Kamali and Hewage 2016; Na 2007). This is due to the use of less qualified workers, a lower cost of professionals, a reduction in costs on site, the possibility of achieving economies of scale. Furthermore, a greater control of the materials and of the construction process allows to increase the quality of the finished product with consequent lower maintenance costs and with a lower probability to provide for variations during the work. As a result, in spite of traditional construction, where only 69% of the buildings respect the initial budget, off-site construction guarantees greater predictability of costs (Boyd et al. 2013).

The production process is completely renewed: 85% of the works are carried out in the factory, significantly reducing accidents at work and congestion on the site. In addition, the need to transport large building components requires significant material strength. For this reason, there is a greater guarantee concerning the high quality of the materials and there is an increased ability to transport components in situ. Furthermore, the use of controlled production facilities guarantees greater certainty in pursuing the client's objectives. An innovative way of conceiving the business and the supply chain offer new sales opportunities in places that are also quite far from the factory. Work in the factory guarantees the possibility to proceed without interruption and is up to three times more productive than work on site. Finally, there is greater transparency of the materials used due to greater traceability of products from the production line to on-site installation. This is possible thanks to the use of advanced technological instruments such as the QR code, the BIM and the IT systems to provide the supply chian to the customer with updated data (Ekholm and Molnar 2009).

From an environmental point of view, off-site construction ensures a significant reduction in the production of waste materials and at the same time increases the possibility of recycling and reuse of unused material. The development of Pug and play modules also makes it possible to dismantle the modules and place them elsewhere. Furthermore, the factory production guarantees the reduction of dust on site, noise, GHG emissions, energy consumption and the movements of all those who work on site (Nadim and Goulding 2010).

3 An Application of Off-Site Constructions in the Tourist Accommodation Sector: Empirical Evidence from an Italian Company

In order to understand how the innovation of off-site processes brings benefits to the private sector and the community, it was decided to analyse an off-site construction process for the construction of hotels all over the world. This choice is not unintentional: in Italy, the tourist accommodation industry is constantly expanding and represents more than 10% of the national GDP. Again, due to its simple and typically modular plan volumetric conformation, hotels are very well suited to the development of off-site construction processes. For this reason, in 2010 an important multinational furniture manufacturer, which made the optimization of the construction process and the simplification of management activities its world-famous business model, with the help of a well-known Italian construction and engineering company and an international hotel chain, patented an innovative technology to build hotels around the world. Today, this construction system is employed to produce hotel modules in Italy that are then transferred and built all over the world.

The principle on which this project is based is represented by the use of an industrialized system that involves a higher quality of what is produced in the factory. As a result, buildings can be constructed in absolute safety, with a considerable reduction in assembly times and with a significant economic advantage. Thanks to the lightness of the building components, this construction system makes it possible to create structures of considerable size and allows easy transport: as an example, to date, this technology has been used for the construction of numerous hotels in Italy, England, Norway, Denmark, Germany and also in countries outside the EU. Furthermore, this technology has been designed according to anti-seismic criteria and is often also used for the reconstruction of industrial buildings damaged by earthquakes.

The off-site level used is almost complete: the entire structure is built in the factory and assembled on site. The toilet area and the central access corridor to the rooms are entirely manufactured and assembled at the factory and the three-dimensional module is transferred to the site for assembly with the rest of the structure. The hotel rooms and common areas, on the other hand, are made up of two-dimensional panels that are produced in the factory and assembled in situ. In short, the construction process on site is reduced only to the construction of the foundations, the assembly of the construction components and the plug and play connections.

The construction process involves the installation of all the systems (electrical, hydraulic, mechanical and ventilation) in the factory: the motors are incorporated into the central corridor leading to the hotel rooms. The hotel rooms can be very large, while the finishes, furnishings and sanitary equipment are made in accordance with local regulations.

In addition, each component of the structure (including the systems) is completely traceable: thanks to the insertion of QR code you can access any information about the product, check the workings and tests the performances. Again, in the event of damage or breakage of any component, by scanning the QR code it is possible to order the piece to be replaced, check the stock or the time required for shipment and finally read the assembly instructions.

There are two types of production lines. The first concerns the three-dimensional modules (bathrooms and systems). The second line refers to the production of two-dimensional panels such as walls, floors, facades, corridors and roofs. The production capacity linked to the development of this technology is surprising: in just eight hours for the first production line it is possible to create two complete bathrooms as well as the necessary plant engineering for two hotel rooms; for the second production line it is possible to produce thirty-six panels, corresponding to eight rooms: one room per hour.

Table 2 Comparison between offsite construction technology and a traditional construction system to built an hotel

Categories	Off site technology	Traditional system
Time	Duration of the construction site: 6 months	Duration of the construction site: 15 months
Costs	Construction: 18,000 Euros/room	Construction: 60,000 Euro/room
	Transportation: 3500 Euros/room (in Italy)	Transportation: 0
Production process	Factory production: 22 days	Factory production: 0 days
	Number of people employed for the production: 160	Number of people employed for the production: 0
	Number of days in the construction site: 150	Number of days in the construction site: 375
	Number of people employed in the construction site: 20	Number of people employed in the construction site: 25
Respect for the environment	Reduction of the waste materials more than the 40%	Km travelled to reach/return the factory: 0
	Km travelled to reach/return the factory: 30	Km travelled to reach/return the construction site: 100
	Km travelled to reach/return the construction site: 100	

Considering the construction of a 90 room hotel, Table 2 compares the benefits in terms of time, cost, production process and respect for the environment through the use of off-site construction of the case study presented and the traditional construction system. Data referring to the traditional way to build an hotel have been reached through interviews to experts in the fields.

With regard to the duration of the construction site, the time is significantly reduced: if with the traditional system it was possible to build the hotel in 15 months, the construction process off site allows to reduce the duration to only six months.

The reduction in costs is extremely significant: the construction cost per room is 18,000 Euros, which is about one third of the traditional construction system. Even if you add up the considerable transportation costs to the construction site—which change on the basis of the kilometers travelled by the factory and the difficulty of reaching the construction site—the construction costs would still be considerably lower than the costs of the traditional construction system.

Unlike on site processes, this system involves production in the factory: to produce all the components it takes about 22 days with the help of 160 workers. The time required to develop in the plant is therefore 3520 man days.

Once all the building elements have been produced, the number of construction days needed to assemble the components and finish them is 150, using 20 workers (about 3000 man days). The traditional construction system involves a considerably longer construction phase: each component is made on site and on average it takes

375 days with 25 workers to complete the hotel (equal to 9375 man days). The off-site construction system therefore saves 2855 man-hours.

Another important aspect concerns the manpower employed. The company that has patented this technology has taken on numerous workers from the factory who live near the work site. On average, each worker travels a maximum of 30 km per day to and from their home and back to the factory. For those who have to assemble the pieces on site, the movements will be higher, sometimes it is necessary to organize real transfers, but the times of work in situ are significantly reduced. In addition, the manpower required to produce the building components in the factory does not have to be skilled, which leads to considerable savings in terms of wages.

From an environmental point of view, the use of a traditional construction system, in addition to requiring the presence of trained and specialized labor, involves a significant displacement of staff who are forced to travel several kilometers every day to reach the site but may also be forced to move throughout the duration of construction. Finally, the use of off-site production processes makes it possible to significantly reduce waste: the panels are produced to the necessary size without producing waste material.

4 Off-Site Construction in the Hotel Sector: A New Opportunity to Renew the Construction Sector

Many studies have compared the performance between off site constructions and traditional construction methods in terms of cost, energy performance, and overall sustainability of the process. Off-site constructions, thanks to the involvement of modularity for construction elements, guarantee better performance (Sonego et al. 2018). The off-site technological system for the construction of hotels is just one of the many best practices that aim to innovate the construction industry to make this sector more performing from every point of view. In particular, the case study has made it possible to understand how factory production—and therefore a different approach to the value chain compared to traditional construction—bring significant advantages in the construction phase and in the finished product to construction companies, developers and the community.

On the construction company side, off-site construction involves a standardised supply chain approach that is more similar to the manufacturing industry than the traditional construction sector. The high degree of standardization and repeatability greatly facilitates project implementation. The use of digital manufacturing allows to increase the efficiency, productivity and competitiveness of the construction sector through the design of prototypes easily adaptable to a variety of functions while ensuring the refinement and variety of the individual project (Grosskopf 2017). The Italian company analyzed, has shown how it is possible to manage the complexity and complications of construction sites located in different places despite requiring exclusive needs. Although each individual project is unique, the information flows and materials are similar. Therefore, the purpose of the Italian company's project was to share and integrate knowledge to create a construction system that could be replicated and adapted to the different needs of the client. Normally, in the traditional construction industry this does not happen: the project is unique and with non-repeatable specifications. In this way it is possible to guarantee the efficiency of each individual project to achieve immediate objectives and to ensure greater profit for the company.

As the company argued, in the short-term off-site construction is more expensive to develop because it requires a greater expenditure of resources and significant investment in new factories, professionals and technologies. Construction has traditionally not been very capital intensive, drawing investment mostly from the consumer. Getting certifications and launching a sales network is highly capital intensive and requires a shift to more industrial management of the company. Yet, the production process of off-site construction requires considerably shorter construction times compared to the traditional system. Nevertheless, the number of workers involved in the factory is considerably higher than the entire workforce involved in the development of a traditional construction site. The costs of the surplus labour and the initial investments are quickly repaid by achieving economies of scale that would not be possible in traditional construction.

For similar reasons, once the prefabrication construction system is implemented, the construction cost of a hotel room is about two-thirds lower than in the traditional construction system. In addition, the time savings associated with the construction is very relevant and it can positively influence the internal rate of return of the development investments.

Finally, in order to optimize off-site construction processes as much as possible, it is necessary to provide for an integrated design that allows for the optimal assembly of components on site while involving multi-disciplinary and multi-level suppliers. For this reason, unlike traditional construction, suppliers and distribution networks are often predefined. Furthermore, in traditional construction a frequent cause of wasted time and effort is independent control of each link in the production chain. This often leads to considerable time and economic wastage, which generally occurs earlier than when they are actually recognised. This discontinuous control, combined with relationships that are not always collaborative, reinforce problems and imply a solution to be found in a short time and with the least possible expenditure of resources. The company analyzed uses a valuable tool that is able to avoid most of these problems: the use of "Building Information Modelling", the so-called BIM 4D, adds the time factor in the construction program to the classic BIM. This program makes it possible to predict most of the drawbacks by avoiding last-minute changes on site, eliminating waste due to production on site and making the installation phase faster. Furthermore, the use of similar technologies allows the design of standardised systems while guaranteeing the maximum variety of designs and finishes. This principle makes the use of current off-site technologies completely different from the prefabricated systems that have been used for the construction of many buildings located in the Italian suburbs.

On the developer point of view, mass customization is a crucial innovation. The limited repetitiveness of the construction sector risks dissipating a significant amount of knowledge between the implementation of a project and the other. Moreover, the lack of common strategic objectives, the lack of loyalty and the propensity to share resources and information make the production process of traditional construction particularly hostile to the development of innovative construction systems (Goulding et al. 2012). For this reason, the customer who requested the development of the construction system analyzed is a multinational whose business model is based on standardization and the production of modular furniture elements: as in furniture, off site constructions ensure at the same time a great variety of aesthetic and functional benefits making more cheaper the construction interventions. The mass customization is already a common practice in several sectors such as fashion, where you can customize an article produced in series as a dress and has been applied to many other sectors such as the automotive industry. Through this productive approach, manufacturers produce small, automated elements that can be arranged in different ways and generate different configurations. Thanks to this technology, investors have the opportunity to fully customize their projects produced in series.

Finally, for the community the benefits are manifold and concern the environmental sustainability that derives from off-site constructions. The production of waste materials can be reduced by up to 40% (Boyd et al. 2013). Yet, the company analyzed stated that the ability to cut and assemble the material in the factory allows them to significantly reduce waste. Furthermore, the possibility of guaranteeing a fixed work site with shorter travel times than on site construction sites, allows for a significant reduction in pollution as well as an increase in the well-being of workers.

5 Conclusions

The benefits of off-site construction sector are well known. The increase in productivity, the greater transparency of the data, the construction system used, the reduction of costs and delivery times together with the increase in the quality level of the final works are just some of the benefits that off-site construction offer. Off-site construction can become a valid alternative to traditional construction technologies in order to avoid the crisis that has hit the sector and to guarantee people quality construction that is at the same time economically and environmentally sustainable.

This article has presented, through the analysis of an Italian case study applied to the hotel construction sector the many benefits of this construction processes for the community and all the actors of private nature. In particular we highlighted how innovation in the construction sector through off-site construction would benefit the community and the private sector without one being to the detriment of the other. The principles and objectives on both sides seem to ensure sustainability, efficiency and lower development costs.

From the point of view of the private actors at stake, the benefits in economic, financial and productive efficiency terms are significant. The case study has made it possible to understand how, thanks to the development of economies of scale, it is possible to reduce construction costs by making these processes more convenient. Off-site construction processes ensure optimum performance by reducing construction times and work in progress variants. From the public point of view, the positive externalities linked to respect for the environment, improvement of workers' welfare and lower production costs are evident. It is not coincidence that several European countries use off-site technologies for the construction of public residences or social housing.

Future research may concern many aspects. First of all, from a pure privately point of view could be investigated the economic benefits deriving from the use of off-site processes. Furthermore, from a social and environmental point of view, all the positive externalities they generate could be investigated and measured.

References

ANCE (2018) Osservatorio congiunturale sull'industria delle costruzioni available at: https://www.ance.it/docs/docDownload.aspx?id=48610

Boyd N, Malik M, Khalfan A, Maqsood T (2013) Off-site construction of apartment buildings. J Archit Eng 19(1):51–57

Court PF, Pasquire CL, Gibb GF, Bower D (2009) Modular assembly with postponement to improve health, safety, and productivity in construction. Pract Periodical Struct Design Constr 14(2):81–89

Dang G, Low SP (2015) Infrastructure investments in developing economies. The case of Vietnam. Springer, Singapore

Ekholm A, Molnar M (2009) ICT development strategies for industrialisation of the building sector. J Inf Technol Constr 14:429–444

Fan L, Wang X, Zhang Y, Gao L, Hu T (2017) Modular construction, structures, and magnetic properties of two manganese coordination polymers based on 3,5-Bis (2–carboxylphenoxy) benzoic Acid. Zeitschrift fur Anorganische und Allgemeine Chemie 643(24):2138–2143

Ganiron TU, Almarwae M (2014) Prefabricated technology in a modular house. Int J Adv Sci Technol 73:51–74

Goulding J, Nadim W, Petridis P, Alshawi M, (2012) Construction industry offsite production: a virtual reality interactive training environment prototype. Adv Eng Informatics 1–17

Goulding JS, Pour Rahimian F, Arif M, Sharp MD (2015) New offsite production and business models in construction: priorities for the future research agenda. Architectural Eng Design Manage 11(3):163–184

Grosskopf KR, Elliott JW, Killingsworth JE (2017) Offsite construction—U.S. market trends in prefabrication. In: Challenges for technology innovation: an agenda for the future—proceedings of the international conference on sustainable smart manufacturing, S2M 2016

Kamali M, Hewage K (2016) Life cycle performance of modular buildings: a critical review. Renew Sustain Energy Rev 62:1171–1183

Mangialardo A, Micelli E (2018a) Off-site retrofit to regenerate multi-family homes: evidence from some European Experiences. In: Calabrò F, Della Spina L, Bevilacqua C (eds) International symposium on new metropolitan perspectives. Springer, Cham, Switzerland

Mangialardo A, Micelli E (2018b) Rethinking the construction industry under the circular economy: principles and case studies. In: Bisello A, Vettorato D, Laconte P, Costa S, (eds) Smart and sustainable planning for cities and regions. Springer, Cham, Switzerland

Nadim W, Goulding JS (2010) Offsite production: a model for building down barriers: a European construction. Eng Constr Architectural Manag 18(1):10–82

Roy R, Brown J, Gaze C (2003) Re-engineering the construction process in the speculative house-building sector. Constr Manage Econ 21(2):137–146

Sonego M, Echeveste MES, Galvan Debarba H (2018) The role of modularity in sustainable design: a systematic review. J Clean Prod 176:196–209

Sparksman G, Groak S, Gibb AGF, Neale R (1999) Standardization and pre-assembly: adding value to construction projects. Construction Industry Research and Information Association (CIRIA), London. Off-site manufactured project, April 2016. [Online]. Available: http://www.thehindu.com/todays-paper/tp-features/tp-propertyplus/offsitemanufactured-project/article8510844.ece

Vernikos V, Robery PC, Nelson R, Goodier C (2013) Implementing an offsite construction strategy: a UK contracting organisation case study. In: Smith SD, Ahiaga-Dagbui DD (eds) Proceedings of the 29th annual arcom conference, reading, UK, 2nd–4th September 2013, pp 667–677

The Urban Park as a "Social Island". The ANP in the Participatory Project of Parco Uditore in Palermo

Grazia Napoli and Manfredi Leone

Abstract An urban park provides many environmental and recreational facilities and services, and moreover it may become a catalyst for social energies and an instrument of community identification. This paper analyses whether participation and bottom-up planning may compensate institutional absences in implementation of urban parks, and how multiple criteria model may support socially shared decisions about their management. These issues are examined from the singular case of Parco Uditore in Palermo (Italy) that is located in a land which has been surprisingly undeveloped, despite the expansion of the city. The phases of promotion, planning and implementation of the park were the result of a synergistic but spontaneous collaboration of multiple actors, whereas an Analytic Network Process model has been built in the current management phase. The model has been provided for supporting a structured participatory process between promoters-managers and users for the selection of the best project among several alternatives, in order to strengthen the environmental, recreational and social role of the park.

Keywords Participatory process · Decision aid · Analytic network process · Urban park · Bottom-up planning

1 Introduction

Urban Park and green areas have assumed an increasingly important role in recent years for the growth of cities as they have contributed to improving the quality of life of urban communities. Moreover, they constitute an important qualitative feature in any urban location and have a direct influence on real estate sub-market prices along with the economic feasibility of private investments (Napoli 2015a; Napoli et al. 2016, 2017).

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In 19th-century London, the implementation of squares in the urban fabric and the Garden City theory contributed a lot to reflect on urban quality due to the presence of green areas.

In Italy, the importance of urban green has been awarded with the adoption of urban planning standards (Interministerial Decree 1444/1968) which made mandatory a significant share of public green areas and/or facilities in the new design of cities. Unfortunately, in Sicily, the share of existing public green areas is often considerably lower than the legal national minimum, and moreover in some neighborhoods of the capital, Palermo, the green standard does not even exceed the measure of 0.5 m^2/inhabitant versus the minimum of 9 m^2/inhabitant.

This inadequate condition has promoted, especially in the last decade, a re-appropriation of public spaces by the citizens and, consequently, an identification of new and often green ways of conceiving their fruition and management. A certain inertia of the public administration, pointed out by the scarcity of economic resources, is opposed to the strong will of the communities to overcome some operational barriers and to seize public spaces, as well as launch new forms of management.

This condition is not an exclusively Italian prerogative. The beginning of the 21st century shows several European communities taking possession of forgotten spaces, cultivating abandoned areas, protecting the landscape and its inhabitants where contemporary society has hastily turned its back. A transversal and European search for "democratic gardens", that produces models of great interest and quality, has in the community the main engine and actor. A democratic research of new poetry, conducted through the experience of sociability, drives towards a new urban aesthetic dimension (Walker and Simo 1994).

The "spontaneous" urban park of the 21st century is also the result of these experiences, a constellation of bottom-up processes characteristic of today's liquid society consolidating and shaping quality spaces/places, ephemeral and solid, evanescent and present, temporary and permanent.

There are numerous experiences of "atypical" European ways of making landscape (Lambertini 2013) that represents the evolution of a design thought that is both historically rooted and expressing a new spatial and vital dimension. We would like to mention Normand Park, a 2010 work by KLA—Kinnear Landscape Architects, created after joining a design competition. The project stands out for its ability to translate a social project into quality spatial outcomes. The intervention is a larger part of a local urban regeneration program launched by the Hammersmith and Fulham Council of London. In this case, huge investments were made available for the recovery and improvement of a system of strategic parks with respect to the local social dimension and the district space system. In particular, the artistic laboratories in which the inhabitants of the local community participated, had a strategic role, specifically involving different segments of the population and entrusting to different artists (videomakers, writers, and photographers) with the task of developing ideas and processes for recognizing the local landscape, evoking ancient customs and outlining future awareness (Lambertini 2013).

Another case of important involvement of the community in a process of garden construction is the experience of the Jardin DeMain, self-construction of urban gardening managed by the COLOCO Studio with the Municipality of Montpellier and some local associations, which engaged the community in a design process in the early stage (April/September 2010) and in its realization later (8–9 October 2010). The building site lasted only 24 h thanks to the preventive preparation of the area, and the planning of the gardens desired by the inhabitants, reversing the status of an abandoned parking area surrounded by dwellings. The transformation was a community festival, connecting public utility and landscape: the act of building, expressed by the inhabitants, was a form of collective reconquest of the city and its public spaces (Lambertini 2013).

The development of 'spontaneous' parks or gardens can be the result of structured or unstructured participation: anyhow taking decision is complex as they involve different social actors and concern various aspects, e.g. environmental, economic, administrative, social, and thus multicriteria evaluations may support decision making in such a context.

A large number of Multiple Criteria Decision Aid (MCDA) has been developed in order to manage the intrinsic complexity of private or public decision problems (Napoli 2018) such as choice, ranking, sorting and description (Roy 1981) or elimination (Bana e Costa 1996), and design (Keeney 1992). Subsequently, the selection of a MCDA method among those available—e.g. Electre, MAUT, Macbeth, Promethee, Rough sets, AHP and AHP—has to be based mainly on the type of decision problem and, also, on the required input data (Figueira et al. 2005; Ishizaka and Nemery 2013; Bouyssou et al. 2006). The MCDA models have been used in a wide variety of fields such as environmental problem with interaction between criteria (Bottero et al. 2015), or development of historical heritage (Della Spina and Calabrò 2018), urban energy retrofitting scenarios (Lombardi et al. 2017), or urban renewal projects and urban planning (Nesticò and Sica 2017; Saaty and De Paola 2017).

The Analytic Network Process (ANP) method, in particular, was developed by Saaty (2005) as a generalization of the Analytic Hierarchy Process (AHP) which deals with dependencies, and it is characterized by the following features: it allows dependence between criteria to be modelled, the input is pairwise comparison made by the decision maker DM, and the output is a classification with scoring. Many decisions regarding environmental (Bottero and Ferretti 2011) or land and urban development have been supported through the ANP (Napoli and Schilleci 2014; Napoli 2015b; Napoli et al. 2019).

This study proposes a multiple criteria model applied within an entirely bottom-up process of implementation and management of a public park, aiming to transform social non-structured participation into structured participation. The methodological approach is based on the combination of different techniques supporting the bottom-up decision-aiding process from a series of alternative actions to the choice and implementation of the best one. The future actions for the development of the park are initially defined through some active listening techniques (direct collection of user votes or by social media), while the ANP model is built by a focus group. Furthermore, as the DM is not a single subject but rather formed by representatives of different social groups, the ANP model is applied separately according to the judgments expressed by each representative. Lastly, an aggregation technique is used to obtain the final ranking and choose the best action.

2 Methodological Approach

The steps of the proposed methodology are the following:

- analysis of legislation and rules regarding the parks, in particular urban standards, the urban Master Plan, and European experiences of bottom-up processes for urban green spaces;
- analysis of participatory management of the park;
- building of a multiple criteria model to aid the decision process involved in park management and development;
- application of the model to each representative of the social groups and aggregation of the individual rankings;
- transfer of the result of the model to a further participatory process for the implementation of the best actions.

2.1 Regulations, Tools and Functions. Training, Management and Use of the Park

The term park may refer to different levels of legislation and rules. When the training intervention scale is the urban one, the reference norm is generally the "urban standards" that are technical specifications for setting the minimum dimensions, except for the amount of square meter per inhabitant to be allocated to general public green or sport green. For the urban provisions, there are also the "F area" parks, whose endowment of 15 m^2. per inhabitant is certainly a true reserve of quality for the modern cities. On the other hand, if we look at the contemporary cities and, in particular, at a large city like Palermo, we realize that the standards are definitely below the minimums by law and, in some cases, these are non-existent.

Quality and quantity of urban green areas are positive features as much for the inhabitant's wellbeing, as for the ecosystems, as the green lowers the average summer temperature and may contribute to reach a hydrogeological urban equilibrium and reduce the effects of an increasingly out of control climate. In this context the implementing actors are public. If some administrations have preferred to invoke the presence of private actors, in concession or entrustment, for the "sport green", the realisation of the "public green" can only be prerogative of the public bodies, whose institutional duties concern the development and management of this piece of the city.

Parco Uditore, on this matter, is an absolute innovation: the land ownership stays public, hosts different amenities, is managed by a highly motivated and efficient collective despite the "poor cooperation" of the offices, and is a reference point for many citizens. From a methodological point of view, the administration was able autonomously to build an identity, a management model, a communication strategy. In the end the Park has become an identity and a transversal and inclusive aggregation, and is a place of recognition and reflection to its community like few others in Italy (Lassus 2004). For all these reasons, Parco Uditore can be defined as a "social island".

2.2 Participation and Multiple Criteria Analysis

The ANP has been selected among several different multicriteria models because of several reasons. First of all, ANP allows relationships among the elements of a system to be modelled, which means that the network model is able to correspond to each specific decision problem. The input data are DM's judgements that may be obtained from direct interviews with all the actors involved in the decision process. The ANP output is a ranking with scores, so it allows identifying the best alternative and provides the relative distances between the ranking positions of the others.

According to Saaty, the type of relation introduced in the model between all the elements and the alternatives is the feedback type, whereas there may be feedback and dependences within and between the clusters of elements (nodes).

The ANP method is set on the following steps: definition of DM's objective, identification of the alternatives, clusters and nodes of each cluster, and of the feedback or dependence relationships between all the elements.

The model is founded on pairwise comparison measurements in accordance with a ratio scale of 1–9 expressed by the DM and following the relationships-dependence, feedback, and loop-that are designed in the network. The pairwise comparison matrixes, as well as unweighted, weighted and limit super matrixes are calculated on the basis of DM's judgements, and then a column of the limit matrix corresponds to the final priority vector. The implementation of the procedure, by using the Super Decisions 2.8 software, gives as results the priorities between clusters, the priorities by clusters, and the ranking of the alternatives.

When the model is applied to two or more DMs and in the case of different rankings, it is necessary to express the relative importance given to each DM and to calculate the weighted average scores. Moreover, the sensitivity analysis may be used to assess whether the final ranking is stable and how the output varies according to different weight systems.

Fig. 1 Left: the city of Palermo and the location of Parco Uditore; upper right: the park perimeter; lower right: the park area in the 2004 Master Plan and the F12, F15 and IC1 uses

3 Parco Uditore: The Case Study of an "Illegal" Park

3.1 The Birth of Parco Uditore

Parco Uditore opened to the public only in 2012, although the rural fund in which the park insists has a very long history, indeed the Morello-Uditore estate can be already identified in the old maps of the geographic system of the Piana di Palermo, commonly called "Conca d'Oro" due to the luxuriant colour of the citrus fruits that filled it. In the map drawn by Strachwitz in 1825 (Dufour 1992), the structure of the roads, fences and fields of the estate are easily identifiable as well as the neighbourhood of Uditore, located along one of the routes connecting the countryside to the center of Palermo (Fig. 1, left).

The Morello-Uditore estate suffered of major changes between 1937 and 1943, when the Italian General Petroleum Company (AGIP) acquired the north-western part of it and built a large underground fuel storage center, to protect it in case of bombing of the city,[1] along with some tunnels and a small barrack which is still existing. The area also includes a rural building, a great *gebbia*[2] and some remaining

[1]Effectively suffered in March 1943.

[2]From the Arabic word 'Gabyia': It means water reservoir.

cultivations of prickly pear cactus,[3] set in parallel rows, existing from 1940s and covering a large part of the estate until the mid-nineties of the twentieth century.

In 1963 the property was transferred from the AGIP to the Sicily Region and it was then leased to the Gelsomino family and used for private agricultural production for two decades, despite being under public ownership. The Gelsomino family was accused of collaborating with the Mafia superboss Totò Riina—who was suspected of using the estate to hide himself—so, after his arrest (1993), the leasing contract was rescinded. In 1996, the prickly pears plants left were largely extirpated and the area was no longer accessible excepted for a few regional administration offices. The estate is currently bordered by Via Cimabue, Via Uditore, Viale Leonardo Da Vinci, Piazza Einstein and by the Circonvallazione (Viale Regione Siciliana) (Fig. 1, upper right).

According to the city Master Plan, the area should be largely occupied by a Museum (F12), an Office Equipment and public Management Executive Offices (F15), and a religious Center (IC1) (Fig. 1, on the lower right). The demolition of the AGIP warehouse is also planned in order to build a new Management Center of the Sicily Region, but luckily the project was never realized.

Studies conducted by Manfredi Leone and Giuseppe Barbera,[4] created the basis for a first research on the area (Amoroso 2009, www.parcouditore.org) and for other scientific publications afterwards. This activity also supported the birth of a group of citizens who had the "dream" of obtaining a new public park in the place that had been a fenced area for more than twenty years.

3.2 *Synergies Between Social and Institutional Actors*

In mid 2011 a wide campaign took off in order to consolidate the pioneer group of Parco Uditore: a wide collection of thousands of signatures (eight thousand) was obtained through numerous public events held between 2010 and 2011. All these subscriptions, supported by social networks (Fig. 2), led the pioneers group to obtain an invitation to a meeting with the Town Planning City Committee. Moreover, a Master Plan modification[5] was registered for the current Master Plan under the signature of Leone and Barbera but, despite several meetings, it was never fully defined, nor approved, so the Park (since the opening) has never got a legal status.

The park is still operative after 6 years from its inauguration (October 15th, 2012) (Fig. 3) due to the tenacity of the working group that laid the foundations of the project[6] and to the political support of the Regional Cabinet of Economy—the office

[3] Opuntia ficus indica.

[4] Professor of Horticulture, Department of Agricultural Studies, University of Palermo.

[5] It is a formal and legal process according the Urban Planning Regional Act (L. R.S. 71/1978).

[6] The pioneers group was formed by Manfredi Leone, Giuseppe Barbera, Piero D'Angelo, Geri Presti, Paola Valenza, Massimiliano Rotolo, Giovanni Callea, Christian Blais. Several helps were provided by Francesco Alfieri, Girolamo Barbaccia, Mariano Capitummino, Luciana Carapezza

Fig. 2 Parco Uditore in the social network and other events

Fig. 3 Views of Parco Uditore

owner of the estate—who took the first concrete actions to allow the opening of the park, although with low-cost constraints (Leone and Valenza 2012).

Gaetano Cascino, Annalisa d'Acquisto, Rosita Giammellaro, Silvia Giarratano, Daniela Livaccari, Sebastiano Lombardo, Giovanni Lo Sasso, wrongstudio.com.

To provide the park with all the needed goods, a call for solidarity involved some small companies and local suppliers, and a multinational company as the sponsor that provided the necessary equipment for the play area and the outdoor gym.

The pioneer group established itself in the “Associazione Parco Uditore”, and in the “Cooperativa Sociale Parco Uditore” later. Thanks to an agreement between the Departments of Economics and the Department of Land and Environment of the Sicily Region Government, the Associazione Parco Uditore entrusts the administration of the newborn Park, with the cooperation and under the scientific supervision of the Department of Architecture of the University of Palermo. A public call in 2017 stated the assignation of the asset to the newly formed social Cooperative for a time span of 15 years.

A little-known news is that Parco Uditore has been twinned with St. James Park, one of the most celebrated urban parks in the world connecting Buckingham Palace and 10 Downing Street.

Despite the willingness and foresight of some public managers of the Sicily Region, the park management has been very difficult due to the lack of public funding that would guarantee the minimum support for worthwhile initiatives, for which the Cooperative has always been financed for with other means.

Another noteworthy topic is the legal consistency of the Park. The constraints preordained to expropriate for public equipment (F12, F15 and IC1 land uses) have expired since a long time ago, but the area has never acquired the legal status of Public Green to achieve the standard by law (Interministerial Decree 1444/1968). On the contrary, in drafting the Provisional Scheme of the new City Master Plan, called “Palermo 2025”, it was thought to cross the Park area with a new road. Such a proposal triggered a popular movement conveyed by the social media—Parco Uditore page—which advised the municipal offices to revisit the scheme. The destination for public green/urban park seems currently to be finally assumed in the planning process that is still on-going, although it has never been showed to the public yet.[7]

3.3 Resilient Strategy: Fundraising and Participation

The aforementioned condition of being “non-financed” by the (public) owner of the area has forced the (private) Cooperative that runs the Park to look for financial support through self-funding and other initiatives, in order to provide a good maintenance of the park.

The supplies of network services (electricity and water supply) are charged to the Regional Government Offices, who funded just few works for the first transformation of the Fondo Uditore into the park and the replacement of the well fence with a new red painted metal fence for the opening of the park (2012). As a side note, the starting cost of the park was of 0.50 Euro/m^2 versus the technical literature that estimates the average cost of a complete urban park around 50 Euro/m^2.

[7] January 2019, the Master Plan Palermo 2025 has not been published yet.

Fig. 4 Fundraising activity

After the first round of participation in the supplies and services necessary to open the park, underlined by the partial sponsorship of these costs, the Cooperative has started facing with the need to cover the management costs and looking for more appropriate financial coverage and has stimulated further participation of the supporters, which today (January 2019) stands at 38,000 on the dedicated Facebook page.

The cooperative has been able to immediately set up a direct relationship with its users always interested in the promoted event and initiatives. Many of the users are also direct supporters and over the years the park managers have formed a corollary of companies that funds the park with donations and/or free services.

The cooperative carries out various activities:

– periodic celebratory parties;
– short supply chain markets (food);
– summer entertainment for children;
– educational projects with schools;
– social projects supported by funding bodies (foundations);
– sports parties promoting a healthy lifestyle and supporting the local sport teams.

Those events led the community to bond with the place and have promoted social aggregation; indeed, they are an opportunity for fundraising campaigns to support Parco Uditore and carry out routine maintenance (Figs. 4 and 5). It should be noted that the staff is formed by volunteers who works 360 days a year, covering the opening hours and the management of the park; all contributions and sponsorships are aimed at maintaining the property through a concretely visible range of actions and a non-canonical “participation”.

Fig. 5 Spring colour party

3.4 Structured Participation and Multicriteria Analysis

As previously described, the implementation of Parco Uditore has involved multiple social and institutional actors—such as citizens' groups, social cooperatives, volunteers, the University of Palermo and the Government of the Sicilian Region. Nevertheless in the first phases of promotion, design, implementation and initial management the participation was unstructured, as it was based on voluntary agreements and negotiations between all the actors (Fig. 6). In the current phase the cooperative is trying to build a structured participation by promoting several activities of listening that involve promoters-managers and users in order to select the actions (e.g. services and equipment) that strengthen the environmental, recreational and identity role of the park.

The development of an Analytic Network Process model (ANP) is a step of this on-going process and, afterwards, the results of the model will be the topic of a forthcoming workshop with citizens and associations for a shared implementation of the selected actions (Fig. 7).

The "Call for ideas" for Parco Uditore was one among other initiatives for an active participation of the park users and was managed by a group named "Crowdfunding civico—idee per il territorio" (Fig. 8). In this campaign, citizens used a semi-structured questionnaire to express their preferences among 45 actions that were divided into three categories "Outdoor equipment", "Sports and leisure" and "Kids playground facilities". Each category was divided into two further groups: "Equipment", "Spaces" and "Activities". The questionnaire allowed the park users to also make supplementary suggestions. In 10 campaign days, 1473 questionnaires were collected and the preferences were 43, 37 and 20% respectively for the "Outdoor equipment", "Sport and leisure" and "Kids playground facilities" categories, whereas "Shading system" was the most voted action.

A cluster of alternatives, that includes some of the park manager proposals as well as the most voted actions by the users, was evaluated through the implementation of

Fig. 6 Steps and actors of the participation process

the Analytic Network Process to choose which action will be implemented and also to obtain a ranking of the alternatives.

The alternative actions are the following (Fig. 9):

A—Recovery of a rural building. In the park, there is a rural building, currently not in use, that may be refurbished to become an indoor venue for recreational activities that cannot be carried out in the open during winter. This action would allow a more intensive use of the park during the autumn and winter months, especially by children living in the neighbourhood.

B—Recovery of a warehouse. Another building, which was originally a warehouse, may be turned in a place for educational activities in collaboration with schools and associations. This action may support the offer of initiatives to the entire community during the whole course of the year.

C—Sports facilities and kids playground. This alternative includes some of the most voted actions in the "Call for ideas" previously described. The action provides for the placement of new sports equipment, such as a beach volleyball court, but also of other games for children (swings, slides, bounce houses, etc.).

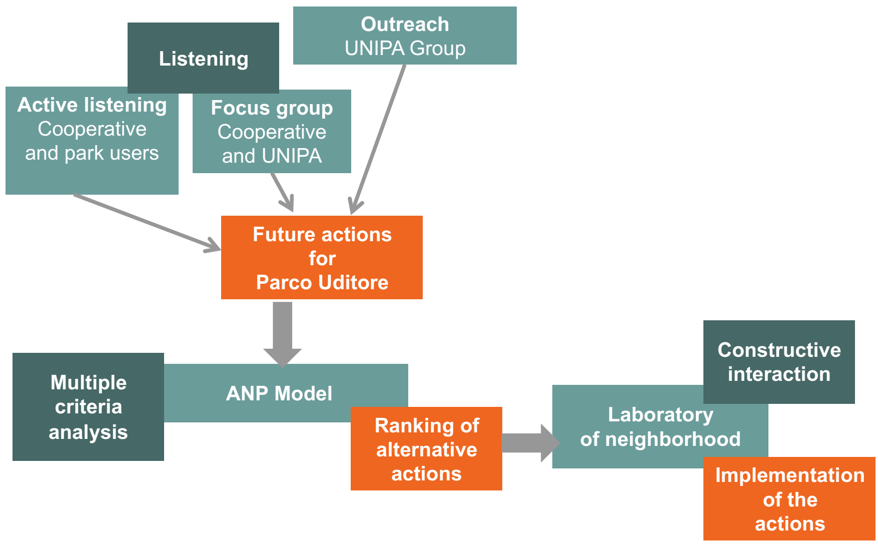

Fig. 7 Current steps of the participatory process of Parco Uditore

Fig. 8 Collection points of questionnaires

D—Outdoor lighting system. Currently the use of the park depends on the duration of solar lighting. The realization of the outdoor lighting system may extend the park opening hours throughout the year favouring the organization of night events in the summer.
E—Shading systems in open spaces. This action was the most voted in the “Call for ideas” campaign and is clearly considered by users as a necessary improvement for the summer season, given that the city of Palermo is located in a Mediterranean area. Shading systems may be totally natural (i.e. trees) or made of natural materials.

A focus group, formed by the park managers and few representatives of the University of Palermo, was put together to elaborate the evaluation model. The interactions

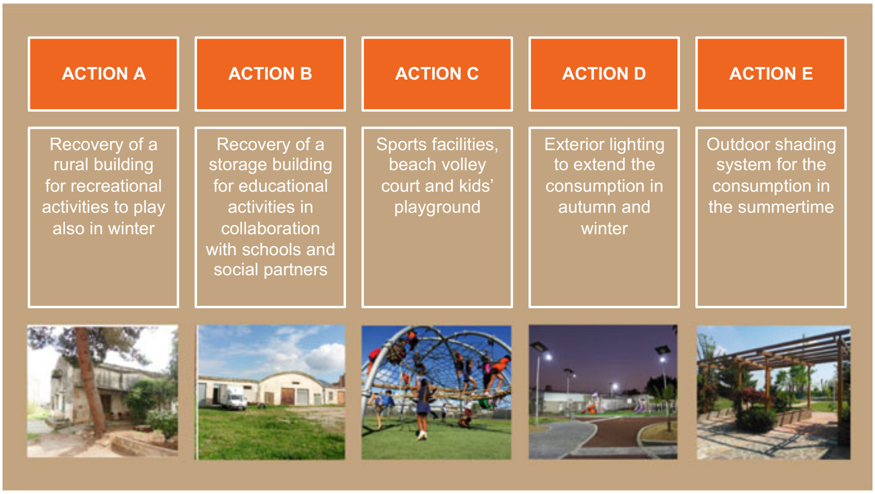

Fig. 9 The "Alternative actions" cluster

within the group led to the definition of: the main criteria of the model (Clusters), the nodes of each cluster, and moreover the network of interactions between the nodes.

The clusters are the following: "Social sustainability", "Environmental sustainability", "Political sustainability", "Economic feasibility", and "Alternatives". The model is represented graphically in Fig. 10, whereas Fig. 11 contains the definitions of the nodes expressed by the focus group.

With reference to the interactions and according to the theoretical foundations of the ANP, the cluster "Alternatives" has interaction relationships with all the nodes; moreover 9 additional relationships between the clusters have been identified (Fig. 12).

4 The Results of the ANP Model for a Structured Participation

The model was applied according to the Saaty's procedure which requires the decision maker to express a preference judgment among all the pairs of elements that are correlated. In this case study, the judgments were expressed separately by two members of the focus group that have different roles, namely Actor 1, as a representative of the cooperative that manages the park, and Actor 2, as a representative of the University of Palermo who has participated in the promotion, design and management process of the park. The judgments were processed using the Super decision 2.8 software. The index of consistency varied between 0.04 and 0.12. The individual

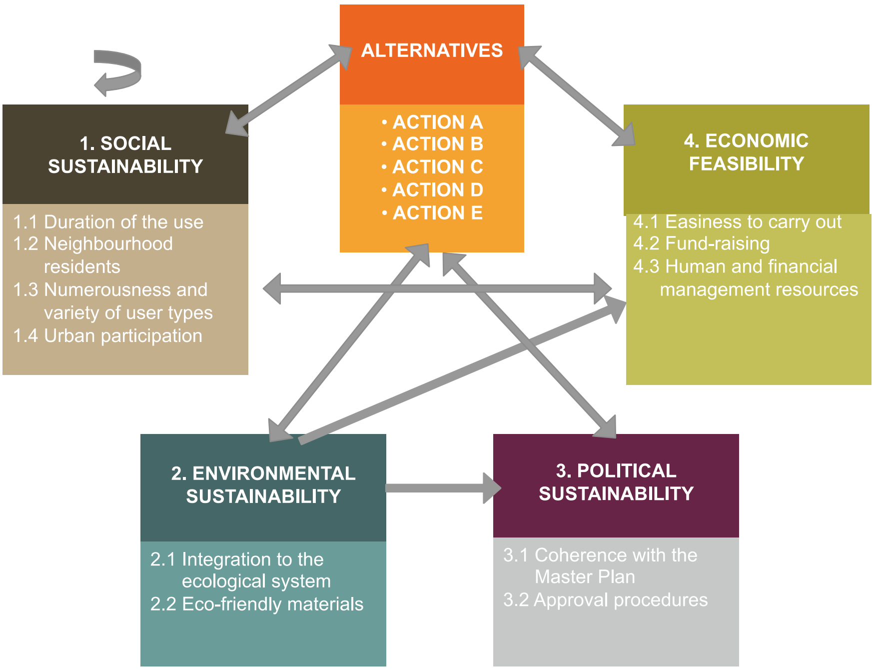

Fig. 10 The clusters, nodes and network of relationships of the ANP model

priorities were mathematically aggregated by both weighted average mean method (WAMM) and geometric mean method (GMM) to provide a final ranking.

The outcome in Table 1 shows that the individual rankings were significantly different, as the alternative *C* was the best one for the Actor 1 while just fifth for the Actor 2, and by contrast the alternative *E* was the best one for the Actor 2 while third for the Actor 1. Moreover, the rankings were different also for the other alternatives. Analysing the results, it can be noted that the alternatives *D* and *E* obtained very close scores for the Actor 1 and consequently they could be considered equivalent, and the same went for the alternatives *C* and *D* for the Actor 2. All these divergences may depend on the different skills and expertise of the actors, and also on the dissimilar potential uses that each actor prefigured for the park, in particular with regard to the alternatives *C* and *E*.

Given the difference between the two rankings, they were aggregated by applying the WAMM and GMM, and giving initially the same weigh (w) to each actor's scores ($w_1 = 0.5$ for the actor 1, and $w_2 = 0.5$ for the actor 2). According to the aggregated scores in Table 2, it emerged that the alternatives *C* and *E* got almost the same score, indeed the prevalence of the alternative *E* on the alternative *C* was very slight and equal to 0.7 and 7.7%, the former referred to the weighted average, the latter to the geometric mean scores. Making the consistency analysis (Fig. 13), it resulted that the weighted average scores of *C* and *E* became equal for a weight distribution of

1. SOCIAL SUSTAINABILITY

1.1 Duration of the use. The improvement of the social and recreational function of the park also depends on the possibility of use during the whole course of the year and in the daytime, even at night and in the evening.
1.2 Neighbourhood residents. Services or equipment can be provided to meet the needs of the neighbourhood residents.
1.3 Numerousness and variety of user types. The social function of the park depends on how the services and equipment are able to satisfy the largest type of users and to increase the number of users.
1.4 Urban participation. Park services and equipment can be used to promote activities open to the entire citizenship.

2. ENVIRONMENTAL SUSTAINABILITY

2.1 Integration to the ecological system. The park integration with the ecological system can be increased depending on the type of action.
2.2 Eco-friendly materials. Even if any action in the park will be implemented using eco-friendly materials, there could be differences according to intervention types.

3. POLITICAL SUSTAINABILITY

3.1 Coherence with the Master Plan. Although the land use according to the Master Plan may vary, the consistency of the alternatives has to be verified.
3.2 Approval procedures. Different types of works or services require approval procedures that can be significantly different in terms of time and complexity.

4. ECONOMIC FEASIBILITY

4.1 Easiness to carry out. An ease technical implementation of the actions and time for completion of equipment or service are taken into account.
4.2 Fund-raising. Each type of action may successfully be fundraised both for the potential involvement of users and for the possibility of finding sponsors.
4.3 Human and financial management resources. After implementation, the equipment or service needs financial or human resources to manage it over time.

Fig. 11 Definition of the nodes of the clusters

$w_1 = 0.51$ and $w_2 = 0.49$. Only if it is given a greater importance to one of the actors, an alternative could obtain a significant prevalence on the other, in particular for $w_1 > 0.51$ the best alternative is *C*, for $w_2 > 0.49$ the best alternative is *E*.

The final weighted ranking in Table 3 proposed an ex-equo first position for the alternatives *C* and *E*, and consequently the DMs suggested to the Cooperative to implement both of them.

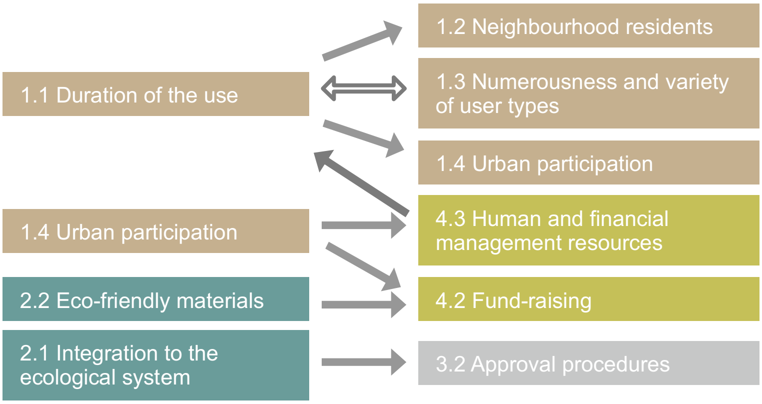

Fig. 12 The relationships between the nodes

Table 1 The ranking of the actions for each actor

Actions	Actor 1		GMM scores	
	Normals	Ranking	Normals	Ranking
A-Recovery of a rural building	0.185186	4	0.187814	3
B-Recovery of a warehouse	0.059406	5	0.239565	2
C-Sport facilities and kids playground	**0.326936**	**1**	0.149034	5
D-Outdoor lighting system	0.219143	2	0.153638	4
E-Shading systems in open air	0.209329	3	**0.269948**	**1**

Table 2 The rankings for the aggregated scores (importance of the actors: $w_1 = 0.5$, $w_2 = 0.5$)

Actions	WAMM scores	Ranking	GMM scores	Ranking
A-Recovery of a rural building	0.186500	3	0.186495	3
B-Recovery of a warehouse	0.149485	5	0.119296	5
C-Sport facilities and kids playground	**0.237985**	**2**	**0.220736**	**2**
D-Outdoor lighting system	0.186390	4	0.183490	4
E-Shading systems in open air	**0.239638**	**1**	**0.237714**	**1**

5 Conclusions

The experience of Parco Uditore is, in some ways, unique: by norm, by practice, by context. It is not common a park run by private actors. In this case the choice was the natural (not obvious) consequence of a bottom-up process in which the team of volunteers plays the roles of promoter, designer, builder, manager, and is supported

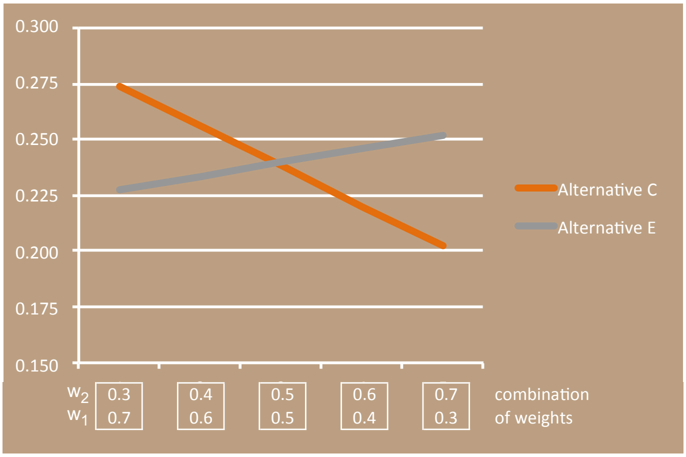

Fig. 13 The scores of the alternatives *C* and *E* to the combinations of importance of the actors

Table 3 The final ranking

	Actor 1	Actor 2	Final
1st	**C**	**E**	**C, E**
2nd	D	B	
3rd	E	A	A, D
4th	A	D	
5th	B	C	B

by an ever-present community, which has been joined over the years by many other groups and/or individual citizens, who have strengthened this social island.

In the current management phase, the cooperation between diverse types of actors has been supported by several listening and structured participatory processes and by an ANP model to select the best alternatives for the park management. The results are very interesting, as the individual rankings were not identical as a consequence of the divergent points of view of the different actors. According to the aggregated weighted scores, two alternatives resulted equivalent and were both selected for their implementation.

Further studies will support the next participatory activities of Parco Uditore, especially the application of the ANP model to more than two actors, in order to represent the point of view of other users or of the public administration, and moreover the implementation of the formerly selected actions in the Laboratory with neighbourhood residents.

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References

Amoroso A (2009) Un progetto di parco urbano a fondo Uditore. Tesi di laurea, Facoltà di Architettura, Università degli Studi di Palermo. A.A. 2008/2009. Relatore Prof. Manfredi Leone

Bana e Costa CA (1996) Les problematique de l'aide à la décision: vers l'enrichissement de la trilogie choix-tri-rangement. RAIRO Oper Res 30(2):191–216

Bottero M, Ferretti V (2011) An analytic network process-based approach for location problems: the case of a New Waste Incinerator Plant in the Province of Torino (Italy). J Multi-Criteria Decis Anal 17:63–84

Bottero M, Ferretti V, Figueira JR, Greco S, Roy B (2015) Dealing with a multiple criteria environmental problem with interaction effects between criteria through an extension of the Electre III method. Eur J Oper Res 245(3):837–885

Bouyssou D, Marchant T, Pirlot M, Tsoukiàs A, Vincke P (2006) Evaluation and decision models with multiple criteria: stepping stones for the analyst. Springer Verlag, Boston

Crowdfunding civico idee per il territorio. https://cwfcideeperilterritorio.wordpress.com. Last accessed 7 Jan 2019

Della Spina L, Calabrò F (2018) Decision support model for conservation, Reuse and valorization of the historic cultural heritage. In: Gervasi O et al. (eds) Computational science and its applications—ICCSA 2018. LNCS, vol 10962. Springer, Cham, pp 3–17. https://doi.org/10.1007/978-3-319-95168-3_1

Dufour L (1992) Atlante storico della Sicilia. Le città costiere nella cartografia manoscritta 1500–1823. Arnaldo Lombardi Editore, Siracusa

Figueira J, Greco S, Ehrgott M (2005) Multiple criteria decision analysis. State of the art survey. Springer, New York

Ishizaka A, Nemery P (2013) Multi-criteria decision analysis. Wiley, Chichester

Keeney R (1992) Value-focused thinking: a path to creative decision making. Harvard University Press, Cambridge, MA

Lambertini A (2013) Urban Beauty! Luoghi prossimi e pratiche di resistenza estetica. Editore Compositori, Firenze

Lassus B (2004) Couleur, Lumiere … paysage. Instants d'une pedagogie. Editions du Patrimoine, Paris

Leone M, Valenza P (2012) Progettare un parco low-cost. Aracne, Roma

Lombardi P, Abastante F, Torabi Moghadam S, Toniolo I (2017) Multicriteria spatial decision support systems for future urban energy retrofitting scenarios. Sustainability 9(7):1252–1265

Napoli G (2015a) Financial sustainability and morphogenesis of urban transformation project. In Gervasi O et al. (eds) Computational science and its applications, vol 9157. Springer International Publishing, pp 178–193. https://doi.oorg/10.1007/978-3-319-21470-2_13

Napoli G (2015b) The value of the useless in the urban landscape of small islands. In: Piccinini et al. (eds) Proceedings Of the 18th IPSAPA/ISPALEM international scientific conference: the usefulness of the useless in the landscape cultural mosaic: liveability, typicality, biodiversity, pp 333–339. WOS:000399691400031

Napoli G (2018) The complexity of value and the evaluation of complexity: social use value and multi-criteria analysis. In: Mondini G, Fattinnanzi E, Oppio A, Bottero M, Stanghellini S (eds) Integrated evaluation for the management of contemporary cities. Results of SIEV 2016. Series: Green Energy and Technology, Springer International Publishing, pp 187–198. https://doi.org/10.1007/978-3-319-78271-3_15

Napoli G, Schilleci F (2014) An application of analytic network process in the planning process: the case of an urban transformation in palermo (Italy). In: Murgante B et al. (eds) Computational science and its applications—ICCSA 2014. LNCS vol 8581. Springer, Cham, pp 300–314. https://doi.org/10.1007/978-3-319-09150-1

Napoli G, Valenti A, Giuffrida S (2016) The urban landscape and the real estate market. Structure and fragment of the axiological tessitura in a wide urban area of Palermo. In: Piccinini LC et al. (eds)

Proceedings of the 19th IPSAPA/ISPALEM international scientific conference, Napoli (Italy) July 2nd–3rd, 2015, pp 67–78. WOS:000399693200005

Napoli G, Giuffrida S, Trovato MR, Valenti A (2017) Cap rate as the interpretative variable of the urban real estate capital asset: a comparison of different sub-market definitions in Palermo, Italy. Buildings 7(3)80:1–25. https://doi.org/10.3390/buildings7030080

Napoli G, Giuffrida S, Trovato MR (2019) A paradigm interpreting the city and the analytic network process for the management of urban transformations. In: Calabrò F, Della Spina L, Bevilacqua C (eds) New Metropolitan Perspectives. ISHT 2018. Smart Innovation, Systems and Technologies, vol. 100. Springer, Cham, pp 672–680. https://doi.org/10.1007/978-3-319-92099-3_75

Nesticò A, Sica F (2017) The sustainability of urban renewal projects: a model for economic multi-criteria analysis. J Property Investment Financ 35(4):397–409. https://doi.org/10.1108/JPIF-01-2017-0003

Roy B (1981) The optimization problem formulation: criticism and overstepping. J Oper Res Soc 32(6):427–436

Saaty TL, De Paola P (2017) Rethinking design and urban planning for the cities of the future. Buildings 7(76):1–22

Saaty TL (2005) Theory and applications of the analytic network process. RWS Publications, Pittsburgh

Walker P, Simo M (1994) Invisible gardens. MIT Press, Cambridge

Peri-urban Open Spaces and Sustainable Urban Development Between Value and Consumption

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Abstract Current rates in population growth and urbanization are threatening sustainability. Increasing soil consumption and dwellings with inadequate characteristics need to be counteracted to ensure well-being of present and future populations. Urban planning is currently characterized by an approach based on standards and restrictions, and, as such, is unable to cope with the above problems. An Ecosystem Service (ES) approach can be valuable in assessing current quality of life in urban settlements and in planning for its improvement. Green open spaces and relationships between urban, peri-urban and rural areas are very important in the provision of Ecosystem Services (ESs) to built-up areas. While many authors focus on approaches aiming to provide a monetary value for ESs, others are more interested in how to operationalize ES use in planning, without having to assess ES monetary value. The authors propose an integrated AMC-GIS approach aiming to improve planning by providing a three-dimensional spatial analysis of productive, protective and cultural-recreational ESs based on the integration of the three RGB channels. Resulting maps provide a spatial representation of the mix of the three ES categories and stress the multifunctional role of many open spaces. Although the model requires further refinement and testing, preliminary results show that this approach may represent an innovative tool both for urban planning and design and for monitoring and correcting urban projects that are already underway.

Keywords Sustainable urban planning · Open space multifuntionality · Ecosystem Services · AMC-GIS

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1 Introduction

The European Environmental Agency (EEA) has recently issued two reports (EEA 2016a, b) highlighting the contribution of urbanization to soil consumption and its increase. Scientists and citizens are increasingly aware that the destruction and alteration of peri-urban open spaces bring about negative effects in terms of territory resilience and capacity to provide Ecosystem Services (ESs) and functions vital for the well-being of population living in the neighbouring built-up areas (MAE 2005). Anthropization and urbanization are the main drivers of negative effects. Indeed, the role of anthropization on climate change and its impact cannot any longer be overlooked, as well as the challenges arising from globalization processes, e.g. ensuring food security and preventing depletion of territorial assets. Priority in the search of effective solutions should be given to cities, where are currently living about 74% of the European and 55% of the world population (UN 2018).

In Italy, Ministerial Decree 1444/68[1] (Repubblica Italiana 1968) addressed, but not solved, the problem of urban resident well-being by introducing Urban Standards, e.g. a maximum ratio between spaces used for residential and industrial settlements and other spaces. When urban standards were introduced, Italy was going through a process of intense urban growth aiming to accrue private rents. At the time, they represented an important innovation, shifting the focus from private to social interests, e.g. the need to guarantee public spaces and to build a “sense of citizenship”.

In the current scenario, quantitative and restriction approaches such as the one of urban standards are no longer adequate. Complexity of issues asks for new planning instruments, based on a multi-dimensional definition of citizen well-being and paying greater attention to issues such as ecological debt of cities and health conditions of urban residents. Within the urban perimeter of many cities (Hansen et al. 2015) there are still significant green, both agricultural and non-agricultural, areas that fulfil important functions. Open spaces, e.g., as permeable land surfaces, improve resilience in the case of heavy rainfall allowing the natural drainage of water and its filtering. Green spaces, depending on their hosting natural or cultivated vegetation, provide a different mix of services, e.g. biodiversity conservation, provision of recreational and socialization spaces, and even places where urban dwellers can grow food. The potential of open spaces depends both on their specific characteristics and on the relationships—in terms of accessibility, closeness to specific urban context and functions, etc.—that they have with the context where they are located. Although open spaces can be considered as common goods, they are usually regarded as inert surfaces, whose potential or effective roles in providing services are neither understood nor acknowledged.

When dealing with a larger territorial scale, it is necessary to focus on the impacts caused by an urban continuum, i.e. the urban sprawl, that blurs the boundaries

[1]DM 1444/68 fixed urban standard, e.g. fixed a maximum ratio between spaces used for residential and industrial settlements and other spaces, i.e. public spaces or spaces for collective uses, public green spaces, parking places. This resulted in a minimum amount of 18 m^2 of public other spaces for each existing or future inhabitant.

between city and countryside in terms of fragmentation of ecological connections, increase of environmental costs generated by life-styles and services, etc. (Assennato 2014).

In conclusion, a shift from the old urban standard approach to new planning approaches taking into account the provision of ESs, may constitute an important innovation in planning and guarantee a higher quality and resilience of urban settlements.

2 State of the Art

Since the publication of MEA in 2005 (MEA 2005) there have been many theoretical and methodological studies on the assessment of ESs, among which The Economics of Ecosystems and Biodiversity by Stanford University (Sukhdev 2008), World Business Council For Sustainable Development (2011), UK National Assessment, Ecosystem Services Partnership (ESP), and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), started in 2012 by the United Nations. In the European Union, an ES mapping has been provided by MAES (Mapping and Assessment of Ecosystems and their Services) (Maes et al. 2013) that utilized a Common International Classification of Ecosystem Services (CICES) (Costanza et al. 2014; Haines-Young and Potschin 2013).

Despite the large scientific production already existing, the debate on how to apply the ES approach, e.g. on the spatial level and on the assessment model to be used, is still open. The main challenges in integrating the concept of ESs and values in landscape planning, management and decision-making have been described by de Grot et al. (2010). As regards ES valuing, some researchers focused on monetary methods (Braat and de Groot, 2012; Costanza et al. 1997, 2014), while others have preferred non-monetary evaluations (Kandziora et al. 2013), evaluation by means of aggregate indicators or evaluation of thermodynamic and biophysical type. Usually the final outcome of a monetary evaluation is the Total Economic Value, namely the sum of use and non-use values associated with a resource or an aspect of the environment. However, monetary valuation will always capture only a part of the "true" or total value of an ecosystem or service (de Groot et al. 2010). Monetary evaluations have been used, e.g.: (a) to increase the public decision-maker awareness on the environmental costs of anthropic activities; (b) to highlight the degree of depletion of natural capital; and (c) to verify the possibility of introducing tools for promoting ES provision by agents or territories, as in the case of Payments for Ecosystem Services (PES).

When evaluating ESs, an important aspect is the territorial scale on which one operates. A very large share of ESs is threatened by pressure on various levels, e.g. political, economic, and cultural level. For some ESs, such as climate regulation, the proper reference scale is the global one. Vice versa, when ESs are used for land planning, many researchers consider an approach taking into account location specificity (MAE 2005) as more appropriate to highlight significant aspects of ES multifunctionality (Potschin and Haines-Young 2013). According to Cortinovis and Geneletti (2018), a main issue in the operationalization of the ES concept in planning is the one of multifunctionality, since the common assumption is that to each area corresponds one single function, and from this derives the current approach to ecosystem-based actions as solution to specific issues. This conflicts with the multifunctionality of urban green infrastructures. Indeed, these authors stress that, despite the exponentially-growing number of studies on urban ESs, a successful transfer is still lagging behind, and the operationalization of the ES concept is far from being in place.

Considering ES values when drafting planning tools may consent the development of a new vision of the territory where built-up areas complement open spaces, by integrating them into infrastructures and existing networks, with the aim to support and strengthen them. Moreover, a multifunctional approach may improve vertical and horizontal coherence among interventions, in order to promote social interaction, leisure, etc. The above approach is defined as “Rural Urbanism” (Buonanno and Terracciano 2014) and it is based on the presence of a connective fabric made of open spaces; this fabric supports and sustains the city and makes it more sustainable and resilient. On a wider scale, Rural Urbanism may create a stronger relationship between agriculture and city through a design strategy in which agriculture takes a central role inside the processes of enhancement of open spaces. This implies a shift of perspective from the restriction of non-urbanized space consumption, by preventing new urban expansion, to the evaluation of ES provided by open spaces, in order to give them visibility, quality and social and productive values, in alternative to real estate value. According to Magnaghi (2013) “in the attempt to re-qualify structural factors in favour of self-sustainable development, the planning of open spaces assumes an all important role. This is because the process helps to re-establish a relation between the city and the rural world which, in turn, becomes instrumental if the tendency towards the degradation of urban, metropolitan, environmental and landscape systems is to be inverted”.

The main challenge of the Rural Urbanism approach is to safeguard unbuilt land and to promote modern projects of environmental enhancement, of conservation and public fruition. Sustainable land management requires “experimental” urban designs based on settlement choices of *densification* that neither increase the urban sprawl nor present the typical characteristics of the compact city that reproduce the classic contrast between city and countryside. The increase of urban density by means of void elimination consents the realization of the so-called “agglomeration economies”, e.g. wider distribution of infrastructure fixed costs, reduction of unitary costs, higher density of firms and workers, socio-economic and service qualification, improvement of public transports, energy saving. Nevertheless, densification can result in a further impoverishment of the city itself, as a consequence of the progressive elimination of permeable areas that are a resource to be safeguarded.

In conclusion, urban standards should be innovatively redesigned as flexible and dynamic performance standards, able to reflect evolving human needs. In other words, it is necessary to focus on quality rather than on quantity, e.g. on the immaterial services provided rather than on the physical infrastructures through which they are provided; this for promoting a more rational use of urban space, meeting the social needs of urban residents (Garzarelli 2014).

In this framework, we present a model of geographic multicriteria analysis (AMC-GIS) for a non-monetary evaluation of ESs provided by open spaces. Thanks to this model it was possible to define the value of some ESs provided by each unit of open space located within an urban context. Aim of the model is to evaluate the opportunity/potentiality/suitability of open spaces, on which tailored strategies for the integration between urban spaces and rural and peri-urban spaces may be based, in order to promote processes of urban regeneration. The model may also be useful for monitoring and improving urban planning schemes and projects, which are already in the process of implementation.

3 Methodology

Most of the services and benefits provided by open spaces are not exchanged on markets and, as such, they are difficult to be evaluated in monetary terms. Besides, the value of an ES is strongly dependent on the relations it has with the space and context where it is produced. The model presented in this chapter, unlike other studies dealing with ESs in planning, e.g. LIFE-SAM4CP project (Giaimo et al. 2016), uses a spatial non-monetary approach based on Geographic Multicriteria Aiding Techniques (GIS-MCA), ranking spatial alternatives according to their specific and often conflicting evaluation criteria, represented by standardized map layers (Malczewski 1999, 2006a, b; Malczewski and Rinner 2015). MCA techniques consider an area as homogeneous and use a single value, usually either the average or the sum, to describe the impacts caused by a transformation. However, the hypothesis of invariance in space of criteria value is scarcely realistic. Through the integration of MCA and GIS it is possible to build models of spatialized MCA based on small units, as the one that we propose, taking into account the variability of values in space.

Among the several multicriteria analysis techniques available (Beinat and Nijkamp 1998; Malczewski and Rinner 2015; Roy 1996) the Saaty's Analytic Hierarchy Process (AHP) has been chosen (Saaty 1980) since it allows to segment a complex decision-making problem into smaller and simpler sub-problems composing a hierarchical structure, within which it is always possible to measure the influence each part has on the whole system. Moreover, there are a number of studies demonstrating the process of hierarchical structuring of spatial decision problems using the concept of AHP in GIS-MCDA. The hierarchical structure is organized in three levels, namely goals, criteria, and alternatives. Criteria are described through attributes and sub-attributes, in order to reach elementary indices represented by cardinal or ordinal values that can be reliably measured or assessed (Malczewski and Rinner 2015; Rovai and Andreoli 2018).

In this model, criteria represent the three categories into which ESs are classified by CICES (Haines-Young and Potschin 2013), namely productive, protective and recreational-cultural ESs. Attributes characterizing each criterion were chosen based

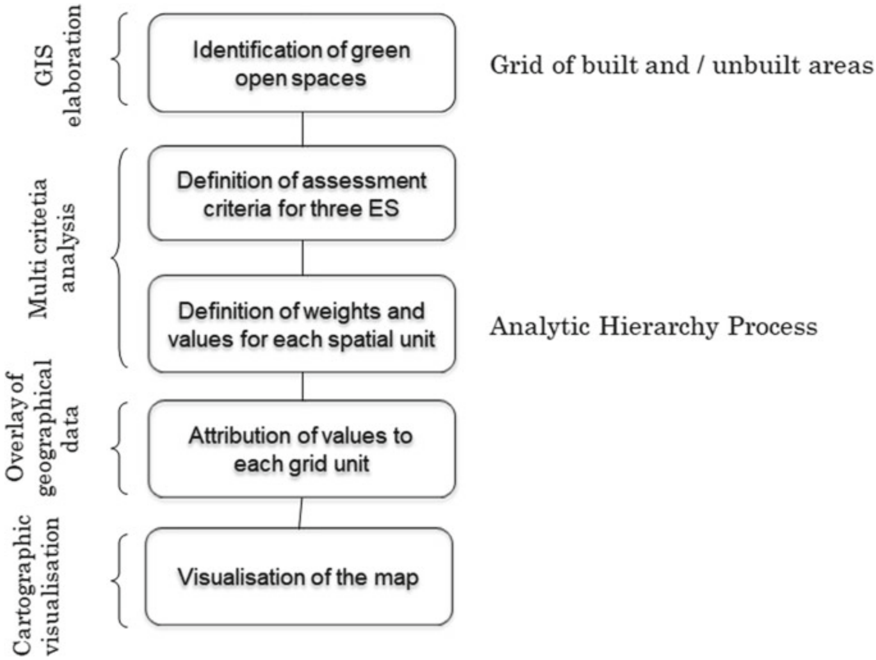

Fig. 1 Steps in the assessment of ecosystem services provided by open spaces and landlocked areas

on literature, previous researches, specific features of the case-study area and spatial data availability. Alternatives are spatial and are represented by units which contain the attribute values.

The following Fig. 1 describes in detail the steps of the assessment of ESs.

In the first step of the analysis (see Fig. 1), the identification of urban and peri-urban green open spaces has been carried out by superimposing a regular grid to the Regional Technical Map (CTR) at a scale of 1:10,000 and to aerial photographs. Three grids have been tested, namely 180 × 180 m, 60 × 60 m and 30 × 30 m, among which the smaller was chosen to allow greater detail (Fig. 2). For each unit, represented by a square of the 30 × 30 m grid, built-up areas have been measured both in terms of surface and in terms of share on the total area. The units characterized by a share of built-up areas higher than 30% have been considered as "built-up areas" and discarded as well as clusters smaller than 5 squares, i.e. 4.500 m^2.

Attributes have been based on the information gathered from "GEOscopio"[2] geo-portal, a webGIS tool that allows accessing, querying and displaying geographical data about Tuscany (Italy). From GEOscopio one may access the Regional Technical Map (CTR), aerial photos starting from 1954 and maps about several themes that are relevant for planning.

[2] http://www.regione.toscana.it/-/geoscopio.

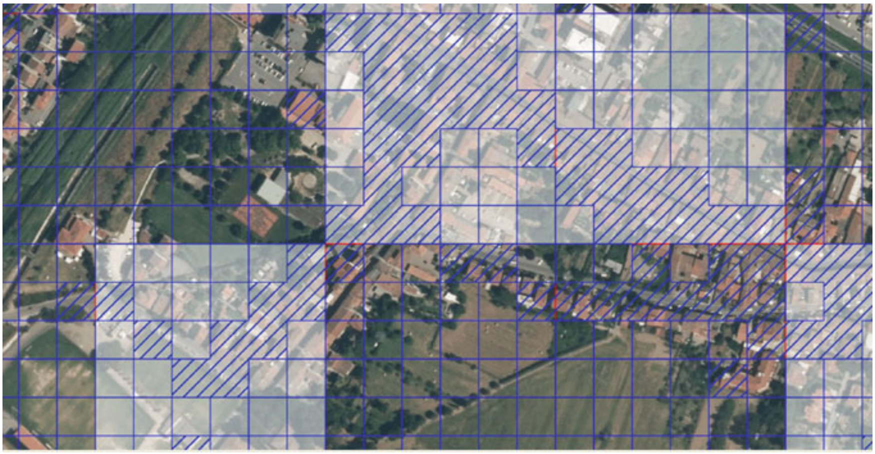

Fig. 2 Identification of urban and peri-urban green open spaces

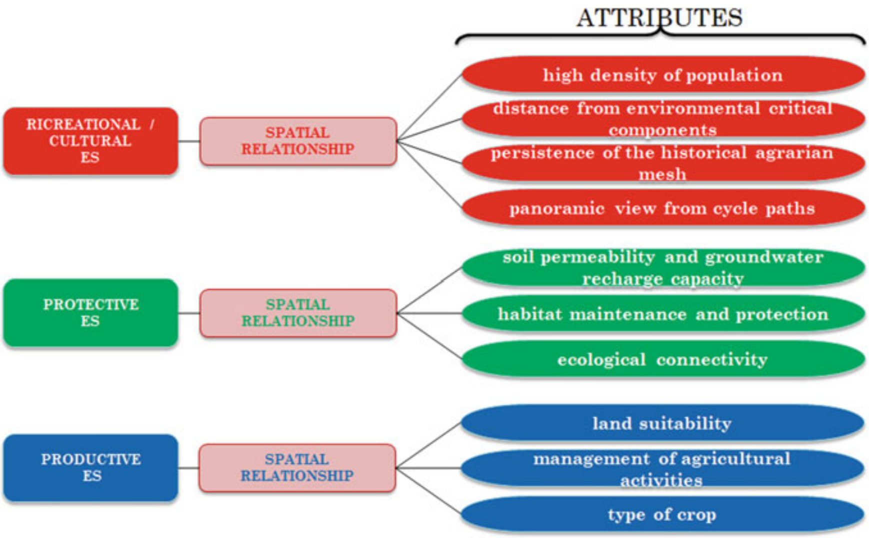

Fig. 3 Criteria and attributes for the assessment of ecosystem services provided by urban and peri-urban green open spaces

In the next step, for each criterion related to an ES category, the attributes characterizing it have been defined. These attributes are described in Fig. 3 and in the following paragraphs.

Productive services include ESs related to open space capacity to produce agricultural and food goods, and thus are mainly related to the production of an economic value. Attributes included in this criterion are the following: (a) land suitability for cultivation; (b) type of management, i.e. professional, semi-professional, hobby, abandonment, and (c) crop category.

Protective services are mainly related to open space capacity to ensure the conservation and reproduction of environmental and ecological resources. This criterion has been described through the following attributes: (a) soil permeability and groundwater recharge capacity; (b) habitat maintenance and protection; and (c) ecological connectivity.

Recreational-cultural services are mainly related to the capacity of a natural and rural context to contribute to the psychological and physical well-being of inhabitants. The relevant attributes for this criterion are the following: (a) distance from areas characterized by high population density, that gives an estimate of people who can benefit from these ESs; (b) distance from environmental detractors, whose presence and closeness decrease the value of other positive ESs; (c) persistence of elements and structures of the historical agrarian fabric, e.g. dense road and water distribution networks, tree rows, small plot size, etc. and, (d) panoramic view from walking and cycling paths, mainly related to landscape fruition.

Some of the attributes have been built on the base of sub-attributes, as in the case of "environmental detractors" attribute, that takes into account the presence of motorways, highways, airports, railways, disposal installations, commercial zones, industrial zones, parking places and landfill of waste.

Criteria and attributes have been evaluated through pair-wise comparison and standardized according to the Analytic Hierarchy Process method, by implementing the following steps:

(a) Hierarchical segmentation of the problem, where the classification of ESs into categories (criteria) and the attributes through which they are assessed have been decided (see Fig. 3);
(b) Pair-wise comparison by using the method of "paired comparison technique". In this preliminary test, pair-wise comparison has been performed by interviewing a panel of experts, including some of the authors and their fellow researchers. Attribute scores have been normalized to a 0–1 range using linear transformation;
(c) Consistency analysis with the aim of verifying that evaluations are consistent;
(d) Hierarchical recomposition of attributes. In this step a value for each attribute was assigned to each 30 × 30 m unit;
(e) Computation of criterion values. The total score for each criterion was computed as a weighted sum of the scores assigned to each attribute (see step d) characterizing that criterion. Weights have been obtained by pairwise comparison involving the same group of experts;
(f) Spatial representation on maps of the values attributed to ESs.

The vector grid was overlapped to the data about attributes used to define the three ES categories and evaluated by using information taken from topographic databases. Each unit or cell inherited, for each of the "n" characteristics describing each attribute, the value computed through the Analytic Hierarchy Process.

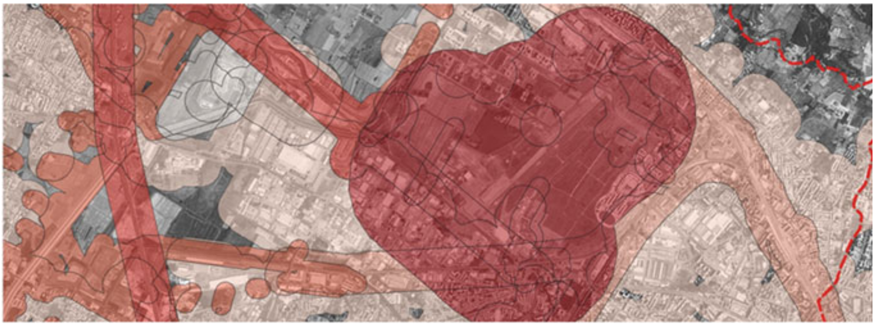

Fig. 4 Recreational-cultural criterion. Extract from the map of the value of environmental detractors located on the area under analysis

Figure 4 represents the spatial distribution of one of the attributes belonging to recreational-cultural ESs, namely “Environmental detractors”. This attribute describes the reduction in value open spaces suffer when they are located in proximity of an infrastructure, such as a major road or an airport, having negative effects in terms of visual impacts, emissions and noise. The methodology for assessing the value of this attribute required the assignment of weights to all the type of detractors by means of a pairwise comparison, and the definition of the zone within which open spaces are negatively affected by each environmental detractor. Darker red shadows in Fig. 4 identify the areas where open spaces are mostly suffering for the presence of detractors. Since this attribute represents a “cost” or “negative effect” for society, when producing the aggregate map of recreational-cultural ESs provided by open spaces, it has been normalized according to an inverse scale.

Then, for each ES criterion attribute values were aggregated according to the scheme described in Fig. 3. Table 1 shows the weight used to compute criteria value.

Each aggregated value represents the capacity of each land unit to provide a specific ES. In order to avoid the ambiguity that may result from adding very heterogeneous services, authors decided not to sum up the values of the three criteria. Indeed, the total value of all the ESs provided may not be able to highlight in a proper way the role of some ESs in specific spatial areas. Moreover, a mono-dimensional gradient of ES provision might even be wrongly interpreted as an inverse indicator of artificialization suitability. For the above reasons, the authors propose as the final step of the analysis a map providing a three-dimensional evaluation of ES categories. This map describes the mix of main functions provided by each unbuilt cell belonging to the case-study area.

The three-dimensional evaluation has been obtained by using a chromatic gradient with three components built through the integration of the RGB channels of a 24-bit image. In other words, the values of the maps describing each ES category, after being standardized into a 0–256 gradient, have been utilized as channel of an RGB image, where red represents recreational-cultural services, green protective services and blue productive services (see Fig. 5).

Table 1 Weight used to compute criteria values starting from attribute values

Criterion	Attribute	Weight
Productive ESs	Land suitability for cultivation	0.50
	Type of management	0.30
	Crop category	0.20
Protective ESs	Soil permeability and groundwater recharge capacity	0.25
	Habitat maintenance and protection	0.25
	Ecological connectivity	0.50
	Distance from highly populated areas	0.25
Cultural-recreational ESs	Distance from environmental detractors	0.25
	Persistence of the historical agrarian fabric	0.25
	Panoramic view from walking and cycling paths	0.25

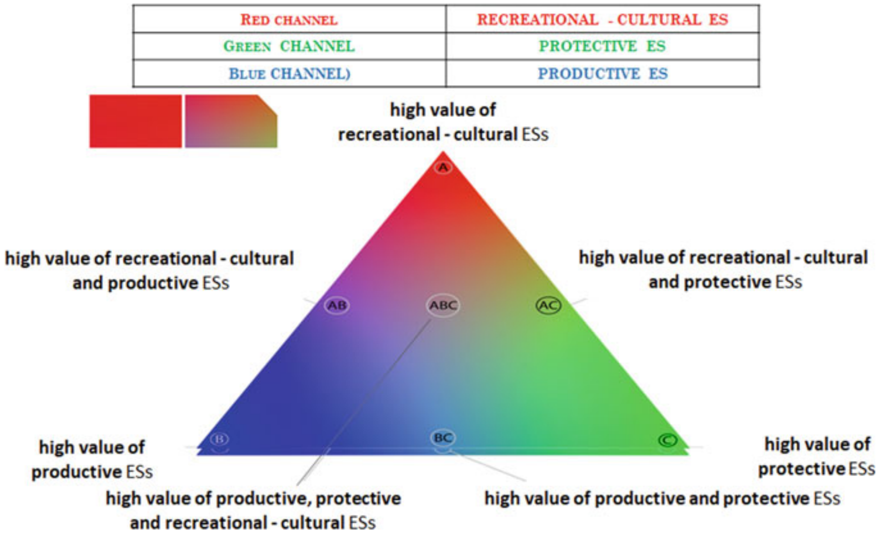

Fig. 5 Explanation of the chromatic representation of the three Ecosystem Service categories

The proposed model has been tested on some areas located in the Tuscany Region (Italy). Although the results are only preliminary and further research and tests should be carried out, the authors deem the model they propose to be an innovative and potentially useful tool for integrating ESs in planning. Some of the results are presented and discussed in the next section.

4 Case Study. Description, Results and Discussion of Preliminary Tests

4.1 Case-Study Area Description

As case-study area has been chosen the Florence-Prato valley, namely an intermontane basin of alluvial origin that is surrounded by a range of hills with an extraordinary value in naturalistic, agricultural, and landscape terms. This territory was deemed as highly suitable for testing our model since it was shaped by significant, both synergic and conflictual, interactions between modernization trends and the permanence of historical roots and geophysical features, interactions that resulted in very complex settlement patterns, characterized by intense fragmentation.

Aerial photographs from 1954 show a well-balanced agricultural landscape, marked by easily recognised typical elements. In the following years, the urban expansion surrounded in a compact way major and minor historical centres, although at different times and with different intensity. Then urban areas expanded more and more up to give raise to two big conurbations, the first one to the north, the second one to the south. Besides, many significant linear settlements arose at the sides of the main road networks, while smaller ones developed alongside historical roads (Paba et al. 2017; Rossi and Zetti 2018). This urban expansion brought about a new residential fabric with wide meshes and varying density, which has deeply transformed the old settlement pattern. Many industrial plants, storage facilities and commercial activities were then born, creating a new productive fabric (Regione Toscana 2015; Zetti 2013). Moreover, the case-study area was interested by a progressive increase of several types of infrastructures such as linear transport infrastructures (e.g. A1/E35 motorway, railways, etc.), energy infrastructures, airport infrastructures, that taken together resulted in a very high infrastructure density.

In summary, the case-study area was affected by intense processes of soil consumption that have especially influenced rural landscape of lowlands, and caused: (a) fragmentation of the agricultural fabric; (b) marginalization of agriculture; (c) depletion of landscape characteristic elements such as historic drainage systems, minor road networks and tree lined roads; and (d) loss of habitats and species typical of lowland agricultural areas (Regione Toscana 2015).

The evaluation of ES provision focused on the area described in Fig. 6, which was delimited on the base of aims and parameters characterizing the research project, rather than on the base of administrative boundaries. The area is bounded, on the

Fig. 6 Map of the case-study area

south by Arno river, on the north by the foot of the surrounding hills, on the west by Bisenzio river and on the east by the consolidate part of Florence city. Seven municipalities are partly included in the case-study area; Florence, Sesto Fiorentino, Calenzano and Campi Bisenzio with a significant share of their total surface, while Prato, Scandicci and Signa only with a low share. The case-study area has a size of 6800 ha, 3053 of which—accounting for 45%—are built-up areas, i.e. areas covered by some sort of artificial element. Unbuilt areas are heavily fragmented and have surfaces going from a few thousand square meters to more than 500 ha, as in the case of the central part of the case-study area, which is intercluded among motorways, airport and main cities on the northern side.

4.2 Case-Study Results and Discussion

The final outcome of the research is a map (see Fig. 7) obtained by overlapping the maps related to the three ES categories according to the chromatic gradient described in Fig. 5. This map, in the authors' opinion, describes and visually represents the specific functions provided by the open spaces located inside the case-study area. Figure 7 should be interpreted as a description of the spatial distribution, rather than of the intensity, of the three categories of ESs provided by open spaces.

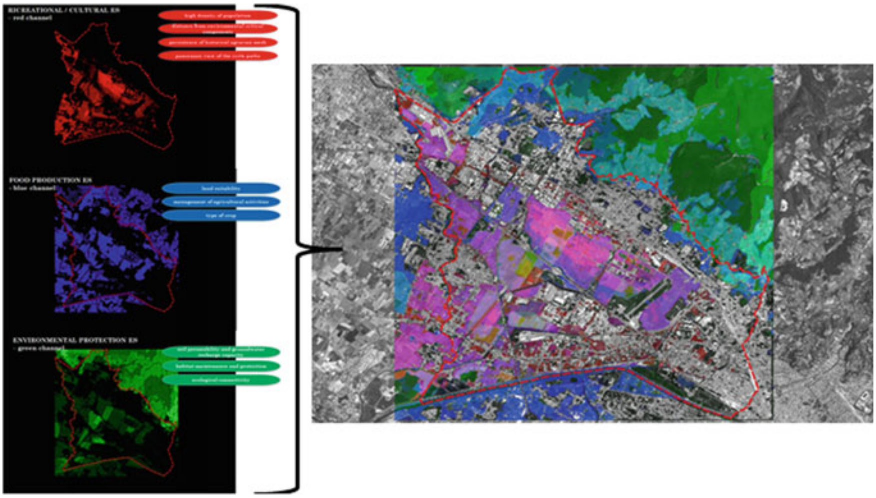

Fig. 7 Map of Ecosystem Services mix provided by each spatial unit of the case-study area

Figure 7 shows that in the central part of the case-study area there is a prevalence of open spaces providing both recreational-cultural and productive ESs, with an increase of productive in respect to recreational-cultural functions when moving from north-east to south-west. This area represents a sort of central island that is fundamental in ensuring the resilience of the whole territory and as such, it is suited to the creation of an agricultural park. The north-western part is characterized by the presence of many small islands survived to the urban sprawl, which have mainly a productive function and are usually characterized by the presence of olive groves and vegetable orchards.

The above short considerations arise from a general analysis of Fig. 7 but, if zooming on specific locations and focusing on specific functions, the map is able to provide for each specific area a deeper knowledge on which tailored interventions may be based.

In conclusion, although the model needs further research, refinement and tests, in the authors' opinion preliminary results show that it has the potential to produce maps able to accommodate open spaces multifunctionality and to provide decision-makers with a useful knowledge framework for planning and design decisions, with the aim to go beyond or at least to complement the approach of urban standards. Indeed, as Pulighe et al. (2016) argue, mapping ecosystem services would allow urban designers and planning practitioners to help and inform policymakers during the decision process and management of urban landscapes.

The case study focused on three categories of ESs in order to test and calibrate the model in terms of interpretation and evaluation and the results where shortly described only in terms of criteria. Nevertheless, in practical applications, the analysis could be organized to provide additional and more detailed information.

ES spatial analysis may represent a support for a better localization of policy interventions, such as agricultural aid, programmes for the conservation and enhancement of ecological connectivity, actions for the promotion of the social and cultural role of rural spaces, aiming to enhance open spaces and the functions they provide. In summary, unbuilt land should be considered as an active subject in the production of well-being and not as a void inert space. Indeed, in the authors' opinion, planning can no longer neglect the role of unbuilt areas, either if currently abandoned and going through renaturalization processes.

5 Conclusion

The Ecosystem Service approach makes apparent the fundamental role that open spaces play in providing functions and services useful for city sustainability and resilience and the consequent need for policies aiming to open space safeguard and enhancement.

Starting from the debate on the effectiveness of urban standards in ensuring population well-being, this study has tried to evaluate the suitability of ES assessment as an approach to go beyond, or at least to complement, the current use of urban standards in planning. Urban standards state only a minimum ratio between residential and industrial areas and other areas and, as such, consider a parking place or a public park as having the same effect on resident well-being. In the authors' opinion, a planning approach that do not consider open space features and spatial relationship with built-up area, may no longer be considered as adequate. The model may overturn the current approach to counteract soil consumption, based on standards and constraints, by emphasizing the multifunctional role of open spaces and contribute to slow down urban sprawl and to prevent agricultural land abandonment.

The innovativeness of the proposed spatial multicriteria model lays in a representation of open space multifunctionality, that do not requires monetary evaluation and the definition of trade-off among Ecosystem Services, as in the case of additive methods. Although the model is still experimental and needs further testing and refinements, it nevertheless allowed the authors to:

- Represent spatially located results with the aim to provide an immediate and intuitive picture of the ES evaluation;
- Identify areas with minor or major suitability/capability to provide Ecosystem Services and the areas that demand for urgent interventions in terms of conservation, redevelopment, etc.

Moreover, it allows conducting scenario analyses, by changing weights given to attributes according to stakeholders' demands.

Thanks to the spatial analysis of area suitability in providing Ecosystem Services, the proposed model may represent an important decision-aid tool: (a) when planning the introduction or the implementation of integrated environmental and territorial policies or (b) to steer public–private partnerships, e.g. among farmers and public administrations, in order to reproduce and enhance ES provision at local level.

The model is an attempt to innovate planning approaches and instruments by introducing systems that may evaluate the opportunities/capabilities/suitability of open agricultural and non-agricultural spaces and assess specific intervention strategies between peri-urban rural spaces and urban spaces, with a view to urban regeneration. The aim is to promote the coexistence and synergy between urban functions and rural functions, thus ensuring the provision of ecosystem services that are critical for urban dweller well-being.

Results highlight the high value of a mapping technique based on the above described principles in terms not only of ex-ante evaluation of planning choices, but also as a monitoring tool for planning instruments that are already underway, in order to adequately correct urban designs, when necessary.

References

Assennato F (2014) Consumo di suolo, servizi ecosistemici e resilienza: un quadro da comporre nella pratica. VIII Giornata di Studi INU "Una politica per le città italiane". Napoli, 12–13 Dicembre 2014. http://www.inu.it/convegni-nazionali-2/viii-giornata-di-studi-inu-una-politica-per-le-citta-italiane/

Beinat E, Nijkamp P (eds) (1998) Multicriteria analysis for land-use management. Kluwer Academic Publishers, Dordrecht, Boston, Mass

Braat LC, de Groot R (2012) The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv 1(1):4–15. https://doi.org/10.1016/j.ecoser.2012.07.011

Buonanno D, Terracciano A (2014) Ruralurbanism. Una visione per la città diffusa. VIII Giornata di Studi INU "Una politica per le città italiane". Napoli, 12–13 Dicembre 2014. http://www.inu.it/convegni-nazionali-2/viii-giornata-di-studi-inu-una-politica-per-le-citta-italiane/

Cortinovis C, Geneletti D (2018) Ecosystem services in urban plans: what is there, and what is still needed for better decisions. Land Use Policy 70:298–312. https://doi.org/10.1016/j.landusepol.2017.10.017

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Turner RK (2014) Changes in the global value of ecosystem services. Global Environ Change. http://doi.org/10.1016/j.gloenvcha.2014.04.002

de Groot RS, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7(3):260–272. https://doi.org/10.1016/j.ecocom.2009.10.006

European Environment Agency (EEA) (2016a) Soil resource efficiency in urbanised areas. Analytical framework and implications for governance, Report n 7/2016 retrieved from https://www.eea.europa.eu/publications/soil-resource-efficiency

European Environment Agency (EEA) (2016b) Urban sprawl in Europe Joint EEA-FOEN report. Report n 11/2016 retrieved from https://www.eea.europa.eu/publications/urban-sprawl-in-europe

Garzarelli F (2014) Verso una riconfigurazione qualitativa-prestazionale delle dotazioni territoriali. Una possibile reinterpretazione della città esistente. VIII Giornata di Studi INU "Una politica per le città italiane". Napoli, 12–13 Dicembre 2014. http://www.inu.it/convegni-nazionali-2/viii-giornata-di-studi-inu-una-politica-per-le-citta-italiane/

Giaimo C, Regis D, Salata S (2016) Ecosystem services and urban planning. NEWDIST

Haines-Young R, Potschin M (2013) International classification of ecosystem services (CICES). Report to the European Environment Agency. http://doi.org/10.1038/nature10650

Hansen R, Frantzeskaki N, McPhearson T, Rall E, Kabisch N, Kaczorowska A, … Pauleit S (2015) The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosyst Serv 12:228–246. https://doi.org/10.1016/j.ecoser.2014.11.013

Kandziora M, Burkhard B, Müller F (2013) Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution. Ecosyst Serv. http://doi.org/10.1016/j.ecoser.2013.04.001

Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, … Bidoglio G (2013) Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Brussels: Publications office of the European Union, Luxembourg. Retrieved from http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Magnaghi A (2013) The role of historical rural landscapes in territorial planning. In Agnoletti M (ed) Italian historical rural landscapes. Cultural values for the environment and rural development. Springer, pp 131–139. https://doi.org/10.1007/978-94-007-5354-9_3

Malczewski J (1999) GIS and multicriteria decision analysis. Wiley, 392 pages

Malczewski J (2006a) GIS-based multicriteria decision analysis: a survey of the literature. Int J Geogr Inf Sci 20(7):703–726. Available at: http://www.tandfonline.com/doi/abs/10.1080/13658810600661508

Malczewski J (2006b) Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis. Int J Appl Earth Obs Geoinf 8(4):270–277

Malczewski J, Rinner C (2015) Multicriteria decision analysis in geo-graphic information science. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-74757-4

Millenium Ecosystem Assessment (2005) Ecosystem and human well-being: synthesis. Island Press, 1–59. http://www.maweb.org/

Paba G, Perrone C, Lucchesi F, Zetti I (2017) Territory matters. A regional portrait of Florence and Tuscany. In: Balducci A, Fedeli V, Curci F (eds) Post-metropolitan territories: looking for a new Urbanity. Routledge Advances in regional economics, science and policy, vol 21. Routledge, Oxon

Potschin M, Haines-Young R (2013) Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecol. https://doi.org/10.1007/s10980-012-9756-x

Pulighe G, Fava F, Lupia F (2016) Insights and opportunities from mapping ecosystem services of urban green spaces and potentials in planning. Ecosyst Serv 22:1–10. https://doi.org/10.1016/j.ecoser.2016.09.004

Regione Toscana (2015) Piano di indirizzo territoriale con valenza di piano paesaggistico, (in Italian) retrieved from http://www.regione.toscana.it/enti-e-associazioni/pianificazione-e-paesaggio

Repubblica Italiana (1968) Decreto Ministeriale 2 aprile 1968, n. 1444, G.U. 16 aprile 1968, n. 97 (in Italian), retrieved from: http://www.camera.it/temiap/2014/12/09/OCD177-705.pdf

Rossi M, Zetti I (2018) In mezzo alle cose. Città e spazi interclusi. Dip. di Architettura (Firenze)

Rovai M, Andreoli M (2018) Integrating AHP and GIS techniques for rural landscape and agricultural activities planning. multiple criteria decision making. In Berbel J, Bournaris T, Manos B, Matsatsinis N, Viaggi D (eds) Multicriteria analysis in agricolture. current trends and recent applications. Springer

Roy B (1996) Multicriteria methodology for decision aiding, vol 12. Springer, US, Boston, MA. https://doi.org/10.1007/978-1-4757-2500-1

Saaty TL (1980) The analytic hierarchy process. Education, pp 1–11. Available at: http://www.mendeley.com/research/the-analytic-hierarchy-process/

Sukhdev P (2008) The economics of ecosystems and biodiversity: an interim report. European Communities. http://doi.org/10.1093/erae/jbr052

UN (2018) World urbanization prospects: the 2018 Revision – Key facts, department of economic & social affairs (DESA). Available at: https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf. Accessed 28 Feb 2018

World Business Council for Sustainable Development (2011) Guide to corporate ecosystem valuation: a framework for improving corporate decision-making. World Business Council for Sustainable Development

Zetti I (2013) Campagna Urbanizzata or Sprawl? Images from the florentine conurbation. In: Living landscapes—landscapes for living, Firenze, Febbraio—Giugno 2012, Planum association—the journal of urbanism vol 2/2013. pp 5–13. ISSN 1723-0993

From Ecosystem Service Evaluation to Landscape Design: The Project of a Rural Peri-urban Park in Chieri (Italy)

Emma Salizzoni, Marco Allocco, Davide Murgese and Giorgio Quaglio

Abstract The concept of Ecosystem Services (ES), namely the benefits that people obtain from ecosystems, clearly highlights the added value that environment and landscape conservation provides for the society and the economy and, more generally, for human well-being. In the last decade, several studies dealt with the needs and ways of integrating ES evaluation into spatial planning policies to foster sustainable development. More recently, the relationship between ES evaluation and landscape design has been increasingly investigated too, and ES have been proposed as a conceptual framework for addressing landscape architecture towards multifunctionality objectives. This chapter presents the first outcomes of an applied research that assumed ES evaluation—understood both as biophysical assessment and economic valuation—as a tool to sustain landscape design choices at the local scale. The study evaluated ES in a rural peri-urban area of Chieri (Turin, Italy), to support the project of a rural-recreational park. In the envisaged park, agricultural, natural and recreational areas coexist and a more sustainable relationship between the dense city and its peri-urban context is promoted. ES evaluation allowed to highlight at the site-scale the ES performance of alternative design choices and to draft possible pathways for the implementation of Payment for Ecosystem Services schemes.

This chapter is the result of the combined research activity undertaken by the four authors. The final written version of paragraphs 1 and 5 is to be attributed to Emma Salizzoni, that of paragraph 4 to Marco Allocco, that of paragraph 3 to Davide Murgese and that of paragraph 2 to Giorgio Quaglio.

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1 Introduction

Ecosystem Services (ES) are commonly defined as the benefits that people obtain from ecosystems (MEA 2005). The ES paradigm can be more accurately described through the so-called "service cascade" model (De Groot et al. 2010; Haines-Young and Potschin 2010), that links, as a chain, the concepts of ecosystem's biophysical structures and processes, functions, services, benefits, and values. The core idea is that ES are those ecosystem functions, underpinned by biophysical structures and processes, that provide benefits to people and thus can be valued.

This strong anthropocentric perspective (Wunder and Thorsen 2014)—that translates a wide range of ecosystem "functions" into "benefits" for people, highlighting the "instrumental" values of nature—has been at the hearth of a long debate in terms of environmental ethics (McCauley 2006; Jax et al. 2013) and deeply criticized by whom opposed to it a biocentric approach based on the "intrinsic" values of nature. One of the most convincing counter-arguments to these critics is that the ES concept is not meant to replace a biocentric approach, but to provide additional and compelling arguments to address the current ecological crisis (Schröter et al. 2014). It is precisely this anthropocentric perspective that makes ES a useful bridging concept between biophysical-ecosystem aspects and human welfare (Braat and de Groot 2012). It is no coincidence that the link between ES and the Sustainable Development Goals 2030 (United Nations) is tight (Wood et al. 2018). The ES concept can thus clearly highlight the added value that environmental and landscape conservation provides for human well-being and the advantages of sustainable development policies.

These potentials of the ES paradigm are closely linked to the explanation and communication of the benefits connected with ES, and so to the capacity of translating the environmental benefits in "values", as envisaged in the service cascade model. In this regard, the suitability of joint evaluation of both biophysical and economic values of ES is widely acknowledged. Economic valuation has undeniable power in terms of awareness raising and in supporting decision-making (Mavsar and Varela 2014).

The integration of ES evaluation into spatial planning policies, to address them towards sustainable development objectives, is however still an open and experimental issue (Lerouge et al. 2017). Several studies addressed the question of how to operationalize ES evaluation for spatial planning and landscape planning in particular (see, among the others, Gómez-Baggethun and Barton 2013; Von Haaren et al. 2016). To this regard, the "spatialization", through GIS-based mapping, of both biophysical and economic values of ES is a crucial step (Maes et al. 2012; Häyhä et al. 2015).

In the last decade, the relationship between ES and landscape design has been increasingly investigated too. Environmental issues and goals have already entered landscape design discipline since the Sixties (McHarg 1969), but the link between landscape design and ES is more recent. After the publication of the MEA Report (2005), the ES paradigm started to fertilise landscape design science (Nassauer and Opdam 2008; Termorshuizen and Opdam 2009). Despite certain epistemological gaps between the concept of ES and the discipline of landscape architecture (Van Lierop 2011), an increasing number of studies proposed ES as a conceptual framework for landscape design, to address it towards multifunctionality objectives, that is the capacity of providing environmental, economic and social benefits (Lovell and Johnston 2009). Performance indicators for designed landscapes based on the delivery of ES were defined as well (Windhager et al. 2010; Sustainable Sites Initiative 2015).

However, the application of the ES concept to landscape design poses some specific issues. One of the most compelling issue concerns the scale of evaluation. Assessment methods need to be suitable for the scale to which they are applied (Mooney 2014). At local scale ES evaluation should rely on empirical and in situ collected data. ES evaluation is usually developed at large scales, while measurement of ES in smaller, more disturbed landscapes and designed landscapes is rarer. Still, small scale urban and peri-urban areas can represent an excellent opportunity to improve ES performance as part of the design process. A local ES evaluation can moreover allow defining systems of Payments for Ecosystem Services (Wunder 2005), empowering local actors in landscape management and increasing the effectiveness of landscape design through long-term maintenance of those landscape elements that provide ES (Antunes et al. 2010).

This chapter presents the first outcomes of an applied research that took up the challenge of evaluating ES at the local scale and in particular in a rural, peri-urban area.

ES evaluation—both in terms of biophysical assessment and economic valuation—was based on a careful in situ survey and was conceived as a driver for the area's landscape design, supporting its conversion to a rural-recreational park. Evaluation was developed both for the area's current state and for three different design scenarios, allowing to highlight the ES performance of alternative design choices and to draft possible pathways regarding the implementation of PES schemes.

2 Territorial Context and Research Objectives

The research area, known as *Fontaneto*, is a rural area of 100 ha situated close to the city of Chieri (Turin, Italy). It is a typical residual peri-urban zone (Fig. 1), surrounded by residential and industrial buildings and transport infrastructures (railway and high-speed roads). The area, which is crossed by two minor watercourses (Rio Tepice and Rio del Vallo), is predominantly characterized by an intensive agricultural activity

Fig. 1 The *Fontaneto* area

(cereal and forage crops), that has non-negligible impacts on the nearby residential areas, due to the use of chemical plant protection products and fertilizers.

Despite some circumscribed restoration projects developed by the Municipality—such as tree planting or the setting up of recreational areas (*Area Cittadino Albero*) and community gardens (*Progetto CentOrti*)—today *Fontaneto* presents a general low environmental and landscape quality (Fig. 2).

Concerning land property, it is worth mentioning that the area is mainly private and highly fragmented (439 cadastral parcels and 175 owners).

However, *Fontaneto* is also an area in transition. In 2019 the Municipality approved a modification of its local urban plan (*Variante strutturale n. 15 del Piano Regolatore Generale Comunale*). According to this modification, that is explicitly aimed at maintaining and enhancing ES provided by soil,[1] some areas of *Fontaneto* that were previously classified as industrial zones and golf courses have been converted in rural areas. The Municipality aims to create a rural-recreational park in which sustainable agricultural areas, natural areas, and recreational areas can coexist. In *Fontaneto* there is, therefore, rooms for testing new pathways of development aimed at fostering a more sustainable relationship between the city and the peri-urban rural context.

The research here presented—developed by SEAcoop, in collaboration with Politecnico di Torino, on behalf of Città Metropolitana di Torino (December 2017–July 2018) and the Chieri Municipality (October 2018–today)—meant to support the area's transition towards an "alliance" with the city, developing a design vision based on *Fontaneto*'s environmental and landscape enhancement. To this aim,

[1]The drafting of the local urban plan modification was supported by the LIFE + project SAM4CP (http://www.sam4cp.eu/en/).

Fig. 2 The *Fontaneto* landscape

the concepts of ES and Natural Capital (Missemer 2018) have been assumed as operational paradigms to address the area's design towards the requested multifunctionality and to envisage a peri-urban park capable of delivering provisioning, regulating and cultural ES. Evaluation has thus been conceived not only as a knowledge tool but also as an operational tool, able to sustain and address landscape design choices.

3 ES Evaluation for *Fontaneto*'s Landscape Design

3.1 Methodological Framework

In order to make evaluation an effective tool to sustain the landscape design choices in the *Fontaneto* area, ES evaluation has been developed as tightly interwoven with the design phase. More specifically, the research has been carried on through the following main steps:

- first of all, we evaluated ES with regard to the baseline, namely the current state of the area;
- secondly, we drafted a Masterplan that defined landscape design interventions aimed at enhancing ES in the area. We focused on the linkages between landscape elements and ES provision, in order to understand which landscape attributes could be manipulated to add or maintain a particular ES (Mooney 2014);
- thirdly, we defined three different implementation scenarios of the envisaged design interventions and we evaluated ES provided by each scenario to highlight the value of ES provided by diverse design choices and the differences with respect to the baseline;
- finally, we defined some possible pathways for the activation of PES schemes in order to implement design interventions.

Evaluation has been carried out in relation to nine ES (Table 1). Starting from the ES classification framework provided by the Common International Classification of Ecosystem Services (CICES, V5.1, 2018, cices.eu), ES were selected according to their representativeness of the main ES classes (Provisioning, Regulation and Maintenance, and Cultural ES) and the primary functions currently performed by the area and envisaged by the project.

In order to evaluate ES, both biophysical and economic indicators were defined. Indicators, instead of computer-based modelling tools, were used, since modelling tools, that have been widely developed in recent years[2] and that are generally useful for assessing services at regional and river basin scales, are not always effective at

[2]See, among the others, ARIES (http://aries.integratedmodelling.org/), or InVEST (https://naturalcapitalproject.stanford.edu/invest/).

Table 1 Biophysical and economic indicators for the evaluation of ecosystem services

Ecosystem services		Biophysical indicator	Structure	Economic indicator	Structure	Economic valuation method
Provisioning	Agricultural production	Amount of agricultural products	ql/ha/year	Value of agricultural products	€/ha/year	Market price
	Wood production	Volume of extracted wood	m^3/ha/year	Value of extracted wood	€/ha/year	Market price
	Groundwater	Volume of water extracted for irrigation use	m^3/ha/year	Value of water extracted for irrigation use	€/ha/year	Market price
Regulation and maintenance	Hydrogeological protection	Surface of vegetation areas acting for prevention of riverbanks erosion	ha	Value of the protective function played by riparian vegetation	€/ha/year	Replacement cost
	Habitat maintenance	Surface of areas able to maintain nursery populations and habitats	ha	Value of the ecosystem capacity to maintain nursery populations and habitats	€/ha/year	Avoided cost and benefit transfer
	Water quality	Amount of nitrogen absorbed by soil	g/m^3/year	Value of the water purification function played by soil	€/ha/year	Replacement cost
	Climate regulation	Amount of carbon absorbed by soil	t/ha/year	Value of carbon absorbed by soil	€/ha/year	Market price
Cultural	Recreation	Number of visits	Visits/year	WTP/visits	€/ha/year	Benefit transfer
	Aesthetic values	Number of visitors	Visitors/year	WTP/visitors	€/ha/year	Benefit transfer

the local scale (Pandeya et al. 2016). Because of the site-scale of the evaluation, indicators, when possible, rely on empirical and in situ collected data (e.g. water quality is based on the analysis of extracted soil samples, Habitat maintenance on the observation of local avifauna, Agricultural production on the survey of local agricultural land uses).

With respect to the economic valuation, we referred to a Total Economic Value (TEV) approach (Pearce 1993) and we considered the different ES as direct (Agricultural production, Wood production, Groundwater, Recreation, Aesthetic values) and indirect (Hydrogeological protection, Habitat maintenance, Water quality, Climate regulation) use values of ecosystems (the non-use values have not been assessed). To define ES monetary values, we made use of various estimation methods—market price, replacement cost, avoided cost, benefit transfer—that have been selected considering the valuation aim (i.e. the type of ES to be valued) and data availability. Concerning each ES, the annual values (provisioning of ES throughout 12 months) were calculated.

3.2 Indicators and Evaluation Methods

Hereafter, the evaluation methods applied in order to calculate indicators are synthetically described.

Agricultural production—This indicator was assessed considering, for each cultivation, the "standard production" as defined by INEA, the National Institute of Agricultural Economics, for the Piedmont Region (market price method). This method entailed a preliminary in situ survey of the actual types of cultivations existing in the area.

Wood production—In this case too, an in situ survey of the main forest typologies was carried out in order to assume a volume of extracted wood for vegetation type (on the basis of the Piedmont Regional Forest Regulation 2011, no. 8/R). The monetary values associated to the assumed volume were defined through an analysis of the local market (market price method) and direct contacts with the local forestry offices ("*Sportelli forestali*", Piedmont Regional Law 4/2009).

Groundwater—This ES was evaluated by considering the following elements: (i) available groundwater amount assessment; (ii) assessment of water needed for the *Fontaneto* area crops. Available groundwater was calculated according to the local hydrogeological setting. Shallow aquifer materials (where groundwater for farming use is stored) are represented by an alternation of silty-sands levels and clay levels. According to aquifer storage coefficient, average groundwater stored volume in the *Fontaneto* area is about 8 mm^3. Crops annual water-need was defined according to Piedmont Region official methodology and resulted in an average annual volume of 1.4 mm^3, indicating a full provision of the service by the local aquifer. Value of water provisioning service was calculated by considering Piedmont Region fees for groundwater withdrawal concessions in agriculture (market price method), that are referred to water discharge (€/l/s). Assumptions made for the model were the following: (a) water provision assured by a single well providing the annual water volume requirement defined for the study area, (b) within an irrigation period from April to September. Resulting water-discharge for the hypothetic well is about 92 l/s. Piedmont Region fee for each l/s is 0.55 €/l/s: total service value for the 100 ha is 51 €/yr, and ES value is 0.51 €/ha/yr.

Hydrogeological protection—The value of this ES was calculated with reference to the role of riparian vegetation in river banks erosion protection. Replacement cost method was applied: cost related to the construction of retaining structures (ecological engineering retention walls, riprap) was calculated for all sectors potentially affected by erosion in case of water flow increase during intense rainfall. The total length of these sectors was defined by GIS analysis and field survey. ES value was then calculated as the product of retaining structure cost (€/m) times the total length of riverbanks potentially affected by erosion. Unit cost was defined according to official Piedmont Region public work pricelist. Total costs were modulated by considering a discount rate of 3% (UE reference rate) over a 20 years period (estimated structure lifetime) and then divided for the *Fontaneto* area, to obtain an ES value of 1366 €/ha/yr.

Habitat maintenance—This ES is intended as the capacity of an ecosystem to maintain nursery populations and habitats (CICES, V5.1, ES code: 2.2.2.3). The assessment of the ES was firstly carried out by referring to the two followings indicators: the farmland bird index (this indicator allows to assess, by "point count" method, the demographic trends of the populations of some bird species) and the "High Nature Value areas", HNV (this indicator allows to evaluate the extent to which agriculture can maintain habitats and biodiversity). The ES economic value was then defined through the avoided cost method—with reference to the subsidies granted under Measure 4.4.1 "Natural elements of the agroecosystem" for the planting of shrubs and trees (Piedmont Region BU8 22/02/2018 D.D. no. 237 of 15 February 2018) and Measure 10.1.4 "Agri-environmental climate payments" for the conversion of arable land to permanent forage crops—and the benefit transfer method for wetlands and watercourses (Scolozzi et al. 2012), and intensive crops (La Notte et al. 2011).

Water quality—This ES was assessed with reference to soils nitrogen retention. For the *Fontaneto* area, nitrogen transfer from soil to superficial water is minimal, due to the local morphology (plain area). Main interactions are related to nutrient leaching from soils to groundwater. Nitrogen soil concentration was determined in the laboratory from soil samples. Grassland soils nitrogen concentration resulted in being lower than in crop soils. Based on these concentrations and soils volume (1 m average thickness and 1.6 t/m^3 bulk density), total nitrogen content was determined for each considered land use. ES economic value was defined following a replacement cost approach. Treatment cost for 1 g of N was defined based on treatment plant costs; this information was applied to calculate the annual cost per hectare for nitrogen removal (€/ha/yr), both for grassland and crops. The difference between the two values represents the ES value, 270 €/ha/yr (the avoidable cost related to the conversion to the less impacting land use).

Climate regulation—The amount of carbon stored by the different land uses (t/ha) was firstly defined (ERSAF 2013). The market price of emissions was then applied as regulated by the European Union Emissions Trading Scheme (http://carbon-pulse.com/, 30 July 2018, 16.91 €/t).

Recreation—In order to evaluate this ES, firstly the number of annual visits was assumed, considering the main activities carried out in the area and the area's gravitation basin. The monetary value was then defined through a benefit-transfer method (unit value transfer). Study sites as similar as possible to the policy site were selected (Bravi and Curto 1996; Tempesta 2015) and the Willingness to Pay (intended as the WTP of visitors for an entrance ticket to Fontaneto) was re-modulated (we considered the rate of inflation and Chieri average income) and transferred to *Fontaneto*.

Aesthetic values—In this case as well, a benefit-transfer method was used (unit value transfer) to define ES monetary value. Due to the scarcity of studies concerning the economic valuation of agricultural area aesthetic values in the Italian context, we had to refer to a Dutch study (van Berkel and Verburg 2014). We then transferred to *Fontaneto* the re-modulated WTP there defined (intended as the WTP of visitors for an annual subsidy that supports farmers to maintain the few areas of permanent grasslands still existing).

3.3 Evaluation Outcomes

According to the sequential steps of the research (Sect. 3.1), firstly we evaluated the baseline, namely the current provision of ES in the *Fontaneto* area. Through the application of the biophysical and economic indicators (Sect. 3.2), we defined, for each ES, per unit (ha) and per year biophysical and economic values, and we applied to the different land-uses existing in the area.

The outcomes of the baseline evaluation, with specific reference to monetary values (Table 2), are in line with the current state of the *Fontaneto* area. Agriculture plays the major role (47.07% of the TEV), while the other provisioning ES (Wood production and Groundwater) present negligible values. Among regulatory ES, values connected to Climate regulation are considerably high (28.08%, but we should always keep in mind the great variability of EU ETS carbon price), while those related to Hydrogeological protection and Water quality are lower (respectively 8.02 and 4.3%). Water quality, in particular, is penalized by the high presence of intensive agriculture. Habitat maintenance ES too presents a poor performance (2.69%), in line with the area's low biodiversity. Finally, with relation to cultural ES, Aesthetic values are extremely low (0.86%), but the Recreation ES presents a non-negligible value (8.92%), highlighting the potentials of rural peri-urban areas as recreational spaces for urban inhabitants.

On the basis of the baseline evaluation outcomes and of the objectives of the Municipality (Sect. 2), we defined a Masterplan for *Fontaneto* aimed at improving the delivery of ES in the area and at meeting the Municipality request for a multi-functional park where rural, naturalistic and recreational areas can coexist. The Mas-

Table 2 Evaluation outcomes—baseline

Ecosystem services		Economic value €/year	TEV (%)
Provisioning	Agricultural production	101,724.37	47.07
	Wood production	87.96	0.04
	Groundwater	45.55	0.02
Regulation and maintenance	Hydrogeological protection	17,325.31	8.02
	Habitat maintenance	5810.30	2.69
	Water quality	9297.66	4.30
	Climate regulation	60,698.30	28.08
Cultural	Recreation	19,273.92	8.92
	Aesthetic values	1869.97	0.86
TEV		**216,133.34**	100

terplan entails three main types of landscape design interventions: (i) interventions explicitly aimed at improving the area's environmental quality, such as cultivation changes from cereals to oil and protein crops (soya crops in particular) to grant a more sustainable agriculture, creation of a wetland to improve local biodiversity, and planting of riparian vegetation for hydrogeological protection; (ii) interventions to improve the area's landscape quality (here meant in terms of scenic-perceptive values), such as planting of vegetation for the mitigation of the visual impact of buildings situated inside and nearby the area; (iii) interventions to improve the area's recreational potential, such as the setting up of recreational areas and tree-lined bicycle paths (Fig. 3). These three kinds of interventions and the underlying objectives are obviously strictly interlinked and overlapped.

With regard to interventions, we envisaged three different implementation scenarios: (i) in the first one (the optimum scenario) all the interventions are implemented; (ii) in the second one (the medium scenario), some landscape elements aimed at improving the areas' environmental quality (e.g. wetland and riparian vegetation) and recreational potential are not implemented; in the third one (the worst scenario) only tree-lined bicycle paths are implemented.

For each scenario we evaluated the overall ES provided, applying indicators to the new envisaged land-uses and functions. The comparison between the scenarios and the baseline, and among the three scenarios (Table 3), gives interesting insights to support the definition of the final project for the rural-recreational park.

The TEV of ES delivered by each scenario is higher than the baseline. The envisaged interventions thus improve significantly the value of ES provided by the area, even if we consider the worst scenario.

Fig. 3 Some of the envisaged landscape interventions: **(i)** creation of a wetland to improve local biodiversity; **(ii)** planting of vegetation to mitigate the visual impact of industrial buildings; **(iii)** creation of a tree-lined bicycle path to connect the city to the *Fontaneto* area and improve its recreational potential

Concerning the three scenarios, the values of ES differ consistently among them. In most cases, ES values grow from the worst to the optimum scenario (only Groundwater and Climate regulation present non-linear dynamics). Agriculture production is the only ES whose values decrease from the worst to the optimum scenario. This negative dynamic is due to the conversion of a part of the current agricultural areas to different functions (e.g. recreational functions, through bicycle paths, or environmental functions, through riparian vegetation). This trend of values catches in an exemplary way the trade-off phenomena that can occur among ES. As highlighted by Turkelboom et al. (2018), "we cannot have it all", that means that maximizing

Table 3 Evaluation outcomes—scenarios

Ecosystem services		Scenario 1 (optimum scenario) €/year	Scenario 2 (optimum scenario) €/year	Scenario 3 (worst scenario) €/year	Baseline €/year
Provisioning	Agricultural production	95,105.18	96,586.88	99,620.18	101,724.37
	Wood production	139.24	119.41	87.02	87.96
	Groundwater	45.81	47.22	46.81	45.55
Regulation and maintenance	Hydrogeological protection	18,866.34	17,630.23	17,630.23	17,325.31
	Habitat maintenance	6109.17	6092.92	5839.81	5810.30
	Water quality	24,282.36	24,246.16	24,028.07	9297.66
	Climate regulation	89,008.39	90,412.60	89,642.13	60,698.30
Cultural	Recreation	50,585.83	37,846.65	25,969.91	19,273.92
	Aesthetic values	47,886.39	27,841.64	5283.75	1869.97
TEV		**332,028.71**	**300,823.71**	**268,147.90**	**216,133.34**

the delivery of all ES simultaneously is often difficult, if not impossible. This is particularly true for provisioning ES (such as agriculture production) whose dynamic is usually inversely proportional to regulating and cultural ES (Braat and ten Brink 2008). In *Fontaneto* this relationship arises in a quite clear manner and poses issues regarding social acceptation and feasibility of the project.

4 Potentialities and Challenges of Payments for Ecosystem Services

It was also to manage these trade-offs that the research defined possible paths for implementing Payments for Ecosystem Services (PES) in the area. PES can be defined as incentive mechanisms to promote the provision of ES. The idea that underlies PES is that who provide ES should be remunerated for doing so, "putting a price" on previously un-priced environmental goods (DEFRA 2013). Differently from compensation actions, that are based on the "polluter pays principle", PES are thus based on the "beneficiary pays principle".

More specifically PES have been defined as "a voluntary transaction where a well-defined ES (or a land-use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider, if and only if the ES provider secures ES provision (conditionality)" (Wunder 2005, p. 3).

This theoretical scheme proves to be significantly more complex when applied in reality. First of all, complex governance systems are usually required. The network of actors involved in PES can be larger than the dual and straightforward relationship "buyer-provider", and it can involve, for instance, intermediary organizations, consultants, governments too (Muradian et al. 2010). Moreover, to grant the main PES features—i.e. conditionality, additionality and permanence—a long-term ES valuation and monitoring action is required, that, in turn, asks for multiple competencies and financial and time resources. Finally, we should recall that the actors, the scale and the typology of ES profoundly influence the structure of a PES model. Therefore, every PES is necessarily a site-specific solution. This is even truer in Italy, where there is not a legal framework for ES (the legislative decree which should have regulated PES in accordance with the principles laid out by Section 70(1) of Law 221/2015, art. 70.1, is still to be enacted).

All these aspects (complex governance, long-term monitoring, site-specific solutions) make PES a technical testing ground for environmental and landscape policies. In Italy, moreover, a strong tradition of "command and control" planning tools and a widespread land property fragmentation do not favour the implementation of PES, that are less common in our country[3] compared to other European countries (Matzdorf et al. 2014).

However, despite these challenges, we think that PES could represent a valuable tool for implementing in *Fontaneto* the landscape interventions described above. PES could improve the effectiveness of the design action by granting real and long-term provisioning of ES. Moreover, the use of PES specifically addressed to farmers in order to incentive them to provide cultural and regulating ES (e.g. by giving up portions of arable land for creating bicycle paths, or planting and maintaining riparian and mitigation vegetation) could contribute to solving the potential social conflicts linked to ES trade-offs.

5 Conclusions

The presented research aimed to turn into practice ES evaluation, considering it not as a purely academic exercise but rather as a tool able to impact on landscape design. To this end, ES evaluation has been thoroughly integrated into the design process, to support Municipality choices. Moreover, ES evaluation has been considered as the basis for carrying on PES schemes to implement the Municipality project of the *Fontaneto* park. To this regard, the authors are working on the possibility of involving the Municipality itself as a "buyer" of local ES. A path for activating a PES scheme between the Municipality and some locale farmers has already been started, and the Municipality has recently dedicated a part of the 2019 annual budget to finance PES in the *Fontaneto* area.

[3]Beyond some interesting experimentation (see for instance Marino 2017).

Prospects of research development will concern the deepening of ES evaluation, and of Cultural ES (CES) in particular (Plieninger et al. 2015; Fish et al. 2016). CES (Aesthetic values and Recreation) have been evaluated through a benefit-transfer method. To improve CES evaluation, we have already started to carry on a survey among local inhabitants concerning CES economic values, using a stated preference method (choice-experiment). The survey is being carried on both through direct interviews and web sources (e-mails and social media). The outcomes of the survey will allow stating more accurately the value of CES in *Fontaneto*.

A further effort will concern the implementation, in 2019, of PES schemes between Municipality and farmers. Several operational aspects still need to be stated (e.g. constitution of landowner association, drafting of a PES contract, definition of the monitoring process), but, when PES will be activated, we are confident that this experience will represent an innovative and experimental practice in the national framework of the landscape planning and design practices.

References

Antunes S, Carmo MR, Gouveia F, Tavares M, Oliveira N et al (2010) Valuation of ecosystem services at the local scale. Case study: the role of the cork oak montado at Herdade da Machoqueira do Grou (Portugal), Final report. Corticeira Amorim SGPS, SA & C.E., Liège

Braat LC, de Groot R (2012) The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv 1(1):4–15

Braat LC, ten Brink P (eds) (2008) The cost of policy inaction: the case of not meeting the 2010 biodiversity target. Report to the European Commission under contract. Wageningen, Brussels, Alterra, Report 1718. Retrieved from: https://www.cbd.int/financial/doc/copi-2008.pdf

Bravi M, Curto R (1996) Stima di beni pubblici con il metodo della valutazione contingente: finalità d'uso e valori. Genio Rurale-Estimo e Territorio 2:56–62

DEFRA—Department for Environment, Food and Rural Affairs (2013) Payments for ecosystem services: a best practice guide

De Groot RS, Alkemade R, Braat LC, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. J Ecol Complex 7(3):260–272

ERSAF - Ente Regionale per i Servizi all'Agricoltura e alle Foreste, Regione Lombardia (2013) AGRICO2LTURA. Il ruolo dell'agricoltura conservativa nel bilancio del carbonio, Quaderni della Ricerca, 153

Fish R, Church A, Winter M (2016) Conceptualising cultural ecosystem services: a novel framework for research and critical engagement. Ecosyst Serv 21:208–217

Gómez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecol Econ 86:235–245

Haines-Young RH, Potschin M (2010) The links between biodiversity, ecosystem services and human well-being. In: Raffaelli D, Frid C (eds) Ecosystem ecology: a new synthesis. Cambridge University Press, Cambridge, pp 110–139

Häyhä T, Franzese P, Paletto A, Fath BD (2015) Assessing, valuing, and mapping ecosystem services in Alpine forests. Ecosyst Serv 14:12–23

Jax K, Barton DN, Chan KMA, Groot RS, Doyle U et al (2013) Ecosystem services and ethics. Ecol Econ 93:260–268

La Notte A, Turvani M, Giaccaria S (2011) Economic valuation of ecosystem services at local level for policy makers and planners. The case of the island of St. Erasmo in the Lagoon of Venice. Environ Econ 2(3):87–103

Lerouge F, Gulinck H, Vranken L (2017) Valuing ecosystem services to explore scenarios for adaptive spatial planning. Ecol Ind 81:30–40

Lovell ST, Johnston DM (2009) Creating multifunctional landscapes: how can the field of ecology inform the design of the landscape? Front Ecol Environ 7(4):212–220

Maes J, Egoh B, Willemen L, Liquete C, Vihervaara P et al (2012) Mapping ecosystem services for policy support and decision making in the European Union. Ecosyst Serv 1:31–39

Marino D (2017) I pagamenti dei Servizi Ecosustemici in Italia. Dalla sperimentazione all'applicazione attraverso il progetto LIFE + MGN. CURSA(pas)SAGGI 3(8). CURSA, Roma

Matzdorf B, Biedermann C, Meyer C, Nicolaus K, Sattler C et al (2014) Paying for green? Payments for ecosystem services in practice. Successful examples of PES from Germany, the United Kingdom and the United States, Muncheberg

Mavsar R, Varela E (2014) Valuation of ecosystem services. Why should we estimate the value of ecosystem services? In: Thorsen BG, Mavsar R, Tyrväine L, Prokofiev I, Stenger A (eds) The provision of forest ecosystem services. Volume I: quantifying and valuing non-marketed ecosystem services. European Forest Institute, Joensuu, pp 41–46

McCauley DJ (2006) Selling out on nature. Nature 443:27–28

McHarg I (1969) Design with nature. Natural History Press, Garden City, NY

MEA, Millennium Ecosystem Assessment (2005) Ecosystems and human assessment. Current state and trends. Island Press, Washington, Covelo, London

Missemer A (2018) Natural capital as an economic concept, history and contemporary issues. Ecol Econ 143:90–96

Mooney P (2014) A systematic approach to incorporating multiple ecosystem services in landscape planning and design. Landscape J 33(2):141–171

Muradian R, Corbera E, Pascual U, Kosoy N, May PH (2010) Reconciling theory and practice: an alternative conceptual framework for understanding payments for environmental services. Ecol Econ 69:1202–1208

Nassauer JI, Opdam P (2008) Design in science: extending the landscape ecology paradigm. Landscape Ecol 23:633–644

Pandeya B, Buytaert W, Zulkafli Z, Karpouzoglou T, Mao F et al (2016) Comparative analysis of ecosystem services valuation approaches for application at the local scale and in data scarce regions. Ecosyst Serv 22:250–259

Pearce DW (1993) Economic values and the natural world. The MIT Press, Cambridge, Massachusetts

Plieninger T, Bieling C, Fagerholm N, Byg A, Hartel T et al (2015) The role of cultural ecosystem services in landscape management and planning. Curr Opin Environ Sustain 14:28–33

Schröter M, van der Zanden EH, van Oudenhoven APE, Remme RP, Serna-Chavez HM et al (2014) Ecosystem services as a contested concept: a synthesis of critique and counter-arguments. Conserv Lett 7(6):514–523

Scolozzi R, Morri E, Santolini R (2012) Delphi-based change assessment in ecosystem service values to support strategic spatial planning in Italian landscapes. Ecol Ind 21:134–144

Sustainable Sites Initiative (2015) SITES v2 rating system, for sustainable land design and development, 2015. Retrieved from: https://www.asla.org/uploadedFiles/CMS/AboutJoin/Copy%20of%20SITESv2_Scorecard%20Summary.pdf

Tempesta T (2015) Benefits and costs of urban parks: a review. AESTIMUM 67:127–143

Termorshuizen JW, Opdam P (2009) Landscape services as a bridge between landscape ecology and sustainable development. Landscape Ecol 24:1037–1052

Turkelboom F, Leon M, Sander J, Kelemen E, García-Llorente M et al (2018) When we cannot have it all: ecosystem services trade-offs in the context of spatial planning. Ecosyst Serv 29:566–578

Van Berkel DB, Verburg PH (2014) Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. Ecol Ind 37:163–174

Van Lierop M (2011) Bridging the ecosystem services concept to landscape architecture, Minor thesis. Wageningen University. Retrieved from: http://edepot.wur.nl/387032
Von Haaren C, Albert C, Galler C (2016) Spatial and landscape planning: a place for ecosystem services. In: Potschin M, Haines-Young R, Fish R, Turner RK (eds) Routledge handbook of ecosystem services. Routledge, London and New York, pp 568–578
Windhager S, Steiner F, Simmons MT, Heymann D (2010) Toward ecosystem services as a basis for design. Landscape J 29(2):107–123
Wood SLR, Jones SK, Johnson JA, Brauman KA, Chaplin-Kramer R et al (2018) Distilling the role of ecosystem services in the sustainable development goals. Ecosyst Serv 29:70–82
Wunder S (2005) Payments for environmental services: some nuts and bolts. CIFOR occasional paper no. 42
Wunder S, Thorsen BJ (2014) Ecosystem services and their quantification. What are ecosystem services? In: Thorsen BG, Mavsar R, Tyrväine L, Prokofiev I, Stenger A (eds) The provision of forest ecosystem services. Volume I: Quantifying and valuing non-marketed ecosystem services. European Forest Institute, Joensuu, pp 17–20

Social and Inclusive "Value" Generation in Metropolitan Area with the "Urban Gardens" Planning

Luisa Sturiale, Alessandro Scuderi, Giuseppe Timpanaro, Vera Teresa Foti and Giuseppe Stella

Abstract The natural environment in urban areas, often described as "urban green spaces", is recognized by numerous researches and experiences as an important element because provide indirect and direct benefits to human health and well-being. Among the objectives of the 2030 Agenda for Sustainable Development, the Goal 11, Sustainable Cities and Communities, is specifically dedicated to urban systems and its ambitious goal is "Make cities and human settlements inclusive, safe, resilient and sustainable". The "urban green spaces" is a heritage of the complex city, which requires careful assessment that considers not only the economic variable, but also the social, environmental and institutional ones. The "urban green spaces" destined to agricultural activities, defined "urban gardens", are able to offer answers to renewed food, environmental and socio-cultural needs. They can therefore be an important instrument for the integration between building renovation and natural and agricultural environments and could contribute to reducing the vulnerability of the urban system. Despite growing attention to "urban gardens" in the scientific literature, their inclusion in urban planning is not yet seen as a strategic element for a sustainable, resilient and inclusive social city model. The research aims to define the value of urban agriculture as an important instrument to regenerate abandoned or degraded urban areas, with a prevalent social and inclusive function. The proposed research is developed in the neighborhood of the city of Catania (Italy), called "Librino". The research analyzes the relations among the beneficiaries of the "urban gardens" of Librino with the aim of assessing the social and inclusive function of the urban agricultural cor of the municipal initiative, applying the Social Network Analysis (SNA) methodology.

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1 Introduction

Sustainable development, rapid urbanization and climate change are the major global challenges facing cities as outlined by a growing number of international and local initiatives/networks and by international policies, such as the 2030 Agenda for Sustainable Development (UN 2015). The document "*Transforming our world: the 2030 Agenda for Sustainable Development*" is a global call for action directed to all stakeholders and countries to act in partnership to eradicate poverty, considered as the key challenge to achieve sustainable development, integrating environmental, social and economic dimensions. The 2030 Agenda establishes 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved within the next 15 years, addressing five key areas of actions: poverty, planet, prosperity, peace and partnership. The Goal 11, *Sustainable Cities and Communities*, is specifically dedicated to urban systems and its ambitious goal is "*Make cities and human settlements inclusive, safe, resilient and sustainable*".

Urban resilience aims at increasing the ability of the whole urban system, including physical, environmental and socio-economic perspectives, to develop its adaptive capacity, resisting and recovering shocks and stresses, and at the same time to reduce its vulnerabilities.

An inclusive city centres on people by understanding that being resilient entails protecting each person from any negative impact. It actively strives towards social inclusion by promoting equality, equity and fulfilment of human rights. It fosters social cohesion and empowers comprehensive and meaningful participation in all governance processes in order to increase and/or to maintain resilience of an urban system.

According to the OECD (2014) "…*resilient cities are cities that have the ability to absorb, recover and prepare for future shocks (economic, environmental, social & institutional). Resilient cities promote sustainable development, well-being and inclusive growth*…".

The natural environment in urban areas, often described as "urban green spaces" (e.g., forests, parks, gardens, greenways), is widely considered to be an important contributor to health and also well-being (Selhub and Logan 2012; Jackson et al. 2013; Jennings et al. 2016; Tzoulas et al. 2007), provide indirect and direct benefits to human health and well-being, which are defined as EcosystemServices (ESs)[1] (Braat and de Groot 2012; CICES 2015; Atiqul Haq 2011; MEA 2005; Gómez-Baggerthun

[1]According to Costanza (1991), "… *they consist of the flows of matter, energy and information coming from the stocks of natural capital, which are combined with the services of anthropogenic artefacts to generate well-being and quality of life* …") offered, which perform the following functions: environmental-regulator; hydrogeological protection; social, recreational and therapeutic; cultural and educational; aesthetic-architectural.

and Martin-Lopez 2015) and Cultural Ecosystem Services (CESs), non-material benefits that arise from human–ecosystem relationships (Sarukhán and Whyte 2005; Chan et al. 2012).

The "urban green spaces" is a heritage of the complex city, which requires careful assessment that considers not only the economic variable, but also the social, environmental and institutional ones. They can therefore be an important instrument for the integration between building renovation and natural and agricultural environments and could contribute to reduce the vulnerability of the urban system.

In recent years, the relationship between the "city" and the "green" assumes a strategic role to reconstruct the relationships among natural, rural, and urban resources in an articulated vision of complex landscapes. This new vision of territorial system has oriented urban planning to insert and/or enhance Green Infrastructures (GIs),[2] in particular "urban gardens", very often strategically located in neighborhoods and peripheral areas.

The "urban gardens", defined as one element of urban GIs, have attracted growing attention in the literature in recent years (Breuste 2010; Calvet-Mir et al. 2012; Kabisch 2015; Drilling et al. 2016; Foti et al. 2018; Sturiale and Scuderi 2018).

Despite the growing attention to "urban gardens" in the scientific literature, their inclusion in urban planning is not yet seen as a strategic element for a sustainable and inclusive social city model.

The research aims to define the value of urban agriculture as an important instrument to regenerate abandoned or degraded urban areas, with a prevalent social and inclusive function. The urban agriculture is able to favor, for its own peculiarities, the creation of systems of relationships among the different stakeholders acting for sustainable urban development and the increasing of urban resilience.

The proposed research is developed in the neighborhood of the city of Catania (Italy), called "Librino". This area belongs to a planning project of 1970, the Japanese architect Kenzo, for the creation of a development area for Catania metropolitan city. Since the creation of the satellite neighborhood to date, there has been a gradual decline in the area with the relative social degradation and the depreciation of the value of the neighborhood properties.

The research analyzes the relations among the beneficiaries of the "urban gardens" of Librino with the aim of assessing the social and inclusive function of the urban agricultural cor of the municipal initiative, applying the Social Network Analysis (SNA) methodology.

The SNA was useful for characterize the relational network structure created by participation of residents, retired group, cultural associations, schools and rec center, farmers, institutions, scientific groups and tertiary companies in social, economic and environmental project activities.

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[2]Green Infrastructures, according to the Community definition, "… *are networks of natural and semi-natural areas planned at strategic level with other environmental elements, designed and managed in such a way as to provide a wide spectrum of ecosystem services. This includes green (or blue, in the case of aquatic ecosystems) and other physical elements in areas on land (including coastal areas) and marine areas. On the mainland, Green Infrastructures are present in a rural and urban context…*" (DG Environment 2013).

The work highlights how, starting from an urban regeneration of the Librino neighborhood, the generation of social and inclusive value brought by the "urban green spaces", and specifically by the "urban gardens", it is of extreme interest, especially for the marginal and degraded areas of the urban mosaic. The value generated by the presence of green spaces in the urban ecosystem, through the application of a vision of *agro-urban-planning*, seems to be a valid instrument for achieving the objectives of realizing resilient and inclusive cities, defined by the DSG 11.

2 Inclusive and Social Sustainable Cities: The Green Spaces in the Urban Ecosystem

In the development of the metropolitan city, the connotation of "urban green spaces" has extended, to include the green space of the complex urban ecosystem, composed of various forms of non-built spaces, including gardens, parks, vertical plants, forestry, agricultural land, wetlands and waterways (and others green and blue infrastructures) (Jim 2002; Monclús 2018; Radovanović and Lior 2017; Scuderi et al. 2016).

The new and more conscious sensibility towards the environmental sphere, supports the idea of a "green city", promotes initiatives of structural integration of the green with the built environment and involves a considerable number of disciplines in a cultural and social debate (Bednarska-Olejniczak et al. 2019; Herzele and Wiedeman 2003).

To assess the sustainability of our cities, indicators have also been developed that take into account the presence of "urban green spaces", thanks to the acknowledged contribution to the quality of life in the city (Gill et al. 2007; Wolch et al. 2014).

In the context of the SDG 11—*Sustainable Cities and Communities*—among the 11 different targets expected that aim to increasing and enhancing "urban green spaces" to make the city resilient, inclusive and sustainable, according to the perspective of this study, is the one 11.7 "*…by 2030 to provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities…*".

The GIs therefore become an important tool of action for climate adaptation, for the enhancement of ESs and biodiversity, and for social cohesion (Maloutas and Pantelidou 2004; Peters et al. 2010; Worpole and Knex 2007) in the model of a sustainable city of the future and inclusive development (Gupta et al. 2015; Sturiale and Scuderi 2018).

The urban ESs of the "urban green spaces" are direct or indirect contributions of urban ecosystems to human well-being (TEEB 2010) (provision of habitats for species, regulating services like air purification, run-off mitigation, and protection against climate extremes), cultural services (immaterial benefits) such as opportunities for recreation, environmental education and spiritual enrichment.

The social cohesion is considered a key correlate of health in cities ("inclusive cities"), then it's important to identify factors that facilitate social cohesion in urban settings. Many recent studies reveal that "urban green spaces" can promote social cohesion, social relationships and place attachment (Arnberger and Eder 2012; Seltenrich 2015; Svendsen et al. 2012).

The social aspect is fundamental in the vision of integral development with which we need to reconsider all the economic, environmental, and territorial processes. Then, it's possible consider a new *systemic conception of the city*, as a space of interaction between economic, social, cultural, and environmental elements that characterise a determined community. In this new vision, the urban agriculture assumes a strategic role to integrate natural and urban resources (Sharp and Smith 2003; Sturiale and Trovato 2013a, b; Sturiale and Scuderi 2018). The urban agriculture helps to improve the GIs of cities, as:

– it provides products (food, fiber, and biomass).
– it generates new services—*cultural ecological services*—(employment and investment, tourism and recreation, health and well-being education, social services, educational services, and therapeutic function).
– it regulates *ecological services* (climate, water, land management, and disaster prevention).
– it maintains biodiversity (DG 2013).

In urban and/or peri-urban areas, especially those most degraded, it feels increasingly necessary to support the development of routes that encourage certain activities, such as social farming and "urban gardens", that employ the tangible and intangible resources of agriculture to promote actions of inclusion (Litt et al. 2011; Scuderi et al. 2018; Sturiale and Scuderi 2018; Wakefield et al. 2007).

The ESs and the CESs must be integrated into the planning and the choices of urban planning policies, making GIs and eco-innovation the fulcrum of an inclusive, resilient and sustainable urban transformation.

3 The Contribution of Urban Agriculture to the Sustainability of Cities: The "Urban Gardens" in the New Model of *Agro-Urban-Planning*

The urban planning of the last decades is moving towards instruments that allow the transformation of the urban mosaic, through the integration of components of the urban and peri-urban territorial system and the regeneration of spaces, attributing new functions to support the development and welfare of the community, linking the different components of the city—territory—environment—agriculture system, following the three dimensions (social, environmental and economic) of the sustainable development approach. The collaboration between public and private actors in local development evidence a good network of relations between the two types of institution can encourage the improvement of the territorial system.

The implementation of GIs promotes an integrated approach to land management, determines positive effects under the aspect: economic, in the containment of some of the damages resulting from hydrogeological instability; environmental, in the fight against climate change and in the safeguarding the quality of environmental matrices (air, water, soil); social, in promoting the well-being of citizens and their social relations and promoting social inclusion.

The new relationships between cities and agriculture that are being developed in Italy (and for many years in other European countries and in the USA as well) point towards a new model of *agro-urban-planning* (Butti Al Shamsi et al. 2019; Sturiale et al. 2010; Sturiale and Scuderi 2014, 2018; Vandermeulen et al. 2006).

Regeneration projects are becoming increasingly common in which urban and peri-urban agriculture are seen as opportunities for the city (Camps-Calvet et al. 2016; Heimlich and Brooks 1989; Simon-Rojo et al. 2015; Timpe et al. 2015).

The new form of "urban rurality", better known as "urban agriculture" (Mather et al. 2006; Mougeot 2000) seems to be finding space that represents a mode of agricultural enhancement of city green spaces that is able to offer social, alimentary, environmental, and cultural responses to people's growing demand for living their city as an integrated space of buildings, recreation, and landscape (Le Texier et al. 2018; Perino et al. 2014; Zasada 2011).

The new forms of urban agriculture are: vertical green; vertical farm; urban gardens; community gardening; collective green; peri-urban agriculture, agricultural parks, urban farms, children's farms, river parks, local products markets, areas of constructed wetlands, alternative energy farms, nature conservation areas, among the most common. The urban agriculture seems to represent an interesting model that is capable of pulling together the multiple social, economic, and environmental needs of the territories and the citizens in terms of sustainability and participatory democracy (Breuste and Artmann 2014; Milligan et al. 2004; Scuderi and Sturiale 2019; Sturiale and Scuderi 2016).

In particular, re-elaborating urban sustainability oriented to urban agriculture, we could identify new functions of the city given by the interaction of three aspects: *inclusive* (social dimension), *productive* (economic dimension) and *ecological* (environmental dimension), listed in detail in Fig. 1. The three dimensions, although distinct in their functions, are not in reality separate but tend to integrate each other.

The model of *agro urban planning*, based on this vision of urban planning integrated by urban agriculture, could help to achieve the objectives of inclusive city and social sustainability, through the different functions of the urban agriculture.

Among the different forms of urban agriculture, the "urban gardens" and agricultural parks, for the experiences acquired and documented previously, could be considered effective to achieve the goal of making cities more inclusive and resilient.

In particular, the "urban gardens" may cover a broad range of typologies, including school gardens, therapeutic gardens, allotment gardens, home gardens, and community gardens. The importance of "urban gardens" (Camps-Calvet et al. 2016) is due to their: social functionality and high intensity of use (Breuste 2010); role in building resilience (Barthel et al. 2013); contributions to human well-being through the delivery of ESs (Breuste and Artmann 2014; Langemeyer et al. 2016).

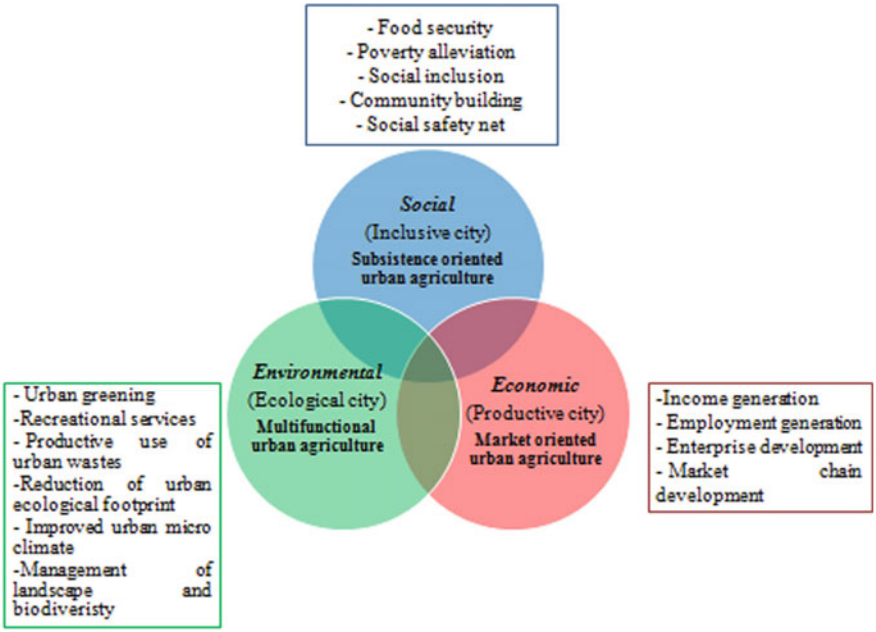

Fig. 1 The dimensions of urban sustainability oriented to urban agriculture (our elaboration on FAR source, 2018)

4 The Social and Inclusive Value of “Urban Green Spaces”: The Case Study of the Urban Garden “*Orti ed Arte di Librino*” (Catania)

The city of Catania is the second city, in terms of importance, surfaces and inhabitants of the Sicily Region with an area of 831 km^2, about 350,000 inhabitants; the extension of the urban green is 4,843,660 m^2, and the urban green per inhabitant is 16.4 m^2. In relation to the socio-economic development of the city, the green areas play an important and specific role both as an urban component, for the conservation and improvement of the landscape and the environment, and as a means for aggregative purposes for social and cultural integration. The GIs have assumed an important role in recent urban redevelopment policies and among the various initiatives, the recent one of the urban garden of Librino is attracting interest among municipalities and actors involved.

The neighborhood of Librino represents a socially complex area with strong environmental degradation; the resident population, about 80,000 people, is characterized by an unemployment rate of about 50%. In this area, however, is concentrated 20% of the green areas of the municipality of Catania, mostly abandoned and subject to degradation.

Table 1 Definition of the benefits of the project "*Orti and arte di Librino*" (Catania)

Social	Economic	Environmental
Safe space Relational exchange Food safety Know how exchange Awareness of food value Social inclusion Better quality of life	Self production Short supply chain Savings on food expenditure Maintenance of public spaces at no cost Training projects	Protection of biodiversity Healthy safety Improvement of the landscape Maintenance of rural culture Reuse of familiar organic waste

Source Our elaborations on information provided by the Municipality of Catania

The urban garden called "*Orti ed Arte di Librino*" (from the name of the neighborhood in which it is located), is part of the "Cities and Regions of the EU for a sustainable food policy" european initiative, that involved the realization of the largest urban garden in Europe, covering more than 50,000 m^2 (Fig. 2a–c). It's placed among the tools of urban agriculture, provided in urban planning, and provides for the allocation of lots of land to the residents of the neighborhood, in order to promote above all the social relations among the actors and the social inclusion.

The cultivations of "urban gardens" present, not for profit, are assigned on loan to the requesting citizens[3] and provide products intended for family consumption according to biologic methods. They have educational, therapeutic, social, environmental value contributing to preserve, to conserve and to enhance the interstitial green areas between the built-up areas of the mostly uncultivated areas and destined for abandonment and degradation. They promote the social relations, the cohesion and social governance, the exchange of knowledge and the enhancement of the urban environment.

The benefits of the urban garden of Librino are shown in the Table 1 classified in the three dimensions of sustainable development (economic, environmental and social).

There are different types of gardens assigned: family, social, community, educational, non-profit associations. Specific types of applicants, recipients, dimensions and functions are associated with each type of gardens.

After two years from the start and the assignment of the first lots of the "*Orti e arti di Librino*" (municipal initiative started in 2016), the data related to the assignments show that 80% is destined to single subjects, for the remaining 20% of the lots to schools and associations.

At the end of 2018, around 90 lots of about 200 m^2 were assigned, with different criteria depending on the type of garden; the typologies of activated gardens are familiar (mainly), social, educational and associations.

In relation to the degraded area and the marginal neighborhood in which the garden is inserted, it emerges that it represents the hope of having safe spaces, improvement of the landscape and a different form of social inclusion that allows the connection

[3] A fee of 0.42 €/m^2/year is foreseen for the duration of the concession—4 years.

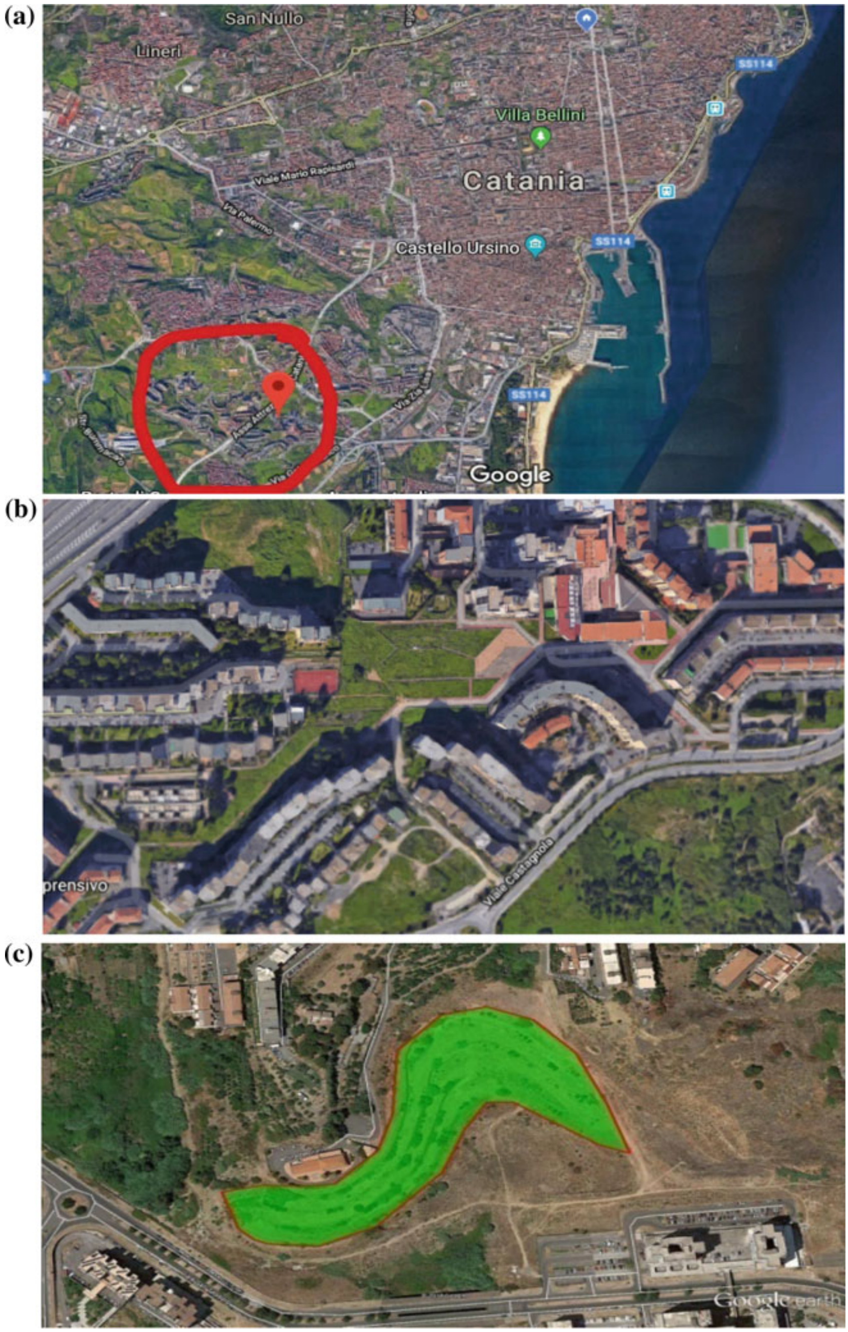

Fig. 2 **a** Localization of the urban garden “*Orti ed Arte di Librino*” in Catania (overview). **b** Localization of the urban garden “*Orti ed Arte di Librino*” in Catania (Viale Castagnola). **c** Localization of the urban garden “*Orti ed Arte di Librino*” in Catania (Viale S. Teodoro)

between the suburbs and the city. The importance of the urban garden of Librino is the location in a socially disadvantaged neighborhood, whose uncultivated green areas are subject to urban decay. It represents a first but important step for urban regeneration but, above all, for the social rehabilitation of the resident population and for the inclusive function.

5 Methodology

The research aims to evaluate the complex system of relationships of the relational network that different actors have developed around various urban agriculture actions, activated by the municipal project in the urban garden of Librino.

The SNA (Scott 2000; Hanneman and Riddle 2005) is an analytical-scientific method that analyzes social reality starting from its reticular structure assuming that the actors participate in the social life creating links with other actors and that these ties influence the mutual behaviour.

All actors involved in social, economic and environmental projects activity (Comino et al. 2016), both in the preparatory phase and in the executive phase, are in relation to each other. The relationship or tie is determined by co-participation in the activities. The relational network generates social capital on the territory.

The research was carried out in 2018, saw a first phase, desk-work, study of the project and evaluation of the initiative based on the documentation provided by the Municipality of Catania.

In the next phase, field work, a direct investigation was carried out in this area in order to characterize the first lots of land allocated for the launch of the urban garden of Librino.

The collection of information was performed using the "face to face" interview methodology, interacting with the technicians of the Municipality of Catania, the sector stakeholders and the residents of the area.

The survey tool was the questionnaire, specially prepared, given to 500 subjects with a direct interest in the Librino area. The questionnaire was structured in order to collect the relationships between the subjects active in the management of the area and the actions activated for the construction of the urban garden of Librino.

The actors of the network studied are: resident citizens; retired groups; cultural associations; schools/rec centres, farmers; institutions; scientific groups; tertiary companies.

The projects/actions in the urban garden of Librino have been brought together in three keys to understanding social, economic and environmental aspects in relation to the multifunctionality that the urban garden has in the territory (Table 2).

A binary affiliation matrix (*actors* × *actions*) that relates the actors to the actions was constructed. Each matrix element assumes a value of 1 if there is a participation in a specific project, otherwise assumes value of 0.

Starting from the affiliation matrix, the following can be calculated: (a) the *actors* × *actors* matrix where each matrix element represents the number of participations

Table 2 Theme and actions (relative ID code) in which the actors of the network participate

Themes	Actions	ID code
Social	Food education projects	S1
	Training projects	S2
	Actions for employment insertion	S3
	Actions for presence in the territory	S4
Economic	Agricultural production	E1
	Self-sustaining	E2
	Investments for implementation and management	E3
	Improvement of the urban context and relative valorization of the building value	E4
Environmental	Actions to improve the quality of the landscape	A1
	Actions to improve the climate	A2
	Actions for the reduction of pollution	A3
	Projects to enhance biodiversity	A4

Source Our elaborations on information provided by the Municipality of Catania

in the project activities that the *i*-row actor have with the *j*-column actor; (b) the *actions* × *actions* matrix where each matrix element represents the number of actors that the i-row action shares with the *j*-column action. Both matrices are squares and symmetrical.

By means of dedicated software, in this specific case through UCINET 6.587 (Scott 2000; Borgatti et al. 2002; Hanneman and Riddle 2005), it is possible to elicit both the graph of the network and certain characteristics such as density and level of centrality.

In the graph the nodes (actors and actions for the *affiliation matrix*, actors for the *actors* × *actors* matrix and actions for the *actions* × *actions* matrix) are connected and linked via a line with the arrowhead pointing to the direction of the link. In the case of the *actions* × *actions* and *actors* × *actors* matrices, the length of the line connecting two nodes is proportional to the strength of the tie between them.

The density, extracted from the dichotomised matrix, is the ratio between the number of effective links and the number of dyads (pairs), or of all the possible dyadic links theoretically existing. In the case that the matrix has a value of 1 then we have the maximum density. That is, each node is connected with all the others in all directions (incoming and outgoing). If the density value is zero, then all the nodes of the network are disconnected.

The centrality level, in this case, is calculated through an index called Power Degree. The Power Degree of a node is the overall number of bonds that it possesses, understood as in-degree and out-degree, namely the number of links that arrive or depart from a given node. It is useful, for the purposes of comparison between networks, to normalise the absolute value and compare it to the total number of possible links (that is, to k − 1, where k is the number of actors in the network). The measures of in and out-degree have great importance in sociological terms, expressing the role played by the actors involved, in that the more links one actor has, the more power he possesses, conferring therefore, a greater opportunity of choice. This autonomy makes it less dependent on the other actors, and therefore more powerful. The direction of centrality poses the nodes as emitters or receivers of information, and therefore distinguishes a role that is dynamic or is one of reference (Scott 2000; Borgatti et al. 2002; Hanneman and Riddle 2005).

6 Results: The Evaluation of Existing Relationships

Affiliation network

Figure 3 shows the graph of the network formed by affiliation matrix connected to the urban garden of Librino. In particular, red colour corresponds to a different actor and blue color to an action; the arrows indicate the direction of the bond; the length of the ties indicates the intensity of the exchange of information between the nodes in the preparatory and executive phase of the projects.

The graph shows that resident citizens, cultural associations and schools have a great ability to attract links with other actors in the network compared to other entities in the territory. Another aspect of the network that emerges is that all the subjects involved are very dynamic in the flow of information concerning the preparation and execution of the projects.

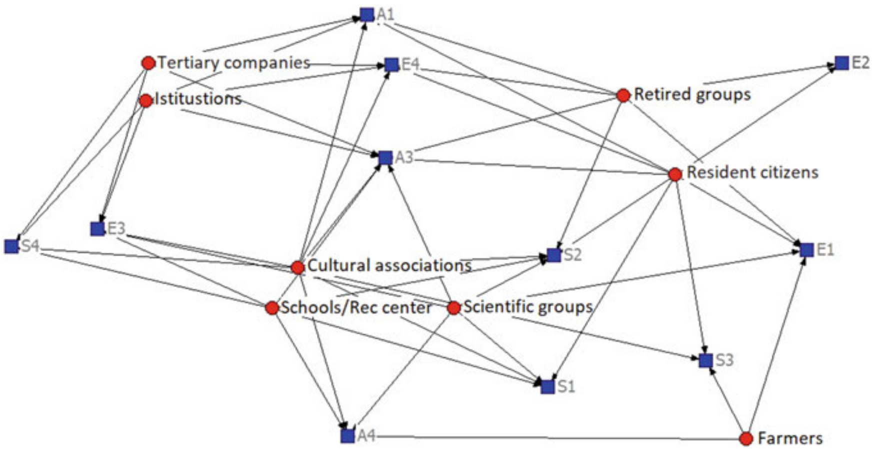

Fig. 3 Graph of the relational affiliation network

Table 3 ID action and actor code and associated % normalized degree (Nrm Deg) measured

ID action code	Nrm Deg (%)	ID actor code	Nrm Deg (%)
A2	58.44	Cultural associations	79.59
A3	58.44	Resident citizens	67.35
S2	45.45	Schools/rec center	59.18
E4	42.86	Scientific groups	59.18
A1	40.26	Retired groups	57.14
E3	37.66	Institutions	55.10
S1	32.47	Tertiary companies	55.10
S4	29.87	Farmers	16.33
A4	28.57		
E1	24.68		
S3	18.18		
E2			

Source Our elaboration and data collected directly from the survey

The communications among the participants instead have a low level, in fact it goes towards an overlap of star networks, where every central element is represented by all the other subjects.

From the density measures, it is evident how the network triggers about 57% of the possible ties, highlighting a medium system of relationships. The value of standard deviation, quite high, in relation to the density value, indicates, however, not a uniform commitment of all the actors to the actions (Density (matrix average) = 0.5729, Standard deviation = 0.4947).

The centrality indicates the action or the actor who is at the center of the network, that is, attracts more ties and it is quantified through the normalized power degree index (Table 3).

The action or the actor identified are those that most influence the network and have a role as a possible reference point.

The central actions are: Environmental actions (in particular A2: action to improve the climate and A3: actions for the reduction of pollution); Social actions (S2: actions to training projects); Economic action (E4 actions: improvement of the urban context and valorisation of property values).

It's interesting to highlight that the actions linked to the specific agricultural production are located in the last place, demonstrating that urban agriculture, in the marginal context considered, has a mainly social and environmental functions and non-productive.

This result can also be highlighted by the relationships among the actors of the network. Indeed, the central actors are: Cultural associations and Resident citizens. Farmers have a marginal role (contrary to what one might think). The results confirm that the function of "urban gardens" is not the economic-productive one of agriculture but that of activating actions of social cohesion and safeguarding the urban landscape.

7 Conclusions

In the city, the agricultural dimension has been reinforced, with diverse functions and various types of integration with the urban mosaic, that allow for a response to the objective of public planning and management entities of the city according to the sustainable model in its three dimensions (economic, environmental, and social).

The urban sustainability is oriented towards planning that will have to consider green spaces in the design of the urban landscape to offer the population significant opportunities to interact with nature and be able to benefit from the ESs offered by them. The "urban gardens" managed collectively, such as allotments gardens or community gardens, these are examples of such places.

The project of the Municipality of Catania has shown that it can promote coordination among the different dimensions of sustainable development, by increasing the flow of information, sharing experiences and creating knowledge and trust.

The network identified with the proposed case study seems to assume still greater significance for the metropolitan area of Catania, in which the needs of the urban and the rural contexts meet. The model of integration studied presents the following characteristics: dynamicity, reciprocity, and relationality.

The social and relational network of the "urban gardens" of Librino has favored the synergistic use of endogenous resources (human, economic, environmental, technological) of rural and urban territories in a climate of mutual trust among the actors (networking, partnership) that it must be supported by adequate planning and multilevel governance actions.

However, SNA analysis show as the relational network, developed during the project activities, can be improved both in terms of participation of all the actors involved and in terms of the type of activity. The development approach currently underway, as shown by the centrality measures, is strongly oriented to social and environmental aspects, especially involving the resident citizens and the cultural associations, leaving a marginal role to the farmers for the economic aspects.

This process, then, necessitates the support of adequate instruments of *agro-urban planning* that in our country are, from the research conducted, in some cases designed and operationally effective, in other cases only in the design phase and, in many other urban realities, unfortunately still absent.

The "urban gardens" are characterized by the prevalence of the social and environmental function, the agricultural practice is only functional to the activation of social inclusion and environmental actions.

In the urban context, the combination of an ortho-farmer turns into a ortho-social-green garden.

It would be desirable the recourse to models of urban governance in which the human and social function of agriculture is recognised and reinforces its role as an instrument for the re-conquest of social, economic, and environmental values in urban and peri-urban areas, above all in areas with social difficulties.

This is the task that is now up to the current administrators: to reverse the route and demonstrate that the coupling of economic growth and land consumption is no longer sustainable. It's necessary to replace the expansive building processes with the virtuous ones of urban regeneration, in which the GIs and, in particular, the "urban gardens" take on an increasingly important role for their functions of social inclusion and environmental protection.

In such a systemic model of integration of urban and peri-urban resources, the agriculture is not seen merely as the set of traditional factors of production of agricultural goods, but also as an actor who is part of a system of integrated relationships with the actor of the city (agricultural enterprises, other enterprises, institutions, and local communities) for the sustainable and inclusive development of the city.

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References

Arnberger A, Eder R (2012) The influence of green space on community attachment of urban and suburban residents. Urban For Urban Greening 11:41–49

Atiqul Haq SM (2011) "urban green spaces" and an integrative approach to sustainable environment. J Environ Prot 2:601–608

Barthel S, Parker J, Ernstson H (2013) Food and green space in cities: a resilience lens on gardens and urban environmental movements. Urban Stud 52(7):1–18

Bednarska-Olejniczak D, Olejniczak J, Svobodová L (2019) Towards a smart and sustainable city with the involvement of public participation—the case of Wroclaw. Sustainability 11:332

Borgatti SP, Everett MG, Freeman LC (2002) UCINET 6 for windows. Analytic Technologies, Harvard, p 185

Braat LC, de Groot R (2012) The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv 1:4–15

Breuste J (2010) Allotment gardens as part of urban green infrastructure: actual trends and perspectives in Central Europe. In: Müller N et al (eds) Urban biodiversity and design. Blackwell Publishing, Hoboken, pp 463–476

Breuste J, Artmann M (2014) Allotment gardens contribute to urban ecosystem service: case study Salzburg, Austria. J Urban Plann Dev 141(3):A5014005

Butti Al Shamsi K, Guarnaccia P, Cosentino SL, Leonardi C, Caruso P, Stella G, Timpanaro G (2019) Analysis of relationships and sustainability performance in organic agriculture in the United Arab Emirates and Sicily (Italy). Resources 8(1):39

Calvet-Mir L, Gómez-Baggethun E, Reyes-García V (2012) Beyond food production: ecosystem services provided by home gardens. A case study in VallFosca, Catalan Pyrenees, Northeastern Spain. Ecol Econ 74:153–160

Camps-Calvet M, Langemeyerab J, Calvet-Mirac L, Gómez-Baggethunde E (2016) Ecosystem services provided by "urban gardens" in Barcelona, Spain: insights for policy and planning. Environ Sci Policy 6(62):14–23

Chan KM, Guerry AD, Balvanera P, Klain S, Satterfield T, Basurto X, Bostrom A, Chuenpagdee R, Gould R, Halpern BS (2012) Where are cultural and social in ecosystem services? A framework for constructive engagement. Bioscience 62:744–756

Comino E, Bottero M, Pomarico S, Rosso M (2016) The combined use of spatial multicriteria evaluation and stakeholders analysis for supporting the ecological planning of a river basin. Land Use Policy 15:183–195

Common International Classification of Ecosystem Services (CICES) (2015) Structure of CICES. European Environment Agency, Copenhagen, Denmark. Available online: http://cices.eu. Accessed on 3 Feb 2019

Costanza R (ed) (1991) Ecological economics: the science and management of sustainability. Columbia University Press, New York

DG (2013) Environment directorate-general for the environment. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Green Infrastructure (GI)—Enhancing Europe's Natural Capital, Bruxelles

Drilling M, Giedych R, Poniży L (2016) The idea of allotment gardens and the role of spatial and urban planning. In: Bell S et al (eds) Urban allotment gardens in Europe. Routledge, London

Foti VT, Scuderi A, Stella G, Sturiale L, Timpanaro G, Trovato MR (2018) The integration of agriculture in the politics of social regeneration of degraded urban areas. In: Mondini G, Fattinnanzi E, Oppio A, Bottero M, Stanghellini S (eds) Integrated evaluation for the management of contemporary cities. Results of SIEV, green energy and technology. Springer, Cham, pp 99–111

Gill SE, Handley JF, Ennos AR, Pauleit S (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environ 33:115–133

Gómez-Baggerthun E, Martin-Lopez B (2015) Ecological economics perspectives on ecosystem services valuation. In: Martinez-Alier J, Muradian R (eds) Handbook on ecological economics. Edwuard Elgar, UK, pp 260–282

Gupta J, Pouw N, Ros-Tonen M (2015) Towards an elaborated theory of inclusive development. Eur J Dev Res 27:541–559

Hanneman RA, Riddle M (2005) Introduction to social network methods. University of California, Riverside, CA (published in digital form at http://faculty.ucr.edu/~hanneman/)

Heimlich RE, Brooks DH (1989) Metropolitan growth and agriculture: farming in the city's shadow. Agricultural economic report 619. Economic Research Service, USDA

Herzele V, Wiedeman T (2003) A monitoring tool for the provision for accessible and attractive green spaces. Landsc Urban Plann 63(2):109–126

Jackson L, Daniel J, McCorkle B, Sears A, Bush K (2013) Linking ecosystem services and human health: the eco-health relationship browser. Int J Public Health 58:747–755

Jennings V, Larson L, Yun J (2016) Advancing sustainability through "urban green spaces": cultural ecosystem services, equity, and social determinants of health. Int J Environ Res Public Health 13:196

Jim CY (2002) Planning strategies to overcome constraints on greenspace provision in urban Hong Kong Town. Plann Rev 73:127–152

Kabisch N (2015) Ecosystem service implementation and governance challenges in "urban green spaces" planning-the case of Berlin, Germany. Land Use Policy 42:557–567

Langemeyer J, Latkowska MJ, Gomez-Baggethun E, Voigt A, Calvet-Mir L, Pourias J, Camps-Calvet M, Orsini F, Breuste J, Artmann M, Jokinen A, Béchet B, Brito da Luz P, Hursthouse A, Stępień MP, Baležentiene L, Bell S et al (eds) (2016) Ecosystem services from "urban gardens", urban allotment gardens in Europe. Routledge, London

Le Texier M, Schiel K, Caruso G (2018) The provision of "urban green spaces" and its accessibility: spatial data effects in Brussels. PLoS ONE 13(10):e0204684. https://doi.org/10.1371/journal.pone.0204684

Litt JS, Soobader MJ, Turbin MS, Hale JW, Buchenau M, Marshall JA (2011) The influence of social involvement, neighborhood aesthetics, and community garden participation on fruit and vegetable consumption. Am J Public Health 101:1466–1473

Maloutas T, Pantelidou M (2004) Debats and developments: the glass menagerie of urban governance and social cohesion concepts and stake/concepts as stakes. Int J Urban Reg Res 28:449–465

Mather AS, Hill G, Nijnik M (2006) Post-productivism and rural land use: cul de sac or challenge for theorization? J Rural Stud 22(4):441–455

Millenium Ecosytem Assessment (MEA) (2005) Global assessment reports: current state and trends. Island Press, Washington, DC

Milligan C, Gatrell A, Bingley A (2004) 'Cultivating health': therapeutic landscapes and older people in Northern England. Soc Sci Med 58:1781–1793
Monclús J (2018) From park systems and green belts to green infrastructures. In: Díez Medina C, Monclús J (eds) Urban visions. Springer, Cham
Mougeot LJ (2000) Urban agriculture: definition, presence, potentials and risks. Growing cities, growing food. Urban agriculture on the policy agenda, pp 1–42
OECD (2014) Overview paper on resilient economies and societies. OECD ministerial council meeting
Perino G, Andrews B, Kontoleon A, Bateman I (2014) The value of "urban green spaces" in Britain: a methodological framework for spatially referenced benefit transfer. Environ Resour Econ 57:251–272
Peters K, Elands B, Buijs A (2010) Social interactions in urban parks: stimulating social cohesion? Urban For Urban Greening 9:93–100
Radovanović M, Lior N (2017) Sustainable economic–environmental planning in Southeast Europe—beyond-GDP and climate change emphases. Sustain Dev 25:580–594
Sarukhán J, Whyte A (eds) (2005) Ecosystems and human well-being: synthesis (millennium ecosystem assessment). Island Press, World Resources Institute, Washington, DC
Scott J (2000) Social network analysis. A handbook. Sage, London
Scuderi A, Sturiale L (2019) Evaluations of social media strategy for green urban planning in metropolitan cities. Smart Innov Syst Technol 100:76–84
Scuderi A, Sturiale L, Bellia C, Foti VT, Timpanaro G (2016) The redefinition of the role of agricultural areas in the city of Catania. Rivista di Studi sulla Sostenibilità 2:237–247
Scuderi A, Foti V, Stella G (2018). Social farm action value: the case study of "Case di Maria". Calitatea 19(S1):475–481
Selhub EM, Logan AC (2012) Your brain on nature: the science of nature's influence on your health, happiness and vitality. Wiley, New York
Seltenrich N (2015) Just what the doctor ordered: using parks to improve children's health. Environ Health Perspect 123:A254–A259
Sharp JS, Smith MB (2003) Social capital and farming at the rural-urban interface: the importance of nonfarmer and farmer relations. Agric Syst 76(3)
Simon-Rojo M, Recasens X, Callau S, Vejre H (2015) From urban food gardening to urban farming. In: Lohrberg F, Licka L, Scazzosi L, Timpe A (eds) Urban agriculture Europe. Jovis, Berlin, pp 22–28
Sturiale L, Scuderi A (2014) The creation of itineraries of "slow travel" in Sicily: the case of "the ways of the Zagara". In: Proceedings of the XVIII IPSAPA interdisciplinary scientific conference. Special issue 2, pp 257–268
Sturiale L, Scuderi A (2016) Le nuove forme del verde nel mosaico urbano: verso una pianificazione agro-urbana per riattivazione di spazi e funzioni. In: Proceedings of the XX IPSAPA interdisciplinary scientific conference, Reggio Calabria (Italia), Luglio 7–8, 2016, Special issue
Sturiale L, Scuderi A (2018) The evaluation of green investments in urban areas: a proposal of an *eco-social-green* model of the city. Sustainability 10:4541
Sturiale L, Trovato MR (2013a) The enhancing of the environmental landscape and the cultural heritage by a project of agricultural park. In: Society, integration, education. Proceedings of the international scientific conference, Udine, 27/28 June 2013, III, pp 201–212
Sturiale L, Trovato MR (2013b) The agricultural park as a tool to enhance the agricultural landscape of the SIC "Timpa di Acireale" (CT). In: Crescimanno M, Casini L, Galati A (eds) Evoluzione dei valori fondiari e politiche agricole. Bologna, Medimond Monduzzi Editore international proceeding division, pp 185–210
Sturiale L, Calabrò F, Della Spina L (2010) Un programma complesso per la valorizzazione e la promozione del mosaico paesistico-culturale del SIC "Collina di Pentimele" (RC). Architettura del Paesaggio, gennaio/giugno, pp 69–85
Svendsen E, Northridge ME, Metcalf SS (2012) Integrating grey and green infrastructure to improve the health and well-being of urban populations. Cities Environ (CATE) 5(1):3

TEEB (2010) The economics of ecosystems and biodiversity: ecological and economic foundations UNEP/earthprint. Available online: www.teebweb

Timpe A, Cieszewska A, Supuka J, Toth A (2015) Urban agriculture goes green infrastructure. In: Lohrberg F, Licka L, Scazzosi L, Timpe A (eds) Urban agriculture Europe. Jovis, Berlin, pp 126–137

Tzoulas K, Korpela K, Venn S, Yli-Pelkonen V, Kazmierczak A, Niemela J, James P (2007) Promoting ecosystem and human health in urban areas using green infrastructure: a literature review. Landsc Urban Plan 81:167–178

United Nations (2015) Transforming our world: the 2030 agenda for sustainable development. United Nations, New York

Vandermeulen V, Verspecht A, Van Huylenbroeck G, Meert H, Boulangerc A, Van Eecke E (2006) The importance of the institutional environment on multifunctional farming systems in the peri-urban area of Brussels. Land Use Policy 23(4):486–501

Wakefield S, Yeudall F, Taron C, Reynolds J, Skinner A (2007) Growing urban health: community gardening in South-East Toronto. Health Promot Int 22:92–101

Wolch JR, Byrne J, Newell JP (2014) “urban green spaces”, public health, and environmental justice: the challenge of making cities ‘just green enough’. Landsc Urban Plan 125:234–244

Worpole K, Knex K (2007) The social value of public spaces. Joseph Rowntree Foundation, UK

Zasada I (2011) Multifunctional peri-urban agriculture—a review of societal demands and the provision of goods and services by farming. Land Use Policy 28(4):639–648

Environmental Economics and Evaluation of the Benefits Deriving from the Regeneration of Natural Ecosystems: The Case of the Diecimare Nature Oasis

Domenico Tirendi

Abstract The intensification and progressive urban growth of the last decades has led to a significant loss of green and naturalistic areas in our cities. Above all in Italy, the creation of new public green spaces can't keep up with the development of the built-up areas. Although it is necessary to provide citizens, through the planning and design of cities, with standards relating to green spaces, the endowment of these often seems lacking, not even meeting the minimum requirements. Living in the city today does not mean living well. Migration from rural areas has progressively increased urban density and anthropogenic pressure towards natural ecosystems. For this reason, in 2015 the United Nations approved the Global Agenda for Sustainable Development (https://sustainabledevelopment.un.org). In particular, Objective 11 of the 2030 Agenda aims to "make cities and human settlements inclusive, safe, durable and sustainable" through actions aimed at "protecting and safeguarding the cultural and natural heritage of the world". Based on this perspective, the objective of the present study is to provide the public operator with elements able to bring out the economic and social benefits related to the adoption of policies of regeneration, reconstruction, recovery, reuse of natural resources and landscape of an important naturalistic area progressively and inexorably abandoned: the Diecimare Park. This is a naturalistic oasis, managed for years by the WWF, an area occupied by chestnut groves and beech trees, elms, alders and poplars planted in the 1700s on the hills that separate the Lattari mountains from the Picentini mountains extending into the municipalities of Cava de' Tirreni, Mercato San Severino and Baronissi. It is a very precious area to be protected and rediscovered as it constitutes a veritable spontaneous botanical garden where hundreds of species of flowers and fauna are mixed. Making an economic assessment of natural and forested public resources to improve and implement services offered to users (information totems, creation of shuttles to/from the city center, creation of car parks, redevelopment of existing paths, creation of new bird observation posts, provision of suitable areas for recreational activities, guided visits by experts, etc.) allows to relate the size of the expenditure to be incurred for the recovery of the forest heritage. These economic benefits can often "escape the market". As they are a public resource, but, through specially prepared assessments,

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such as the Contingent Valuation (CV) that uses questionnaires to be given to a sample of tourists and residents we can "capture" some intangible benefits such as preserving the quality of life and biodiversity.

Keywords Natural parks · Economic evaluation of natural assets · Contingency assessment · Travel cost method

1 Introduction

Although it is necessary to provide citizens, through the planning and design of cities, with standards related to green spaces, their endowment often seems lacking, not even meeting the minimum requirements. In fact the era of the industrial city, aptly described by Calvino (1963) in "Marcovaldo ovvero le stagioni in città" is now over, at least in Italy.

Parks, therefore, represent the last barrier to oppose the widespread overbuilding of the cities affected by an often ornamental nature.

2 Taxonomy of Landscape Values

Many people, including environmentalists, believe that economic disciplines have not only seriously faced problems related to the natural environment, but have often been co-responsible for the upheavals perpetrated against, as they are limited and oriented towards the sole pursuit of economic efficiency to be achieved minimizing the difference between benefits and costs.

In reality, this could have been shared with a traditional economic approach, but since the 60s (Turner et al. 1993), Environmental Economics have paved the way for the monetization of benefits (also in the form of opportunity costs) that nature can provide, with great economic value.

Nature, in fact, above all in the form of "Park" or naturalistic Oasis offers a series of benefits related to the self-regulation of natural or geo-bio-chemical cycles of water, oxygen, carbon, nitrogen, phosphorus, etc., to provide a suitable habitat, food and regenerative capacity for biodiversity, to mitigate disasters such as landslides, floods, to provide food, materials and energy to people (economic capital) and also to offer tangible and intangible benefits of type aesthetic and recreational, visual-perceptive, therapeutic, educational, cultural, historical, spiritual and religious to people (See Fig. 1: Matrix green typologies in urban areas and related services performed by Millennium Ecosystem Assessment 2005, re-elaborated by PN Studio 2010).

In this regard, the Millennium Ecosystem Assessment describes four categories of eco-system services that can be grouped into four broad categories (Millennium Ecosystem Assessment 2003):

	FUNCTION	TYPE OF GREEN	Natural areas	Urban and periurban forests	Periurban Parks	Parks and urban gardens	Private green	Vegetable gardens	Filter bands	Rows	Hedges	Roof garden	Vertical green	Cycle paths
SOIL, NUTRIENTS AND PRIMARY PRODUCTION	ADJUSTMENT FUNCTION	Environmental	x	x	x	x	x	x	x			x	x	
		Climate	x	x	x	x	x	x	x	x	x	x	x	
		Ecological	x	x	x	x	x	x	x	x	x	x	x	
		Natural risk	x	x	x	x	x		x					
		Soil protection	x	x	x	x	x	x						
		Water regulation	x	x	x	x	x	x	x			x	x	
	ECONO MIC	Energy	x	x	x	x			x			x	x	x
		Food	x	x	x			x						
		Wood	x	x	x	x				x				
	SOCIAL-CULTURAL	Landscaping	x	x	x	x	x	x	x	x	x	x	x	x
		Hygienic	x	x	x	x	x		x	x	x			
		Therapeutic	x	x	x	x	x	x				x	x	x
		Aesthetic	x	x	x	x	x	x	x	x	x	x	x	x
		Educational	x	x	x	x		x				x	x	x
		Cultural	x	x	x	x								x
		Ricreational/Tourist	x	x	x	x								x
		Historic	x	x	x	x				x	x			x
		Spiritual/Religious	x	x	x	x								

Fig. 1 Perceived benefits

– life support (such as nutrient cycle, soil formation and primary production);
– regulation (such as climate and tide regulation, water purification, pollination and pest control);
– supply (such as the production of food, drinking water, materials or fuel);
– cultural values (including aesthetic, spiritual, social, educational and recreational ones).

Attempting to "capture" these benefits is the task of every researcher who sets himself the ambitious goal of evaluating the landscape.

The landscape is a public resource from which society derives both benefits for use and non-use (Signorello 2007). The present contribution aims to offer a summary of the commonly applied methodologies for the economic evaluation of the landscape (Santos 1998; Stellin and Rosato 1998; Nunes 2002; Tirendi 2003; Signorello et al. 2005), not neglecting highlighting the most significant aspects and operational practices of the updated literature concerning the estimation of goods without a market, as well as applying these methodologies to the economic evaluation of a naturalistic Oasis today immersed in degradation and victim of abandonment: the Diecimare Park.

The landscape is a public resource linked to a specific territory, nowadays progressively more fragile because it is subject to "pressures" of various kinds. When it concerns the protection of the natural landscape, which becomes increasingly scarce, due to the wild cementification that has changed the face of our country from the 1950s to the present day, public intervention is invoked up by everyone demanding protection at an appropriate level.

People receive numerous benefits from the landscape whether they use it or not, as summarized in Fig. 1. Its value is not directly detected by the market (shadow-price); however, to know how much these benefits "weigh" in monetary terms (in fact normally only direct and indirect costs are very well known) this exercise is not at all infertile or academic as it is necessary to strengthen and justify public intervention, especially in times such as the current ones of economic crisis, "spread" to the stars, containment of costs of public expenditure and constant growth of inflation.

A public good such as a landscape, a park or a naturalistic oasis, counting many benefits and being non-excludable and non-rival in “consumption”, requires complex and articulated theories and evaluation tools to translate the individual usefulness into monetary terms.

The Total Economic Value (TEV) (Turner et al. 1993), refers, in fact, precisely to the assessment of the preferences of individuals and not to the value itself (intrinsic) of environmental resources. The evaluation of the benefits of individuals starts from the assumption that people perceive (and therefore are willing to pay) a “price” for these resources in terms of ticket, tax or contribution, travel expenses, etc. if they receive from their consumption a utility at least equal to a certain monetary disbursement. These individuals, in the same way as any consumer, will compare the usefulness that comes from the use of these goods with the consumption of other goods and/or alternative services (opportunity costs) related to leisure such as visit to a museum or a film at the cinema, etc.

TEV can be interpreted as the sum of the use value and the value independent of use. In turn, the value in use can be traced back to the value of direct use, the indirect use value, the option value or deferred use, while the value independent of use can be assessed as the sum of the value of existence and of hereditary or legacy value (Fusco Girard and Nijkamp 1997).

3 Evaluation Approach

The evaluation of naturalistic and landscape resources, from an exquisitely methodological point of view, lends itself to the use of evaluative tools of the Pigouvian type (Cornes and Sandler 1985), based on the principle “who receives the benefits pays”, explained through the use of direct evaluation methodologies such as contingency or indirect assessment such as Travel Costs or Hedonic Prices. The direct methods, based on the questionnaires to be subjected to predetermined samples of individuals, have as a sole contraindication that they have to be considered credible by the interviewed people, as well as that of minimizing the strategic behaviors of these in order not to make the whole evaluation process vain.

If the hypothetical scenarios and the chosen payment vehicle should be credible and strategic behavior minimized or eliminated altogether, the contingency assessment is the evaluation tool that best allows us to provide an accurate estimate of the TEV. It directly consults the end users of a “product” and allows the construction of the most appropriate sustainability indicators to grant landscape-territorial planning with the wishes and preferences expressed by local communities in full transparency, effectiveness and efficiency, as desired by the European Landscape Convention of the Council of Europe (https://www.coe.int/en/web/landscape).

The economic value is based on the economic theory focused on rationality and on the sovereignty of the individual-consumer who will choose to consume one good rather than another based on his own preferences, or more precisely, from the utility that derives from it in terms of compensating or equivalent variation. If the variation of

Table 1 TEV of naturalistic resource, own elaboration

Use value				Non use value	
Related to the market	Not related to the market	Indirect	Option	Existence	Bequest
Wood	Landscape	Climatic effects	Biodiversity	Biodiversity	Biodiversity
Fruits, mushrooms and chestnuts	Recreational services	Salubrity of the air	Landscape	Landscape	Landscape
Hunting		Rainwater regulation	Quality of the air	Quality of the air	Recreational services
Fishing		Biological substances	Rainwater regulation		Market goods
		Reduction of landslide risk	Biodiversity		Quality of the air
		Increase of the price of homes			Climatic effects

the offer of a naturalistic asset such as the Parco Diecimare produces an improvement of individual well-being, the compensatory variation (VC) expresses the maximum willingness to pay (WTP) to ensure an improvement and the minimum willingness to accept (DAA) to offset the loss compared to the expected improvement. If the variation in the offer of the Parco Dicimare, viceversa, would result in a deterioration of individual well-being the equivalent variation (EV) corresponds to the maximum willingness to pay WTP to avoid that decrease in usefulness as well as the minimum willingness to accept a sum of money for compensation for the damage suffered.

TEV of a naturalistic resource can be summarized in Table 1.

Contingent Valuation (CV) (Carson 1997) is an assessment method based on "declared preferences" through the administration of questionnaires on selected samples of individuals who are asked to express their maximum willingness to pay to obtain an improvement or to avoid a deterioration or the loss of a certain public resource under investigation.

It is concretely structured in three phases (own elaboration):

1. Start (who/how/where/when/why): these questions will introduce questions in relation to various aspects: [who] identifying the beneficiaries to be defined through targets and frames of the reference sample; administration of the questionnaire (inquiry to be made online, by post, in person, etc., [where] the place where the property is located and the choice of where to make the surveys (near the survey site or off site); [when] the time in which to carry out the investigation, i.e. when having to analyze the "application": in anticipation of changes to the "offer", after a calamitous event, harmful or better in anticipation of this;

[because] the cause or the purpose of estimation is fundamental. Based on the purpose it will be necessary to define what value to express in monetary terms);
2. Running (design of the questionnaire, choice of the application format, verification in the field with appropriate pilot studies, adjustments in the running and definitive administration of the questionnaire);
3. Finish (verification of the results obtained, econometric analysis of the data).

The CV is, beyond the limits, a powerful tool, versatile and useful in decision-making processes concerning the natural environment and cultural heritage. Turner et al. (2003) report that when a British forestry company thought to drain and use the Flow Country, a wetland in Scotland visited by only a few people, a contingency assessment study was started on questionnaires sent by mail to families, which gave very surprising results. The people, in fact, showed a WTP for the protection of the Flow Country higher than it would have been possible to gain from the cultivation of timber plants. What needs to be minimized and excluded is the adoption by the interviewed subjects of "strategic behavior".

The detractors of this evaluative methodology, in fact, affirm that the hypothetical nature of the scenarios would imply a vague approximation of the real value. The estimate made with the CV is recognized to be legally binding in the USA and regulated by law since the early 90s (Arrow et al. 1993). A 1980 US law, the Environmental Compensation and Liability Act, known as Superfund Law, foresaw that public bodies such as Ministries and Local Governments could claim compensation for damage to the environment including forests, lakes, water, fauna, flora, swamps, coasts, soils, slopes, etc. The DOI (Department of Interior) was asked to shed light on which values and estimation methodologies should be adopted to explain these damages.

The Ministry, in turn, delegated the NOAA (National Oceanic and Atmosphere Administration) to pronounce on the validity of the estimates obtained with the VC and on the opportunity to estimate the passive use values (bequest and existence). There were oppositions to the TEV estimation criterion and the use of CV, but the NOAA asked the two Nobel Prizes in Economics Kenneth Arrow and Robert Solow to chair an expert committee (NOAA Panel) to express themselves on the validity and veracity of the estimates obtained with the CV for the assessment of environmental damage. The Panel set seven rules for a correct use of the CV (Carson 1997):

1. CVs must start with an accurate and understandable description of the scenario;
2. CVs must report to the interviewee that the expense for a certain purpose (valorization of a park, compensation for damage, etc.) would reduce their spending capacity for other goods;
3. To inform the interviewees about the presence of surrogate goods, for example if you are about to ask for a contribution for the maintenance of a certain park to specify how many are already available or are to be;
4. Add to the interview questions to 'check' to see if the respondents have actually understood the questions and identify the reasons for their answers;
5. To prefer questions in a referendum form: yes or no, to take or leave, avoiding open questions, to check the maximum availability;

6. The CV should request the willingness to pay to prevent future accidents rather than the minimum acceptable compensation for an accident that has already occurred (even if the second question is the theoretically correct one for an accident that has already occurred);
7. Prefer the administration of personal interviews, no telephone calls or worse in an epistolary form.

Indirect evaluations using the Clawson method or Travel Costs (TCM) that can be used to estimate the recreational use value of a cultural or environmental resource make it possible to integrate and validate the studies obtained with the CV (Tirendi 2003). The assumption is that the value in use of a resource is worth at least the cost of the trip necessary to visit it. It seems quite obvious, but to many eminent economists the question did not seem such a simple deduction, as often the Directors of the US natural parks turned to them to settle the age-old question of what was the economic value of a park. Unfortunately they always received a negative answer because even with safe values there remained a margin of uncertainty. Fortunately, Harold Hotelling did not think so (Hotelling 1947) and with this insight, dating back to 1947, but perfected later by Wood and Trice (1958) and by Clawson and Knetsch (1966), was the first to provide a monetary measure for recreational services.

In short, the value of a "non-market" resource can be deduced by observing the behavior of some individuals who face a "journey" to enjoy the resource itself. This consumption includes, in the case of a park, the cost of the trip to reach it, the entry ticket and the additional expenses incurred on site as well as the opportunity cost of time. The method presupposes a complementarity between the resource and the expenditure consumed for use, and therefore can also be applied to determine the marginal utility of improving the quality of the resource itself.

4 Territorial Context

The Diecimare Park (Fig. 2) is a naturalistic oasis that extends in the municipalities of Cava de' Tirreni, Mercato San Severino and Baronissi which boasts a thousand-year history. Around the year one thousand, in fact, the mountains of the Diecimare Park belonged, thanks to the donation of the Lombard Prince Gisulfo II, to the Monastery of the SS. Trinità di Cava de' Tirreni and the Municipality of Cava de' Tirreni. Because of the frequent controversies on how to manage the common property, the Royal Council of 1580 decreed that the Church used only the right of grazing, while citizens of Cava were granted the civic use of obtaining lumber. In 1770 the inhabitants of Casale di S. Lucia attempted, tilling the existing wood, to make the Valley of Diecimare cultivable, but there were landslides caused by the first rains and the immediate restoration of the Valley was ordered by the Decurionato, an ecclesiastical authorities. When in 1866 the immovable properties of the Ecclesiastical Authorities were transferred to the State, the area of the Diecimare Park also became property of the State. More recently, due to the excessive exploitation of natural resources, it

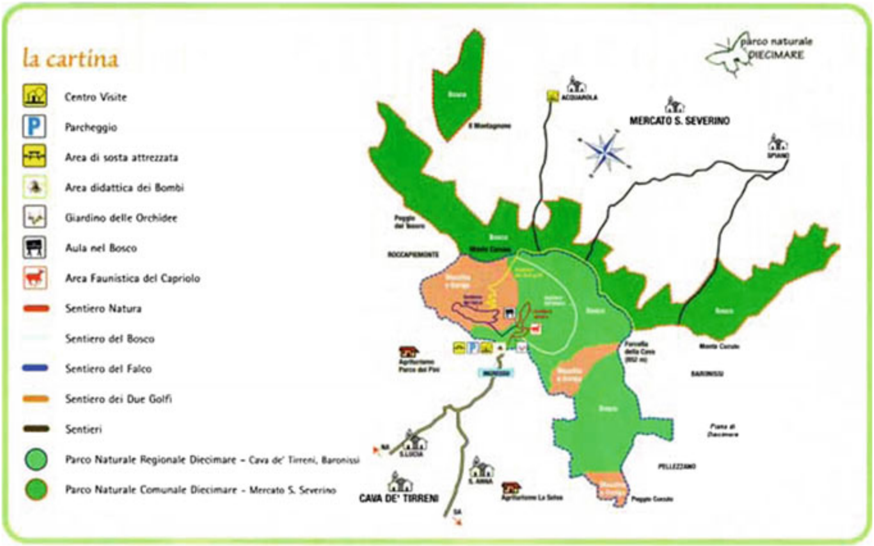


Fig. 2 Map of the park (information panel in the park)

was intended to safeguard a part of this area by creating a protected natural area in 1980. Unfortunately, almost forty years later, it is in a state of neglect and widespread degradation. The territory specifically concerns an area bounded by the high grounds of Monte Caruso and Forcella della Cava (832 m asl) and covers about 444 ha. These terrains have marine origins while the Diecimare plain is made up of debris and pyroclastic material coming from the Campi Flegrei caldera. The slopes along Mount Caruso are covered with steppe areas and Mediterranean scrubland consisting of myrtle, holm oak, lentisk, heather and strawberry tree. On the other hand, the slopes of Forcella della Cava are decidedly greener and are characterized by the presence of oak, alder and chestnut woods. The fauna is very rich especially for insects, among which the macaon stands out (Fig. 3), a very elegant and colourful butterfly symbol of the Park.

The Park, due to the very varied presence of butterflies and insects including the rhinoceros beetle, the bumblebee (Fig. 4), the praying mantis and the stick insect, as well as being a site chosen by migratory birds, mostly raptors, both nocturnal and diurnal, and many other smaller species such as titmouse, finches, wagtails and blackcaps that inhabit many trees, makes up a real open-air educational laboratory for the observation and study of insects and birds.

The neglect and abandonment, even of the WWF, which until a few years ago was in charge of this naturalistic oasis are putting a strain on the existence of the Park, whose infesting vegetation has now made some paths impassable. From the entrance of Cava de' Tirreni there is a parking lot and a visitor centre (which is currently closed) where volunteers welcomed people.

Fig. 3 Macaone butterfly (reproduction of watercolor painting by Lucia Matteo, private collection)

Fig. 4 Signage of the park. *Source* authors' picture

Fig. 5 Bumblebee *Source* authors' picture

Inside the Park there were some equipped rest areas that were used mostly during the summer and Easter Monday, as well has educational observation areas of bumblebees, orchids, butterflies (Fig. 5), the wildlife area of roe deer and the depths of the forest where nature itself demonstrated its daily miracles. There are four main paths (Fig. 6):

1. The Nature Trail that is easy to follow and full of educational panels, ideal for school children and beginners as it allows you to have a general view of the habitats present in the Park, along the faunal area of the roe deer and the orchid garden.
2. The Path of the Woods that allows you to admire the last patches of mountain and sub montane forest.
3. The Path of the Falcon that branches off the slopes of Monte Caruso where it is easy to see hawks and buzzards.
4. The path of the two gulfs, which after an uphill climb allows you to follow the ridges between Monte Caruso and Forcella della Cava, where you can observe both the Gulf of Salerno and Naples.

Fig. 6 Park avenue *Source* authors' picture

5 The Survey and Outcomes

The survey was conducted in 2009 on a sample of 500 individuals, when the Parco Diecimare (at least as far as the territory of Cava de' Tirreni) was still in good condition as it was still managed by the WWF. Subsequently, mainly because of arson and lack of funds, the agreement with the WWF ended and began the slow and inexorable decline of the area mainly caused by illegal spills of asbestos sheets, flues and pipes (waste from building sites), from continuous damage to the posters still present on the paths of the natural itineraries and fire sighting towers. There are also damages the picnic area, the small hut that served as a visitor centre (only the foundations remain) due to by vandalism and by the many fires that have not even spared the area once reserved for roe deer.

Two questionnaires were used, one with the bidding-game format (subject of this contribution) and the other in dichotomous format. The technique of eliciting the application format to be used in the CV investigations involves four main types: (a) bidding-game, (b) payment card, (c) open-ended and (d) dichotomous choice.

The chosen method of bidding game is based on the simulation of a real “auction game” between interviewer and interviewee in which, after having defined an initial price suggested by the interviewer, the price itself is repeatedly modified on the basis of acceptance or refusal of the interviewee, to establish the maximum price that the latter is willing to pay to win the asset. One of the main advantages of this technique derives from the ability to provide comparatively better results than other techniques, as it constitutes a favourable market situation for respondents (Cummings et al. 1986). Contrarily, one of the main disadvantages of this format is that the price defined by the interviewer could influence the respondents’ statements by determining what is called an “anchorage problem” (Blame et al. 1999) at the price initially proposed. This problem has been resolved offering four different levels of the initial bid: €5, €8, €10, €16.

After putting the interviewed subject at ease, giving him a series of verification questions to understand if this was his first visit to the Park (otherwise he had to register how many times he had visited or he would have visited during the year), if the visit itinerary included other places (and if so, to avoid the “part of whole bias”), if he had been particularly interested in the protection of natural resources and if during the year he had visited other Parks. After this first step, the second phase was to briefly describe the Diecimare Park, while the third presented the hypothetical scenario and triggered the “auction game”. The hypothetical scenario was as follows:

“Currently he has not paid anything to access the Park (if the interview is conducted on-site) or currently the entrance to the Park is free and the guided tours cost €3 per person. The Municipalities of Cava de’ Tirreni, Mercato S. Severino and Baronissi, with the aim of improving and expanding the services offered, are planning to introduce a shuttle service that connects the entrance with the parking area, the expansion of the areas intended for picnics, the redevelopment and implementation of existing routes through the creation of new paths, the introduction of additional fences and the improvement of services within the Park such as the creation of additional observation points, information boards and an astronomical observatory and guided tours by experienced staff. This would require an economic contribution that would reflect the cost of the new services offered. If you had an entrance ticket for the Diecimare Park, would you be in favour or against it?”.

The fourth (and last part) of the survey includes the socio-economic characteristics of the interviewed sample and the geographical area of origin.

The results of the survey in the form of a frequency histogram are shown in Fig. 7. Subsequently, the cumulative frequency curve was calculated and through Microsoft Excel software to estimate the functional form that would best give mathematical

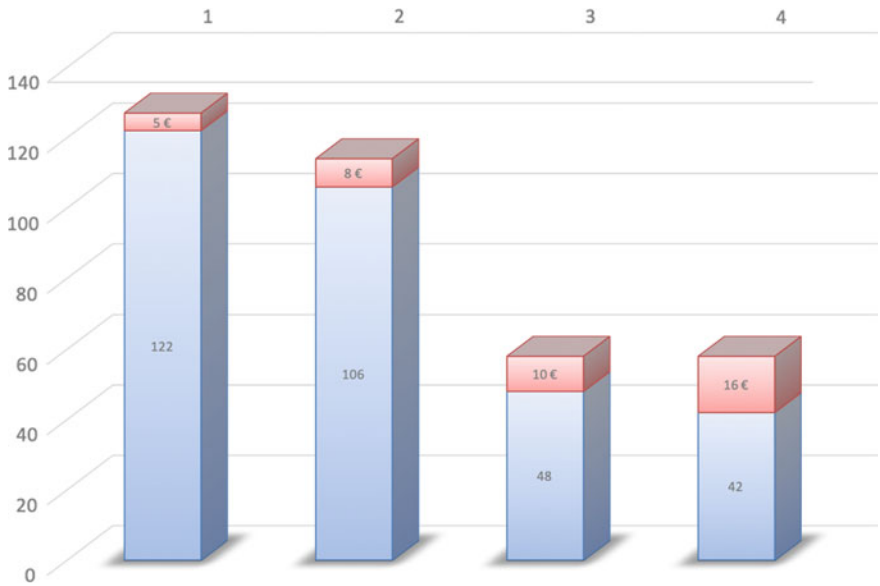
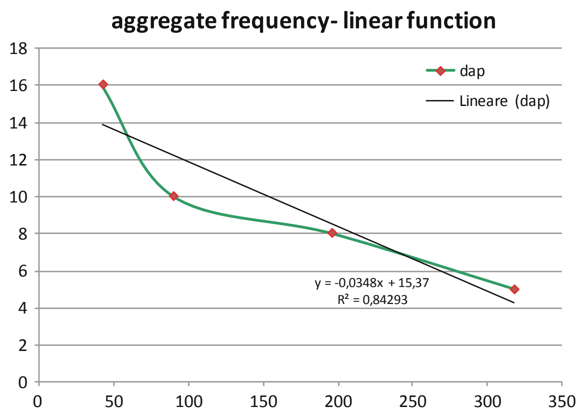


Fig. 7 Frequency histogram, own elaboration

Fig. 8 Linear function, own elaboration



significance to the data collected. The estimated functional forms were: linear, exponential and logarithmic. The logarithmic function gave a better R-squared (0.95688) and therefore has been used (Figs. 8, 9 and 10).

The utility of individuals is expressed by the of the consumer's surplus and is defined as the positive difference between the price that an individual is willing to pay to receive a certain good or service and the market price of the same good. The maximum that an individual is willing to pay is called a "reserve price". For example: if an individual is willing to pay €16 for a particular asset, but finally gets the same good at €10, he will have a (totally psychological) surplus of €6.

Fig. 9 Exponential function, own elaboration

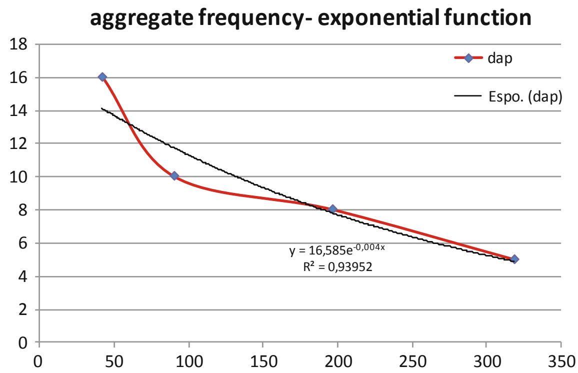
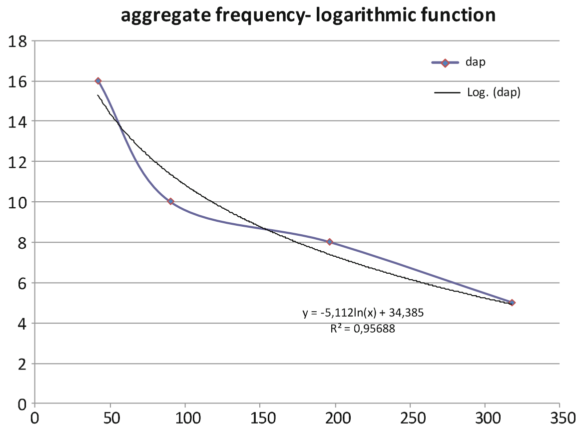


Fig. 10 Logarithmic function, own elaboration



With reference to the aggregate function of individual annuities, by extension, consumer surplus is defined as the sum total of individual surplus.

In general, the demand for an asset decreases as the price increases, so the demand curve has a decreasing trend (see Figs. 8, 9 and 10). In the case of "non-market" goods, for which individuals can not bear any price, the whole area under the demand curve will be identified as consumer surplus.

Therefore the logarithmic function proved to be the best option to represent the curve of the declared preferences.

The area under the demand curve, duly "discounted" to current events, will represent the recreational use value of Diecimare Park. In the face of 318 visits declared by the sample of 400 respondents in May and June 2009 we will have:

$$\text{Consumer's Surplus} = \int_{1}^{318} \text{DAP}\,\text{dN} = \int_{1}^{318} (34{,}385 - 5112\ln \text{F})\text{dN} = 3.157\,€$$

Table 2 Number of inhabitants directly involved, own elaboration

Town	Number of inhabitants
Mercato San Severino	22.346
Cava de' Tirreni	50.968
Baronissi	17.061

Unit values in euro per hectare			
	Vmax	**Vmin**	**Rif. Tab.**
Arable land irrigated	107.000	50.000	H703A
Arable land	40.000	20.000	H703A
Irrigate garden	115.000	55.000	H703A
Vineyard	60.000	40.000	H703B
Olive grove	43.000	22.000	H703G
Orchard	90.000	52.000	H703C
Oaks tree field	9.000	6.000	H703D
Coppice wood	7.000	2.200	H703I
Chestnut	43.000	20.000	H703D
Citrus grove	125.000	60.000	H703F
Lemon grove	150.000	70.000	H703F
Carob grove	15.000	10.000	H703M
Pasture	5.000	2.500	H703A
Abbandoned land	15.000	10.000	H703L
Unproductive wasteland	4.000	3.000	H703M

Fig. 11 Unit values in euro per hectare (Iovine and Curatolo 2014)

This value is divided by the number of visits declared to obtain the average DAP which is €9.93 ≈ €10.00.

This value represents the consumer surplus expressed by the interviewed sample.

To extend the data of the "sample" to the entire population of users of the Park, reference was made to the total number of inhabitants of the three municipalities (Table 2) in which the Diecimare Park is located. The assumption is that the "population" involved would behave similarly to the sample interviewed on site.

The population is given by the following proportion:

$400{:}\,318 = 90.375{:}\,\mathrm{X}$

$\mathrm{X} = 71.848\ \mathrm{visits/year}$

The consumer's surplus, therefore, will be: €718.480, which discounted a rate of social discount of 2% will give a value of use of the Park amounted to €35,924,000 which corresponds to a VET of about €110,000,000 which, considering the 444 ha, it ensures an economic value of about 248,000 €/ha, far superior to the most profitable crop (Limoneto) present in Cava de' Tirreni (Fig. 11).

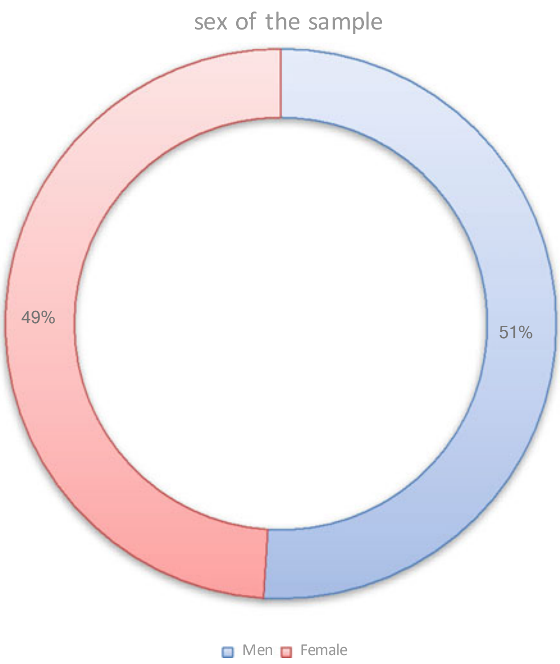


Fig. 12 Sex, own elaboration

The following are the statistics on the sample of the interviewees (Figs. 12, 13, 14 and 15).

The results obtained with the Contingency Assessment were subsequently compared with an indirect evaluation method such as the Travel Cost Method. It uses the following analytical formulation to estimate the value of recreational use, through the costs incurred to reach the site of interest:

$$CT = \left[\text{km\_tot} \ \frac{\text{Fuel Cost}}{5} \right] + \left[\frac{\text{Km\_tot}}{\text{Average value}} \ \frac{\text{Income} \times 12}{1730} \right] 0.333$$

wherein:

Km_tot is obtained from the complete distance of return;
Fuel cost is obtained from the cost of the fuel used (petrol, gas, diesel);
Average value is obtained from the average speed assumed in southern Italy in mixed cycles (city/highway);
1730 is obtained from the average annual working hours of an Italian citizen;
0.333 is obtained from the opportunity cost evaluated as a third of the hourly wage.
In light of these considerations, having used the price per liter of petrol as fuel cost,

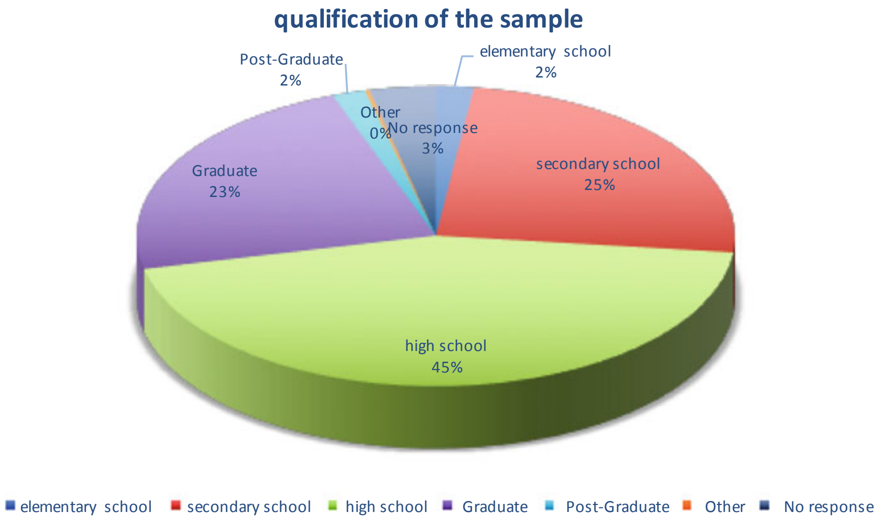


Fig. 13 Qualification, own elaboration

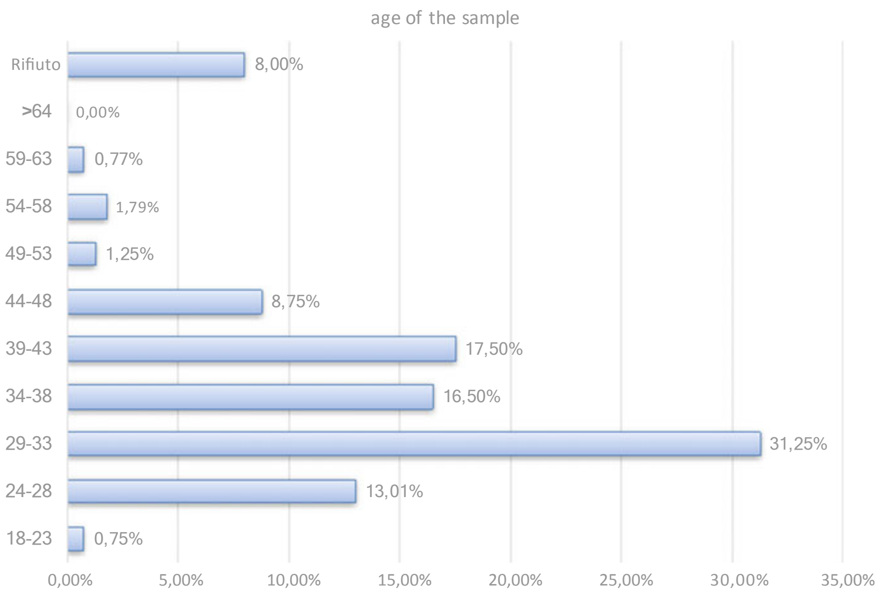


Fig. 14 Age, own elaboration

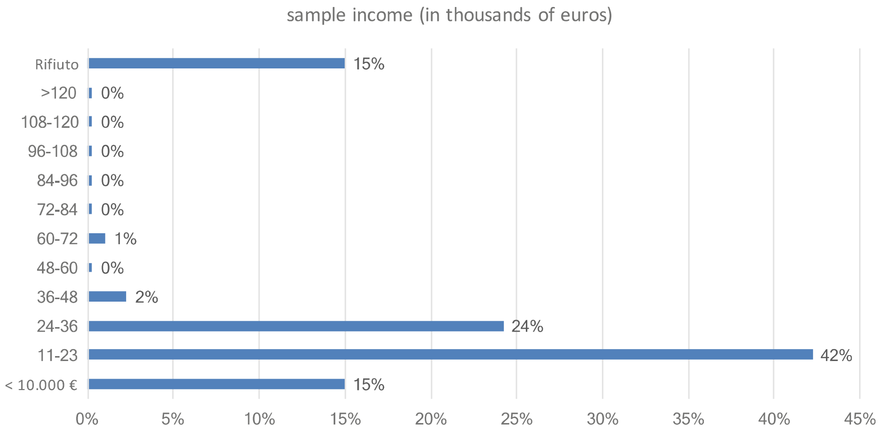


Fig. 15 Income, own elaboration

PROV	F	WTP
Caserta	2	€ 33,00
Benevento	9	€ 31,00
Avellino	11	€ 30,00
Napoli	100	€ 18,00
Prov Na	373	€ 12,00
Salerno	406	€ 6,00

Fig. 16 Origin of visitors and travel cost, own elaboration

equal to €1568/l and as an average income of €20,000, the aggregate frequency and the related curve were obtained, as well as always through Ms Excel we proceeded to obtain the logarithmic regression that reported a R2 equal to 0.9378, as represented in Figs. 16 and 17.

The area under the curve was calculated with the following defined integral:

$$\text{Consumer surplus} == \int_{1}^{406} \text{FN}\,\text{dN} = \int_{1}^{406} (40{,}299 - 4756\ln \text{F})\text{dN} = 6{,}649{,}389\,€$$

which divided the 406 presences returns a value of about €16, which is higher than €10 estimated with the CV, also because this estimation model also includes the opportunity cost.

Whether using "artificial markets" that make it possible to estimate the willingness to pay for use and non use values, through the Contingent Valuation, both using the Travel Cost Method, is necessary to give a monetary value to the environmental goods.

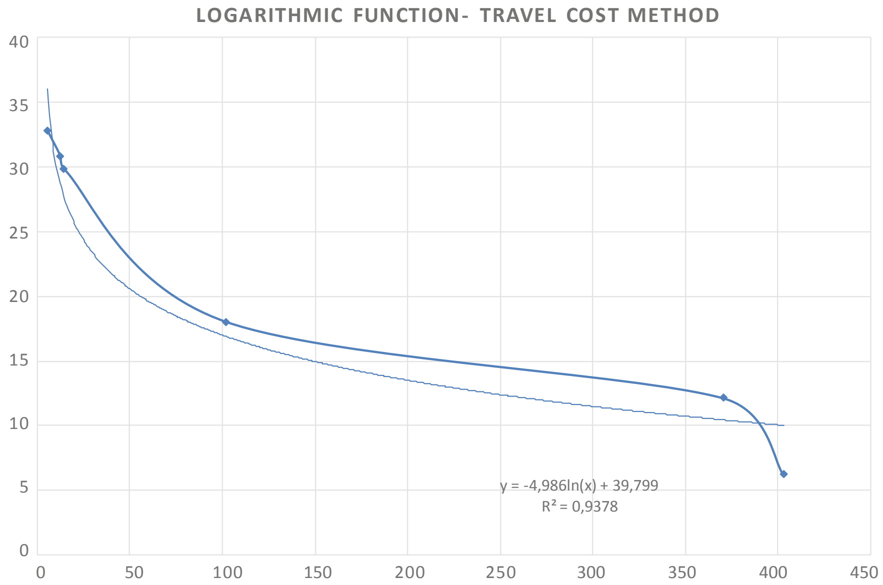


Fig. 17 Logarithmic function—estimate of the frequency curve, own elaboration

Precisely because environmental goods are "outside the market", political and economic operators are led to underestimate the benefits due to the high uncertainty that weighs on their overall values and meanings and, on the contrary, to favor those goods whose advantages are less "blurred" and expressed clearly in monetary terms; moreover, economic operators who exploit and pollute natural resources are often not inclined to cover their costs.

The monetary valuation of environmental goods without a market may be more or less imperfect; nevertheless, an explicitly formulated assessment for the benefit of political decision-makers and the public is always better than nothing, since in this case actions are undertaken on the basis of some implicit evaluation, which is hidden from public opinion (Turner et al. 2003).

This study is emblematic to make the environmental, recreational, touristic and landscape importance of a site in a state of neglect to be understood through the benefits (including economic) lost to politicians and citizens, so that everyone is aware of the richness of our environmental and cultural heritage.

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References

Arrow K, Solow R, Portney PP, Leamer EE, Radner R, Schuman H (1993) Report of the national oceanic and atmospheric administration panel on contingent valuation. Fed Reg 58:4602–4614
Blame RK, Bennett JW, Morrison MD (1999) Yea-saying in contingent valuation surveys. Land Econ 75:126–141
Calvino I (1963) Marcovaldo, ovvero le Stagioni in città, Mondadori, Milano, ed. 2016
Carson RT (1997) Contingent valuation: theoretical advances and empirical tests since the NOAA panel. Am J Agric Econ 79:1501–1507
Clawson M, Knetsch JL (1966) Economics of outdoor recreation. The Johns Hopkins Press for Resources for the Future, Inc, Baltimore
Cornes R, Sandler T (1985) Externalities, expectations, and pigouvian taxes. J Environ Econ Manage 12(1):1–13
Cummings RG, Brookshire DS, Schulze WD (1986) Valuing environmental goods: a state of arts assessment of the contingent valuation method. Totonia, NJ, Roweman and Allanheld
Fusco Girard L, Nijkamp P (1997) Le valutazioni per lo sviluppo sostenibile della città e del territorio. Franco Angeli, Milano
Hotelling H (1947) The economics of public recreation. The Prewitt report. National Parks Service, Washington
Iovine A, Curatolo M (2014) Listino dei valori immobiliari dei terreni agricoli. Campania 2015, Exeo
Millennium Ecosystem Assessment (2003) Ecosystems and human well-being. Island Press, Washington, DC
Millennium Ecosystem Assessment (2005) Vivere al di sopra dei nostri mezzi: patrimonio naturale e benessere umano. www.millenniumassessment.org
Nunes PADL (2002) The contingent valuation of natural parks. Edward Elgar, Northampton
Santos JML (1998) The economic valuation of landscape change. Edmond Elgar Publishing, USA
Signorello G (2007) La valutazione economica del paesaggio: aspetti metodologici e operativi. XXXVI Incontro di Studio Ce.S.E.T., Firenze University Press, pp 83–102
Signorello G, Missiato M, De Salvo M (2005) The economic valuation of landscape. An annotated Bibliography, Envalab Working Paper, Catania
Stellin G, Rosato P (1998) La valutazione della funzione ricreativa di un'area protetta. In Stellin G, Rosato P, La valutazione economica dei beni ambientali. Metodologia e casi studio, Cittàstudi ed
Tirendi D (2003) La valutazione di contingenza per la stima delle risorse culturali ed ambientali, in Genio Rurale - Estimo e Territorio, no 5. il Sole 24 Ore Edagricole, Bologna, pp 12–22
Turner RK, Pearce DW, Bateman I (1993) Environmental economics. An elementary introduction. John Hopkins University Press, Baltimore
Turner RK, Pearce DW, Bateman I (2003) Economia Ambientale, il Mulino. Bologna, Italia
Wood S, Trice A (1958) Measurement of recreation benefits. Land Econ 34:195–207. University of Wisconsin Press, USA

Part III
Economics and Decision Making in Urban Regeneration

A Stakeholders-Oriented Approach to Analyze the Case of the UNESCO's Man and Biosphere Reserve CollinaPo

Francesca Abastante and Isabella M. Lami

Abstract The paper investigates the combined use of storytelling and the Simos-Roy-Figueira (SRF) method to support the identification of the most important decision criteria in a decision process concerning a valorization strategy for a UNESCO's MaB reserve. The approach is illustrated with an Italian case study ("CollinaPo"), describing one of the four focus groups where it has been applied, as part of a training course to discover and valorize the values and peculiarities of the area. The choice of a combination of storytelling and SRF has been also induced by the very varied composition of the workshop participants: the two methods are intuitive and entertaining, the latter in particular allows to select and weight the criteria on a subjective scale that stimulate the stakeholders' acceptance. The fact that several common criteria arose across of different groups despite the limited time and the variety of the participants, seemed a positive indicator of the goodness of the choice. The participants pointed out this sense of "belonging" to UNESCO's MaB reserve "CollinaPo" beyond the division into individual municipalities, expressing a clear vision of the need to act as a "network" on the territory to reinforce the attractiveness of the area. Even if the article illustrates the results of a single case, it incorporates a series of reasoning related to three workshops already done in the same project, and other applications are scheduled.

Keywords Sustainable development · SRF method · Stakeholders-oriented approach · Storytelling

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1 Introduction

According to the Brundtland report (Keeble 1988), "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition has to be understood in an economic perspective involving environmental, social, technical and financial aspects that together support the so-called green economy. In this sense, the sustainable development is a globally endorsed principle whose practice is multidimensional and complex as highlighted by the United Nations General Assembly in the Sustainable Development Goals of the Agenda 2030 (un.org).

Among the widespread sustainable development programs, particularly interesting is the UNESCO's Man and the Biosphere (MAB; Dyer and Holland 1988). The MaB is an intergovernmental scientific program launched in 1971 whose primary objective is the rationale use and protection of the biosphere resources. In particular, the MaB aims to analyze and improve the strong interdependence among the environment and the people who live it, promoting the protection of natural ecosystems and the equitable distribution of benefits. In order to reach this objective, the MaB advocates new approaches to the economic development that are socially, culturally and environmentally sustainable (unesco.org).

In this perspective, the MAB program can be defined as an evaluation tool of the UNESCO (Ishwaran et al. 2008) according to four main steps: (i) to identify the climate changes imputable to the human and natural activities and the subsequent effects on people and environment; (ii) to study the dynamic relationships among ecosystems and socio-economic processes considering the de-growth of cultural and biologic diversity; (iii) to ensure the human and environmental well-being in a context in which rapid urbanization and energy consumption are carriers of environmental change; (iv) to promote the exchange of knowledge of environmental problems and solutions and strengthen the education for sustainable development (Ishwaran et al. 2008).

Here emerges the need for policies and strategies to propose concrete actions able to properly address the sustainable development of the UNESCO's MaB reserves.

Accordingly, an important element of complexity is constituted by the shallow knowledge of the MaB reserves in terms of available information useful to design sensible sustainable development strategies (Brunetta et al. 2018).

To help overcoming this problem, this paper proposes the use of new approaches in order to support the traditional evaluation perspective based on numerical data (Abastante et al. 2012). Those new approaches can be defined as "stakeholders-oriented" since they can make up for the vagueness of information and knowledge through the interaction between actors and experts (Abastante et al. 2018, 2019; Abastante 2016; Abastante and Lami 2013, 2018; Beccali et al. 2003) in a participatory process. In this sense, the stakeholders-oriented are methodological and applicative approaches able to integrate the multiplicity of values intrinsic in sensible and effective decision processes (Lami and Tavella 2019; Tavella and Lami 2018; Lami and Abastante 2014).

In particular, the paper investigates the use of the Simos-Roy-Figueira (SRF) method (Figueira and Roy 2002), also known as "playing cards" method, combined with a previous step based on a "storytelling approach".

The "stakeholders-oriented" approach has been used to support the discussion around the UNESCO's MaB reserve "CollinaPo" (Turin metropolitan area, Italy) and to identify the most important decision criteria able to support a valorization strategy of the aforementioned reserve. It is important to stress that this paper reports the partial results of an ongoing research.

The chapter is structured as follows: after the introduction, Sect. 2 reports the basic elements of the methodological approach, Sect. 3 analyses the case study applying the SRF method, Sect. 4 provides the discussions while Sect. 5 concludes the paper highlighting the future development of the research.

2 Methodological Approach: The Stakeholders-Oriented Approaches

Determining the importance of the decision criteria and their relative weights to support the decision choices is complex.

The literature suggests many methods able to help solving this issue (Lombardi et al. 2017; Lami and Abastante 2014). According to Wang (2009), these methods can be divided into two main groups:

1. "*Equal weights*" methods: the weights of criteria are evaluated as Wi = 1/n; i = 1, 2, …n. Equal weights method was popularized and applied in many decision-making problems.
2. "*Rank-order weights*" methods: the weight of the criteria takes into account the relative importance among criteria as:
"$w_1 \geq w, \geq \cdots \geq w_n \geq 0, \sum_{i=1}^{n} w_i = 1$". This method can be usually classified into two main categories:
    (a) Subjective weighting method (e.g. Playing cards, Pairwise comparison, AHP), which are mainly based on the stakeholders and decision makers' preferences and visions and are therefore called "stakeholders-oriented" approaches.
    (b) Objective weighting method (e.g. TOPSIS method, Minmax deviation method), which are based on mathematical methods.

Although the stakeholders-oriented approaches have been rarely considered, we strongly believe that they can be very helpful in situation characterized by a scarcity and/or vagueness of the available knowledge. In particular, the stakeholders-oriented approaches are simple to be implemented and are usually well accepted by the stakeholders. Interestingly, the stakeholders-oriented approaches (Hamdy et al. 2017) are very intuitive and engaging methods, which allow clearly to select and rank a set of preferred decision criteria. Hence, we can affirm that the novelty of this paper is based on the stakeholders' involvement from the early phase of a valorization strategy process.

The first step of the stakeholders-oriented approach here applied is based on the storytelling, which is «the set of techniques to tell and share a story that generates interest and which conveys a message in order to convince and adhere to a conclusion that presents itself as definitive» (Lewi 2009). Storytelling facilitates unlearning which corresponds to unlearning individual and disciplinary perspectives, as well as knowledge taken for granted. Writing in a more narrative way improves understanding, it allows us to go beyond the objectivity of scientific and qualitative approaches, favoring different points of view and interpretations. Storytelling's goal is to promote empathy among stakeholders, in order to create the good context for discussing interdisciplinary issues that can become conflictual.

2.1 Simos Roy Figueira—SRF

The SRF method (Figueira and Roy 2002) is a generalization of the consolidated approach proposed by Simos (Simos 1990) generally called "Playing Cards" (Siskos and Tsotsolas 2015; Aşılıoğlu and Memlük 2017). It is considered as a Multicriteria Decision Analysis (MCDA) because it allows people involved to think about and express the way in which they wish to hierarchize multiple criteria in a given context (Figueira and Roy 2002; Zheng et al. 2016).

The method demands a limited cognitive effort to the stakeholders involved thanks to the material supports used and the procedure itself. A set of cards is created (similar in form to playing cards) corresponding to the criteria identified. Similarly to what often happens in ordinary life when it is necessary to decide which are the most relevant aspects to take a decision, the stakeholders are invited to define a sort of criteria (the literature suggests from the least important to the most important). In this way, the stakeholders will rank in ascending order according to the importance they want to ascribe to the criteria (Figueira and Roy 2002). The SFR also contemplates the possibility that there are two or more criteria of equal importance, in this sense a subset of ex equo "criterion cards" can be built.

The stakeholders are then asked to think about the fact that the importance of two successive decision criteria in the ranking can be more or less close.

Therefore, the stakeholders insert "white cards" between two levels of the ranking in line with the logic expressed by Figueira and Roy (2002): no white card means that the criteria have not the same weight but that the difference between the weights can be chosen as the unit for measuring the intervals between weights; one white card means a difference of two times; two white cards mean a difference of three times and so on. Obviously, the greater the difference between the mentioned weights of the criteria, the greater the number of white cards.

The last step is the definition of the so called "z value", whose calculation constitutes the main difference between the original "Playing Cards" proposed by Simos and the SRF method. To define the "z value", the stakeholders are asked to express how many times, the last criterion is more important than the first one in the ranking. After the stakeholders' provided a complete ranking and the ratio through the "z value", the preferences expressed are converted into weights using the SRF algorithm. This step can be supported by the SRF dedicated software (Maystre et al. 1994), or DecSpace (Costa et al. 2019).

The reader can refer to Figueira and Roy (2002) for more comprehensive details, since providing a detailed description of the algorithms supporting the SRF method is beyond the scope of this paper.

3 Case Study: The UNESCO's MaB CollinaPo

Currently, the UNESCO's MaB network involves 686 different reserves in 122 Countries and in particular 15 reserves in Italy (Fig. 1).

The CollinaPo reserve (Turin metropolitan area, Italy) obtained the UNESCO's MaB acknowledgment in 2016 thanks to the application managed and promoted by the association called "Ente Parco", which performs a strong activity of facilitation of systemic network programs.

The CollinaPo is the most urbanized among the Italian UNESCO's reserves. It is a unique territory, far from the traditional stereotype of the natural area but characterized by environmental and landscape wealth difficult to find elsewhere. In fact, the CollinaPo reserve includes an anthropized tissue where a river and a hill coexist together with different natural habitats, historical architectural excellences and a metropolitan area (biosferadelpo.org).

As showed in Fig. 2, the UNESCO's MaB CollinaPo involves 86 Municipalities of the Turin metropolitan area and it is located along the river Po axis between the foothills of Turin, where the river heads north, and that of the upper plain.

From a natural point of view, the CollinaPo reserve shows two extremely interesting elements: the river Po and the Turin hill. In particular, the reserve comprises different protected green parks and numerous sites inserted in the so called "Nature Network 2000", which identifies 35 habitats of community interest as a testimony of a high biodiversity (unesco.org). Those habitats are called "core areas" and are surrounded by protective buffer zones in order to properly guarantee the ecologic, functional, physical and territorial continuity. This is possible mainly thanks to the river Po, which acts as an ecologic corridor protecting the core areas with the riparian vegetation.

Fig. 1 The location of the 15 Italian UNESCO's MaB network. *Source* biosferadelpo.org

Parallel to the nature elements, the reserve is characterized by many economic activities as agriculture, industries, tourism. If properly managed, those can constitute an advantage for the territory in exam since they make the reserve a laboratory for experimentation and implementation of sustainable management practices of natural and cultural resources. The CollinaPo reserve assumes a key role for the conservation of biodiversity: the system is indeed an important ecological network that performs the crucial function of conservation of species, communities as well as ecosystems.

In this heterogeneous situation, the aim of the paper is to identify the decision criteria able to support the requalification and enhancement of the UNESCO's MaB CollinaPo proposing effective valorization strategies in a sustainable perspective.

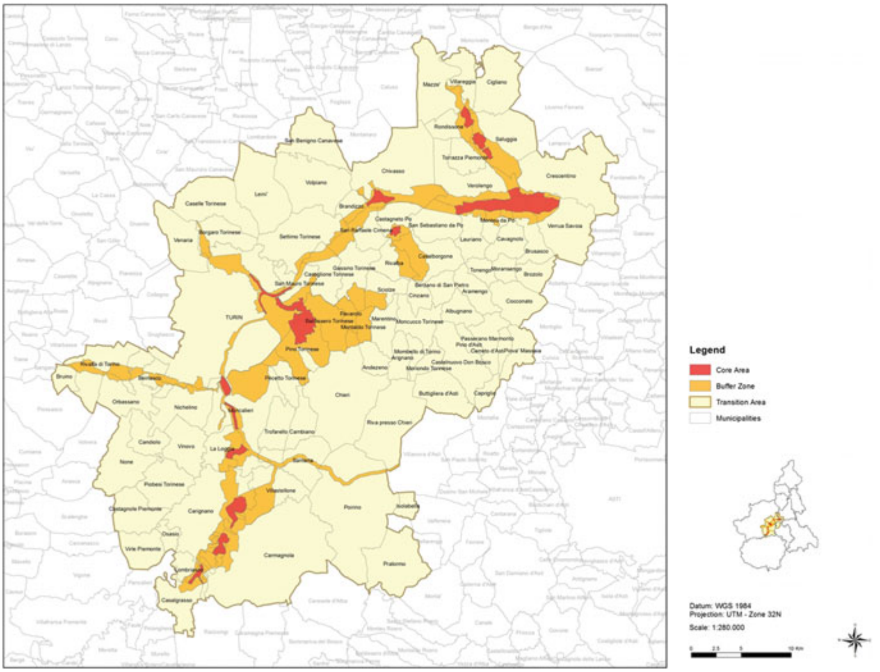

Fig. 2 Location of the UNESCO's MaB CollinaPo. *Source* parks.it

3.1 Application of the SRF

In order to reach the aforementioned objective, we applied a combination of storytelling and SRF method as a stakeholders-oriented approach (Abastante et al. 2017). The present research is based on four different focus groups on the territories of the CollinaPo reserve, and it is part of a training course to discover and valorize the values and peculiarities of the area, funded by Iren Local Committees. The course includes two training modules (one of which is partially structured in workshops) and guided tours, repeated in four different municipalities of the 86 municipalities in the MaB CollinaPo. The course is intended for citizens interested in enhancing their territory, operating in several sectors. Since the research is still ongoing, this paper aims at reporting the first results obtained during the one of the focus groups.

The stakeholders involved in the discussion and participating to the focus group were 20 citizens and representatives of the Public Administration with different backgrounds and jobs and between 25 and 80 years old (Table 1).

From Table 1 emerges that the composition of the participants is balanced in terms of gender and jobs.

After having identified the stakeholders, the focus group has been structured into four main working sections. During the first one, we presented to the stakeholders the objectives of the focus group paying particular attention to the theoretical aspects of

Table 1 Composition of the stakeholders

Current job	Female	Male	Total
Teacher	2	0	2
Restoration/commercial activities	2	1	3
Tourism	2	2	4
Public administration	2	2	4
Student	1	1	2
Association	0	3	3
Retired	2	0	2
Total	11	9	20

the urban sustainability processes (Lami 2019) as well as to the SRF methodological approach. In the second section, we use a simplified version of the storytelling, asking to the stakeholders to reflect about the possible decision criteria perceived as the key elements of the territory, answering to specific questions. In the third section, the stakeholders worked in groups. Finally, a general discussion was stimulated, starting from the comparison of the different rankings. In the following text we will illustrate the last three phases.

In order to support the stakeholders in thinking about the decision criteria, we posed them three questions that should be able to stimulate the definition of the problems and potentialities of the territory highlighting the point of views and thought of each stakeholder. In this perspective, the storytelling is used to develop shared vision and future goals, through narrations from a personal point of view.

The questions were of the type:

1. In your opinion, which are the main strengths and weaknesses of the territory in exam? *Describe with a maximum of 4 sentences which are the most important characters of the reserve CollinaPo from different point of view (natural/touristic/cultural/gastronomic…).*
2. In your opinion, what is missing or what could be developed in the receptive/tertiary/residential/tourist sector? *Describe with a maximum of 4 sentences which are the most promising sectors able to guide a valorizing strategy of the territory.*
3. In your opinion, which are the decision criteria/key elements useful to evaluate the actions proposed at point two? *Describe with a maximum of 4 sentences which are the decision criteria useful for a public administrator in order to guide a valorizing strategy of the territory considering a limited budget.*

After having privately answered to the three aforementioned questions, the stakeholders were better situated to face the group work. They were therefore divided into three heterogeneous groups supported by facilitators with the aim of discussing the different point of views and to define the most important criteria reaching the consensus.

Once each group defined an agreement in terms of the decision criteria to be considered, they were asked to provide a ranking of the decision criteria using the sets of "criterion cards" and "white cards" according to the SRF method.

In Fig. 3, the yellow cards refer to the social aspects, the green cards refer to the environmental, the blue cards refer to the technical while the red cards refer to the economic aspects. As it is possible to notice, the overall social aspects identified by the three groups are 5, the environmental aspects are 2 while the technical and economic aspects are 6.

Accordingly, the number of criteria related to each aspect is quite balanced with the exception of the environmental aspect. With this respect the three groups are aligned in affirming that the environmental aspects are fundamental for the valorization strategies of the CollinaPo reserve. However, since the stakeholders are expert connoisseurs of the territory in exam, they affirmed also that the environmental conditions of the CollinaPo reserve are very good since they are widely taken into account by the UNESCO and therefore it does not constitute a criterion for the decision problem in exam.

4 Discussion of the Results

In order to properly discuss the results, we first analyzed the decision criteria that the 3 groups have in common.

In details, the decision criterion "online promotion" has been indicated by each group. This criterion refers to the need to define a promotional strategy of the territory that should be shared among the municipalities involved. This aspect could be solved by an effective website or a promotional campaign conducted via social networks. Moreover, the group 1 considers this criterion as the most important one, highlighting it as an actual promotional strategy (Fig. 3).

The groups 1 and 3 identifies the "network creation" as a social criterion affirming that one of the main weaknesses of the CollinaPo reserve is the lack of communication among the involved municipalities and a vague synergy of the Public Administrations. Those two groups advocate the need for a transition from a hierarchical organization model to a relational one. This could help in implement the tourism enhancement.

The group 1 and 2 highlighted the criteria "public funds", "widespread reception" and "local transport", even with different priority orders. The criterion "public funds" calls for more public funds in terms of money. In particular, the Public Administration would need participate to national and international financing programs in order to acquire new financial resources to be invested on the CollinaPo reserve.

The criterion "widespread reception" is related to the need of defining a shared receptive strategy diffused on the territory (as: AirBnB or Bed and Breakfast). In fact, currently in many of the CollinaPo municipalities there are no hotels and the receptive options are underdeveloped compared to the increasingly growing number of tourists. Improving this aspect would be strategic for the territory since it could lead to attract more tourists and, consequently, to grow monetary income.

Fig. 3 The rankings provided by the three groups with SRF

At the same time, the “local transport” is perceived as a huge problem for the CollinaPo reserve. The CollinaPo is in fact well connected with external territories mainly thanks to different high-speed railway lines crossing Turin. However, the local transports are scarce and inefficient both from the bus and train point of view. The frequency of bus and train passages is not appropriate and the same is the timing. This makes very difficult to the users of the territory to move without a private car.

Both group 2 and 3 identified the criterion “cultural growth” even if with a low importance: group 2 positioned this criterion at the last place while group 3 at the penultimate. This criterion advocate for a more consciousness of the residents about the CollinaPo reserve potentiality. This aspect should be implemented starting from schools and families that should teach the culture of the territory. The reason for which the groups decided not to attribute a high importance to the “cultural growth” criterion is because they affirmed that this aspect can be considered as a consequence of other criteria: improving for example the “online promotion” could lead to an improvement also in terms of culture and consciousness.

From Fig. 3, it is possible to notice also the most important decision criteria according to the SRF ranking provided by the groups.

Group 1 has indicated “online promotion” as the most important aspect followed by the “nature infrastructure”. This group is the only one having focused the attention on the environmental and natural aspects, recalling the need to maintain and implement natural infrastructures including pedestrian and cycle paths.

The most important criterion according to the reasoning of Group 2 is the “increase in employment”. During the discussion among the stakeholders it emerged that a great responsibility about the CollinaPo activities is delegated to voluntary people. This is a huge social and economic risk since the volunteers are often exploited. It is therefore necessary to implement strategies to relieve volunteers and to create jobs.

Always talking about Group 2’s ranking, from our point of view a very interesting criterion is “need for a facilitator” understood as the need for a strong direction of the territory. In fact, big territories as the CollinaPo reserve lack of effective valorization strategies because of the lack of a figure or entity able to coordinate them.

Finally, group 3 identified two different criteria as the most important ones: “vision” and “target definition”. According to the logic expressed by group 3, it is necessary to have a strong overall vision as well as clear objectives in order to propose effective valorization strategies. Those objectives may be few but they have to be feasible. The decision criterion “target definition” is strongly related to the previous one: to define a vision, it is necessary to identify a target to which the vision is addressed. The identification of a specific target (tourists, residents etc.) is in fact essential for a good project.

5 Conclusions and Future Development

Many territories started to define future valorization strategies. One of the main problems in proposing new strategies is the lack of proper data and relevant decision criteria able to address the design (Abastante and Lami 2012). Hence, this paper illustrated a stakeholders-oriented approach for defining and ranking the decision criteria required for assessing territorial valorization strategies. In particular, the paper investigates the combined use of storytelling and the Simos-Roy-Figueira (SRF) method (Figueira and Roy 2002), to support the discussion around the UNESCO’s MaB reserve “CollinaPo” for identifying the most important decision criteria able to support a valorization strategy of the aforementioned reserve. It is important to stress that this paper reports the partial results of an ongoing research.

The method proved to be a flexible and participative approach able to consider social and urban planning aspects and suitable to support decision processes in the absence of open-data or sensible and complete information (Pfenninger et al. 2017). The choice of a combination of storytelling and SRF was also induced by the very varied composition of the workshop participants: the two methods are intuitive and entertaining, the latter in particular allow to select and weight the criteria on a subjective scale that stimulate the stakeholders' acceptance (Lombardi et al. 2017).

The fact that several common criteria arose across of different groups ("online promotion", "network creation", "public funds", "widespread reception" and "local transport") despite the limited time and the variety of the participants, seemed to us a very positive indicator of the goodness of choice. The participants pointed out this sense of "belonging" to UNESCO's MaB reserve "CollinaPo" beyond the division into individual municipalities, expressing a clear vision of the need to act as a "network" on the territory to reinforce the attractiveness, otherwise the marginal points of interest would be too dispersed (Ingaramo et al. 2017).

Finally, we recognize that the paper presents the limitation of illustrating the results of a single case, reducing the generalizability of the conclusions with respect to the applicability of these tools to territorial decision-making processes. But, even if the article illustrates one specific experimentation, it incorporates a series of reasoning related to three workshops already done in the same project, and other applications are scheduled. The opinions gathered in the focus group, the enthusiastic and proactive response of the participants seem encourages the impression that the method is suitable for the context and the objective of the research.

References

Abastante F (2016) Multicriteria decision methodologies supporting decision processes: empirical examples. Geam-Geoingegneria Ambientale E Mineraria-Geam-Geoengineering Environ Min 149:5–18

Abastante F, Bottero M, Greco S, Lami IM (2012) A dominance-based rough set approach model for selecting the location for a municipal solid waste plant. GEAM, Geoingegneria Ambientale e Mineraria 3(137):43–54

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2018) Choice architecture for architecture choices: evaluating social housing initiatives putting together a parsimonious AHP methodology and the Choquet integral. Land Use Policy 78:748–762

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2019) A new parsimonious AHP methodology: assigning priorities to many objects by comparing pairwise few reference objects. Expert Syst Appl 127:109–120

Abastante F, Lami IM (2012) A complex Analytic Network Process (ANP) network for analyzing Corridor24 alternative development strategies. In 2012 2nd International Conference on Communications, Computing and Control Applications (CCCA), Marseille, France, 6/8 December 2012, Code 95662, pp 17–24

Abastante F, Lami IM (2013) An analytical model to evaluate a large scale urban design competition. GEAM, Geoingegneria Ambientale e Mineraria 139(2):27–36
Abastante F, Lami IM (2018) An integrated assessment framework for the requalification of districts facing urban and social decline. Green Energy Technol 535–545. https://doi.org/10.1007/978-3-319-78271-3_42
Abastante F, Lami IM, Lombardi P (2017) An integrated participative spatial decision support system for smart energy urban scenarios: a financial and economic approach. Buildings 7
Aşılıoğlu F, Memlük YD (2017) Determining and mapping eco-cultural subregions using GIS and Simos procedure. J Indian Soc Remote Sens 45(3):553–567
Beccali M, Cellura M, Mistretta M (2003) Decision-making in energy planning. Application of the electre method at regional level for the diffusion of renewable energy technology. Renew Energy 28(13):2063–2087
Brunetta G, Salizzoni E, Bottero M, Monaco R, Assumma V (2018) Measuring resilience for territorial enhancement: an experimentation in Trentino. Valori e Valutazioni 20(69):78
Costa AS, Lami IM, Greco S, Figueira JR, Borbinha J (2019) A multiple criteria approach defining cultural adaptive reuse of abandoned buildings. Int Ser Oper Res Manag Sci 274:193–220
Delta Po Biosphere Reserve, biosferadelpo.org. Accessed the 10 of February 2019
Dyer MI, Holland MM (1988) UNESCO's man and the biosphere program. Bioscience 38(9):635–641
Federazione Italiana Parchi e riserve, parks.it. Accessed the 10 of February 2019
Figueira J, Roy B (2002) Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure. Eur J Oper Res 139:317–326
Hamdy A, El Zayat M, Marzouk M (2017) Using Simos' procedures to rank indicators for city rating system. IJASRE 3
Ingaramo R, Salizzoni E, Voghera A (2017) Valuing forest ecosystem services for spatial and landscape planning and design. Valori e Valutazioni 19:65–78
Ishwaran N, Ana P, Nguyen HT (2008) Concept and practice: the case of UNESCO biosphere reserves. Int J Environ Sustain Dev 7(2):118–131
Keeble BR (1988) The Brundtland report: 'our common future'. Med War 4(1):17–25
Lami IM (2019) The context of urban renewals as a 'super-wicked' problem. Smart Innov Syst Technol 100:249–255
Lami IM, Abastante F (2014) Decision making for urban solid waste treatment in the context of territorial conflict: can the analytic network process help? Land Use Policy 41(1):11–20
Lami IM, Tavella E (2019) On the usefulness of soft OR models in decision making: a comparison of problem structuring methods supported and self-organized workshops. Eur J Oper Res 275(3):1020–1036
Lewi G (2009) Mythologie des marques: quand les marques font leur storytelling. Pearson Education
Lombardi P, Abastante F, Torabi Moghadam S, Toniolo J (2017) Multicriteria spatial decision support systems for future urban energy retrofitting scenarios. Sustainability 9
Maystre L, Pictet J, Simos J (1994) Methodes multicriteres ELECTRE—description, conseils pratiques et cas d'application a la gestion environnementale. Presses Polytechniques et Universitaires Romandes, Lausanne
Pfenninger S, DeCarolis J, Hirth L, Quolin S, Staffel I (2017) The importance of open data and software: is energy research lagging behind? Energy Policy 101:211–215
Simos J (1990) L'evaluation environnementale: un processus cognitif negocie. These de doctorat, DGF-EPFL, Lausanne
Siskos E, Tsotsolas N (2015) Elicitation of criteria importance weights through the Simos method: a robustness concern. Eur J Oper Res 246(2):543–553
Tavella E, Lami IM (2018) Negotiating perspectives and values through soft or in the context of urban renewal. J Oper Res Soc 23:1–26

UNESCO (2019) Man and biosphere program, unesco.org. Accessed the 10 of February 2019
United Nations (2019) About the sustainable development goals, un.org. Accessed the 10 of February 2019
Wang JJ et al (2009) Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renew Sustain Energy Rev 13(9):2263–2278
Zheng P, Xu X, Xie SQ (2016) A weighted preference graph approach to analyze incomplete customer preference information in QFD product planning. In: 2016 IEEE international conference on industrial engineering and engineering management (IEEM), IEEE, pp 1070–1074

The Process of Sharing Information in a Sustainable Development Perspective: A Web Visual Tool

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Abstract Proposing effective strategies in a sustainable development perspective is the focus of considerable debates, which often develop into uncertain and vulnerable decision contexts. Numbers and quantitative information in fact often dominate the process of decision-making but they are not easily comprehensible through quick and simple reasoning. Nonetheless, the huge quantities of data that describe our cities and regions could provide excellent bases to analyze spatial data in order to assess territories and simulate future development scenarios. The application of innovative digital tools in the analysis of territorial issues offers new advantages and opportunities for the improvement of communication values in policies and decision-making processes, concurring to overcome conventional approaches to territorial management. The paper describes the application of the Interactive Visualization Tool (InViTo), a web tool based on maps and visual analysis allowing data to be filtered, explored, interconnected and compared on a visual interface. Data visualization, intended as the way to see the unseen (McCormick et al. in Computer Graphics 21(6), 1987), is here used as a new paradigm to highlight the positive and negative effects on spatial systems considering the impacts of choice-alternatives along multiple dimensions. The correlation between information and their localization generates an essential instrument for the knowledge of urban dynamics and resilience in answering to specific policies. The investigation of a number of case studies shows the possibilities and opportunities given by the use of InViTo in creating a shared knowledge between actors involved in decision-making processes and in offering a challenge for integrating new perspectives on the analysis of future cities and regions.

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1 Introduction

The on-going urbanization has led to an increased focus on cities (UN 2012) highlighting their inability to offer adequate facilities to their population. In fact, such complex congregation of people tend to become disordered places (Johnson 2008) generating sets of material and non-material problems, which often cause a decrease in terms of values. The material problems comprise among others difficulty in waste management, scarcity of resources, traffic congestions, aging infrastructures and energy management (Borja 2007; Marceau 2008; Toppeta 2010; Washburn et al. 2010). The non-material problems are instead related to social and organisational matters associated "with multiple and diverse stakeholders, high levels of interdependence, competing objectives and values as well as social and political complexity" (Abastante et al. 2012; Johnson 2008; Weber and Khademian 2008; Chourabi et al. 2012).

In this sense, urban and social issues can be considered as "wicked problems" (Rittel and Webber 1973; Abastante et al. 2019) creating potential conflicts and unanticipated effects. Due to the complexity of the cities, the mission of an urban project is never so clear including a wide number of data, variables, parameters, indexes and qualitative elements usually barely measurable.

Moreover, while in the past one of the difficulties in urban planning was the lack of data-measuring activities, nowadays the problem is the opposite: there is a huge amount of quantitative and qualitative data but they are often difficult to read. This difficulty adds a further level of complexity to the planning of strategic solutions. This is particularly true when talking about sustainable development which incorporates different concepts as: sustainable economy, sustainable environment, sustainable society.

In terms of data, the available databases need to be not simply able to visualise data but also to extract and process different kind of usable information (Mingers and Rosenhead 2004; Belton and Stewart 2010; White 2006; Montibeller et al. 2008; Pensa et al. 2014; Lami and Franco 2016; Abastante 2016).

The application of Information and Communication Technology (ICT) is often mentioned as part of the solution to those complex problems and the term 'smart city' is increasingly being used in this context (Hilty et al. 2011; Lövehagen and Bondesson 2013).

However, despite that ICT are definitely enhancing the opportunities for spatial planning changing the common vision of the social inclusion (Goodspeed 2011, 2012; Resch et al. 2014) they often present huge difficulties in being applied in daily practice (te Brömmelstroet 2010; Vonk et al. 2005): (1) it takes a long time to calculate results which hinder the interaction between data models and users; (2) data models generally have low flexibility to adjust to specific needs; (3) most of these support systems have limited abilities in communication.

Communication is in fact one of the main features to be considered when talking about effectiveness of ICT for smart cities but the approach of communication by simply "writing down your objectives and stating your priorities, is inadequate for decisions worthy of thought" (Keeney 2013; Lami et al. 2014; Lami and Abastante 2017; Abastante et al. 2018).

Thus, spatial planning is currently encountering new approaches to the use of technology. In particular, both the academic researchers and professionals are increasing their interest in data-driven methods (Kamenetz 2013; Lanzerotti et al. 2013; Kokalitcheva 2014) investigating new tools in order to allow information to be easily extracted from data and disclosed to the stakeholders involved in an urban planning process (Abastante and Lami 2013; Bawa-Cavia 2010; Neuhaus 2011; Chua et al. 2014).

In this context, the paper investigates three case studies describing the application of the Interactive Visualization Tool (InViTo), which is a web tool based on spatial maps and visual analyses allowing data to be filtered, explored, interconnected and compared on a visual interface (Pensa et al. 2014). The aim of InViTo is to build a shared basis of discussion among the actors involved being interactive in order to allow adjustments during an urban process. Furthermore, InViTo offers a way to represent different typologies of geo-referenced data and to combine them in order to visualise the "hidden connections" (Dodge 2005) among these. In this perspective, it seems to be a useful tool to support strategies of sustainable development.

After the introduction the paper is organized as follows: Sect. 2 reports the methodology adopted focussing on the development of the InViTo tool; Sect. 3 shows some examples of applications of InViTo; finally, the conclusions resume the potentialities of the methodology adopted and the future developments.

2 Methodology

2.1 The InViTo Tool

InViTo has been developed starting from 2011 (Pensa and Masala 2014). It has been conceived as a visual support for spatial planning and decision-making processes. In this sense, InViTo is a toolbox for supporting the analysis, the exploration, the visualisation and communication of data in order to facilitate policy and decision-making, improving the communication between actors coming from different backgrounds.

In its current version, InViTo can be classified within the category of Spatial Decision Support System (SDSS) (Malczewski 1999; Abastante et al. 2017; Lombardi et al. 2017) as a Web-GIS tool. In fact, it is a web platform able to show and present GIS data and let people to play with those in order to increase the level of knowledge on spatial issues among both expert and non-expert people. Nevertheless, the new developments allow the exploration of non-spatial data too, so that interactive info-graphics can be visualised and analysed. The construction and development of the InViTo tool, crossed different phases and involved many steps. In particular, it is possible to recognized six development steps: the construction of the web platform, the back-end, the front interface, the data filtering, the map weighting and the data visualization.

The building of a web platform structure was the first essential step to develop the tool creating the general framework. Its construction took several months and has been progressively adapted to the development of other elements composing the tool. It is important to underline that, in order to be really accessible, this part of the tool was completely based on an open source structure and open source initiatives.

From the point of view of the IT structure, InViTo is composed by two main sections: the back-end and the front interface.

The **back-end** is destined for GIS technicians, planners and administrators of different projects. In this section, the logged-in users can create new projects and manage existing ones deciding the information that need to be seen by final users. Moreover, in the back-end interface, the logged-in users can decide the filter modality choosing among checkbox, dropdown menu, range sliders or single choice range sliders. Finally, specific buttons provide possibilities for customising the visualisation or for enabling particular elements such as tables, analysis grids or background maps. Accordingly, the back-end interface is flexible and allows a high level of customization. This is useful when managing project devoted to the identification of strategies of sustainable development, which involve different aspects.

The **front interface** is destined for final users. In fact it can be public and allow people visualizing, filtering and exploring data related to specific projects. The front-end interface is graphically structured by two main elements: a viewer window containing an interactive map and a vertical menu on the left side containing all the parameters settled by the logged-in users in the back-end interface (Fig. 1).

The structure of the front interface can be in turn divided into three subsections: data filtering, map weighting and data visualization.

The **data filtering** section allows data to be interactively selected and filtered by the end users in order to customise the visualisation. InViTo basically works as other GIS viewers. However, it does not visualise only the different layers of a set of data, but it allows users to explore the single records of a dataset by the use of different kind of pre-settled filters. Moreover, the filters can be grouped in the so called “panels”. The panels can be defined as macro-sections of qualitative and quantitative data so that the visualisation can be driven through a particular path to follow. Moreover, InViTo allows data to be investigated at different levels with also intersection of attributes, in order to analyse data clusters in relation to specific parameters. In this sense, InViTo overcome the data-map representation to arrive to the visualisation, intended as the discipline to see the unseen (McCormick et al. 1987).

The **map weighting** section allows the filtered maps to be overlapped and weighted on the basis of their priority. The aim of the map weighting section is to provide users with a tool for analysing the localisation of expected effect of specific elements and evaluating the sum of effects on the basis of a specific mathematical curve associated to the layers. The map weighting is currently based on the sum of maps as in the basic methodology of the Multicriteria Decision Analysis

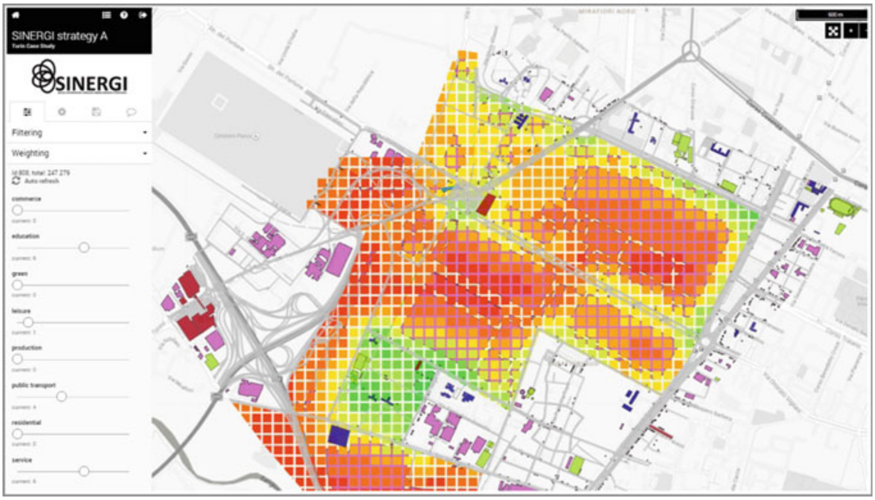

Fig. 1 Front interface of InViTo: a window containing an interactive map on the main frame and a vertical menu on the left side

(MCDA—Figueira et al. 2005). Further developments of InViTo will improve this section in order to integrate the opportunity to develop MCDA directly in the tool as the spatial Multicriteria Analyses combining GIS and MCDA (Malczewski 1999; Ferretti 2013).

The **data visualization** settings allow a high level of customization on colours, dimensions, styles, map styles (between Open Street Maps or different Google Maps styles) and on a series of utilities by means of which the tool is expected to offer a wide range of possibilities for users to improve their analytical skills and enhancing the discussion. An interesting possibility of the tools is constituted by the visualization of interactive tables and charts showing data according to the filters activated in the filtering section. The tables show the attributes related to the filtered data, providing pre-settled additional information field by field. The charts show the values of the filtered data in relation to the whole set of data, highlighting the selected geometries.

The distinctive features of InViTo are therefore dynamicity and interactivity, which make it open to variously skilled users and suitable to be part of instrumental equipment for meetings and workshops. In fact, it can be used by a single person or collectively during discussion sessions. In this case the displayed map can become the interface for sharing opinions and reasoning. In fact, its quick responses and visual interface offer possibilities for improving the discussion among people, providing a shared basis for enhancing the debate.

3 Case Studies

Spatial decisions and policymaking processes affect, or can affect, the geography of an area at different spatial scales. This can happen with a very wide spectrum of consequences, which can be studied by different discipline fields such as urban planning, transport planning, mobility, environment, social and economic sciences. The InViTo structure was conceived as open as possible in order to avoid constraints in the use of the tool. Thus, it can be used for dealing with different case studies, with different purposes and afferent to various disciplines. The following three case studies show some example of applications of InViTo.

3.1 SINERGI Project

The Social Inclusion through Urban Growth Strategies (SINERGI) is a project funded by the "Europe for Citizens" programme. It involved four cities as Skopje, Lisbon, Turin and Zagreb, in a number of seminars and workshops oriented to the improvement of the process of social inclusion within the urban planning.

In order to achieve the project objective, InViTo has been chosen to perform the SINERGI workshops. The first workshop was held in Skopje in December 2014 and was focused on the evaluation of three infrastructural scenarios for an urban area in the same city. The second workshop was held in Turin in June 2015 and concerned the renewal of a huge dismissed urban area with an industrial past and many future projects insisting on it (Fig. 2).

Both the workshops had a diversified public, composed by city administrators, technicians, academics, students and social representatives. A number of discussions emerged outlining possibilities and opportunities given by the use of interactive maps designed to facilitate and improve the interaction between the information and the actors involved in the planning process.

The tool has been used to detect critical areas and areas with more opportunities. After the discussion of some design alternative options, InViTo has been applied to evaluate "what if" scenarios. The outcome provided by the tool gave no solutions, but opportunities for the participants involved in the workshops to discuss and elaborate a shared solution.

3.2 CODE24 Project

During an Interreg IVB NWE Project named "CoDe24" (INTERREG IVB NWE, 2005; ERDF European Territorial Cooperation 2007–2013, 2010; Abastante and Lami 2012), the Interactive Visualisation Tool has been used for several events and purposes. One of these concerned the exploration of the total number of trains arriving

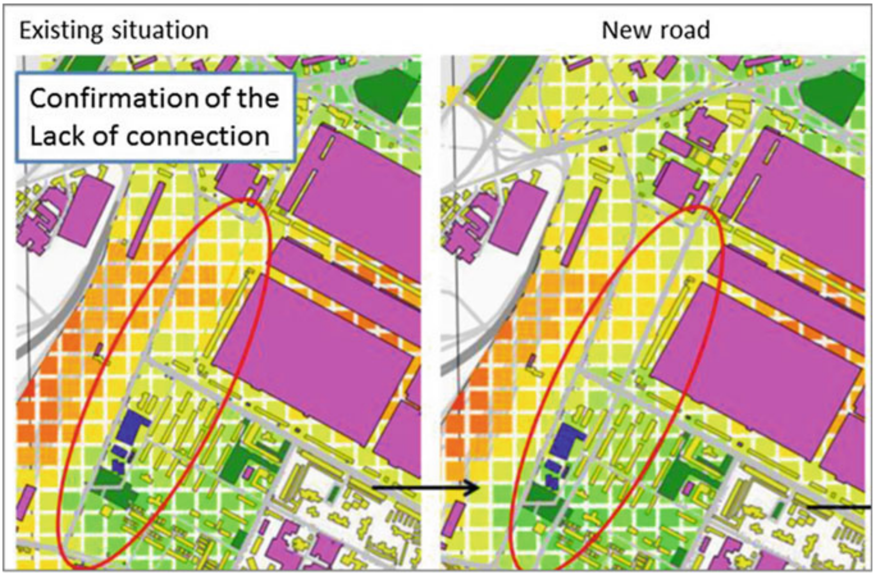

Fig. 2 The use of InViTo during the second SINERGI workshop held in Turin in June 2015: identification of an infrastructural lack and checking of design ideas

and departing from the Frankfurt am Main railway station between 8.00 a.m. and 9.00 p.m. of a common working day (Fig. 3).

The visualisation of data is interactive. Users can choose the setting and filtering of a number of parameters, such as the train typologies, the city of origin or the city of destination.

Unlike other projects, in this case the represented data are not spatial. They are organized within an info-graphic without background maps or geographical references. The geographic information is restricted in the selection of filters.

The online use of this application provided the possibility to share the information between the partners of the project. Furthermore, it generated an intuitive visualisation of the railway connections of an important city like Frankfurt am Main, showing the arriving trans, the outgoing ones and those that are crossing the city, the typology of the trains and the possible connections among the different trains. Colours and thickness of lines change according to the setting made by the users, providing further information on the selected elements.

3.3 Tweets in Barcellona

A third case study concerns the visualization of tweets sent from the metropolitan area of Barcelona in the period January 7–19, 2015. The research is part of the TUD

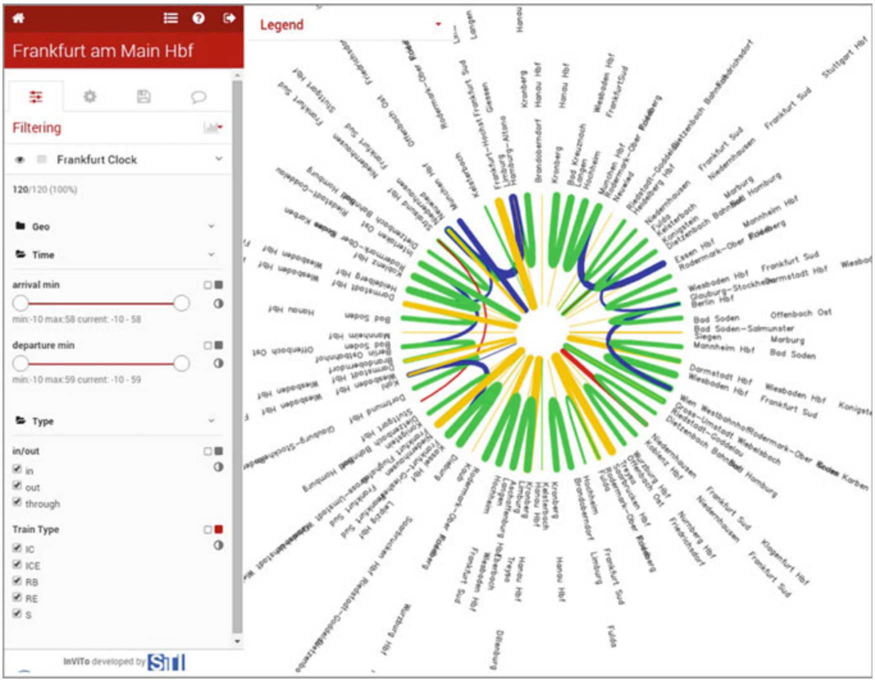

Fig. 3 The use of InViTo for visualising the railway connections of Frankfurt am Main between 8.00 a.m. and 9.00 p.m

COST Action TU1306—Fostering knowledge about the relationship between Information and Communication Technologies and Public Spaces supported by strategies to improve their use and attractiveness (CYBERPARKS). The objective of the research was the improving of the design of public open spaces by means of information captured by the analysis of user-generated data.

The data collected from Twitter have been elaborated and uploaded in InViTo. The visualisation allows users to interact with a large amount of data (more than 67,000 records) and to understand the urban patterns generated by Twitter's users by the self-exploration (Fig. 4).

The large amount of maps that can be obtained by such a data exploration is sufficient to identify several urban patterns and understand some dynamics on the use of the city. In particular, the tool showed to be very important for analysing the tweets following both a spatial and a temporal logic. The differences in tweets spatial distribution according to the temporal period selected, provided new insights on the analysis of the city. These outcomes highlighted a number of issues related to the tourism and the use of the city in relation to the origin country of people visiting Barcelona.

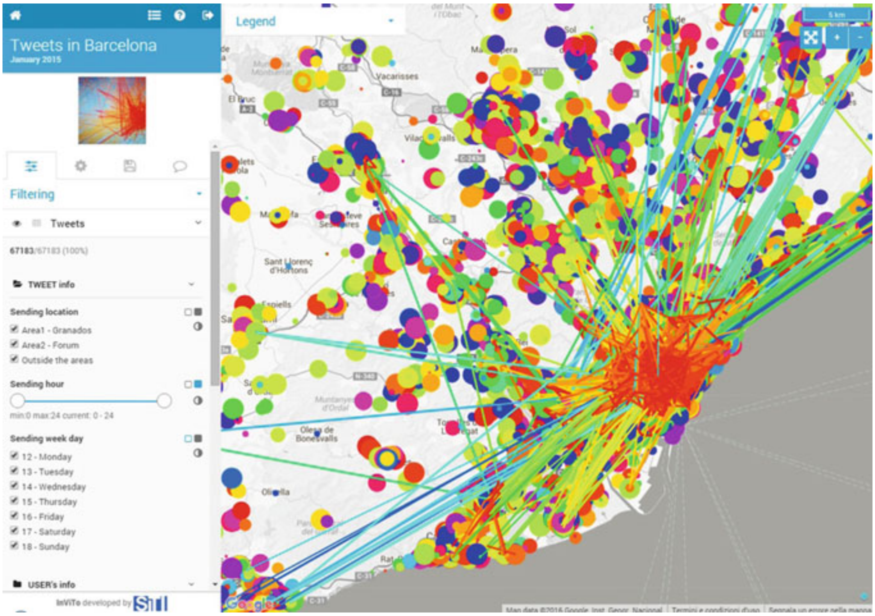

Fig. 4 The visualisation of Twitter Data in Barcelona, collected in January 2015

4 Conclusions

The three case studies are a small example of possibilities in applying the tool. As showed, InViTo can be a powerful tool in many participatory process since it is able to visualize data but alto to analyse usable information.

The high level of customisation of the filtering and weighting sections as well as of the visualisation provide a large amount of opportunities for the information sharing between large groups of people. The use of visualisation goes against a technocratic vision of cities and increases the power of experts. It allows planners, city administrators, technicians, but also common citizens, to improve their awareness of urban problems. A higher knowledge enhances the decision-making process, providing opportunities for better choices.

Furthermore, a high flexibility of the tool allows the instrument to be adapted to the case study and not, as often, the planning adapted to the possibilities given by the tool. By this way, the urban tool is not a constraint but a real support to the sustainable development of cities.

Future developments of InViTo will foresee the improvement of the MCDA section currently drafted in the tool in order to better weight the maps provided and enhance the usability of InViTo in supporting urban planning.

References

Abastante F (2016) Multicriteria decision methodologies supporting decision processes: empirical examples. Geoing Ambient Mineraria GEAM 149:5–18

Abastante F, Bottero M, Greco S, Lami IM (2012) A dominance-based rough set approach model for selecting the location for a municipal solid waste plant. Geoingegneria Ambientale e Mineraria GEAM 3(137):43–54

Abastante F, Lami IM (2012) A complex analytic network process (ANP) network for analyzing Corridor24 alternative development strategies. In: Communications Computing and Control Applications (CCCA). 2nd International conference on Marseille, France, 6/8 December 2012. Code 95662, pp 17–24

Abastante F, Lami IM (2013) An analytical model to evaluate a large scale urban design competition. Geoingegneria Ambientale e Mineraria 139(2):27–36

Abastante F, Lami IM, Lombardi P (2017) An Integrated participative spatial decision support system for smart energy urban scenarios: a financial and economic approach. Buildings 7(4):103

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2018) Choice architecture for architecture choices: evaluating social housing initiatives putting together a parsimonious AHP methodology and the Choquet integral. Land Use Policy 78:748–762

Abastante F, Corrente S, Greco S, Ishizaka A, Lami IM (2019) A new parsimonious AHP methodology: assigning priorities to many objects by comparing pairwise few reference objects. Expert Syst Appl 127(2019):109–120

Bawa-Cavia A (2010) Sensing the Urban. Using location-based social network data in urban analysis. In: 1st workshop on Pervasive URBan Applications PURBA '11. San Francisco

Belton V, Stewart T (2010) Problem structuring and multi criteria decision analysis. In: Hergot et al. (eds) Trends in multiple criteria decision analysis, International Series in Operations Research and Management Science, vol. 142. Springer Science and Business Media, pp 209–239

Borja J (2007) Counterpoint: intelligent cities and innovative cities. E-Journal on the Knowledge Society, 5. Available at http://www.uoc.edu/uocpapers/5/dt/eng/mitchell.pdf

Chourab H, Nam T, Walker S, Gil-Garcia J, Mellouli S, Nahon K, Pardo TA, Scholl HJ (2012) Understanding smart cities: an integrative framework. In: System Science (HICSS), Grand Wailea, Maui, Hawaii, pp 2289–2297

Chua A, Marcheggiani E, Servillo L, Vande Moere A (2014) FlowSampler: visual analysis of urban flows in geolocated social media data. In: Aiello M, McFarland D (eds) International conference on social informatics. Barcelona

Dodge M (2005) Information maps: tools for document exploration, CASA, working paper series 94. University College London, London. Retrieved November 5, 2013, from http://www.bartlett.ucl.ac.uk/casa/publications/working-paper-94

Ferretti V (2013) Le Analisi Multicriteri spaziali a supporto delle procedure di pianificazione e valutazione: analisi e classificazione della letteratura scientifica. Geoingegneria Ambientale e Mineraria 2:53–66

Figueira J, Greco S, Ehrgott M (2005) Multiple criteria decision analysis: state of the art surveys. Springer Verlag, Boston, Dordrecht, London

Goodspeed R (2011) The coming urban data revolution. Retrieved January 8, 2015, from Planetizen: http://www.planetizen.com/node/51158

Goodspeed R (2012) The Democratization of big data. Retrieved January 2015, 02, from Planetizen: http://www.planetizen.com/node/54832

Hilty L, Lohmann W, Huang E (2011) Sustainability and ICT—an overview of the field with focus on socio economic aspects. Notizie di Politeia 17(104):13–28

Johnson B (2008) Cities, systems of innovation and economic development. Innov Manage Policy Practice 10(2–3):146–155

Kamenetz A (2013) How cities are using data to save lives. Retrieved January 13, 2015, from Fast company: http://www.fastcoexist.com/3021498/how-cities-are-using-data-to-save-lives

Keeney RL (2013) Identifying, prioritizing and using multiple objectives. EURO J Decision Process 1:45–67

Kokalitcheva K (2014) How a swarm of data is helping Chicago re-map urban life. Retrieved January 12, 2015 da Venture Beat: http://venturebeat.com/2014/05/14/how-a-swarm-of-data-is-helping-chicago-re-map-urban-life

Lami IM, Abastante F, Bottero M, Masala E, Pensa S (2014) Integrating multicriteria evaluation and data visualization as a problem structuring approach to support territorial transformation projects. EURO J Decis Process 2(3–4):281–312

Lami IM, Franco LA (2016) Exploring the affordances of collaborative problem-solving technologies in the development of European Corridors. In: Drewello H, Scholl B (eds) Integrated spatial and transport infrastructure development: the case of European North-South Corridor Rotterdam-Genoa. Springer Publishers, London, pp 65–80

Lami IM, Abastante F (2017) Social Housing evaluation procedures: literature review and steps forward. Geam-Geoingegneria Ambientale E Mineraria-Geam-Geoengineering Environ Mining, 150:15–28

Lanzerotti L, Bradach J, Sud S, Barmeier H (2013) Geek cities: how smarter use of data and evidence can improve lives. Retrieved January 13, 2015 da The Bridgespan Group: http://www.bridgespan.org/Publications-and-Tools/Performance-Measurement/Geek-Cities-Data-Improves-Lives.aspx#.VLZ9BSvF9Ks

Lombardi P, Abastante F, Torabi Moghadam S, Toniolo J (2017) Multicriteria spatial decision support systems for future urban energy retrofitting scenario. Sustainability, 9:1252. https://doi.org/10.3390/su9071252

Lövehagen N, Bondesson A (2013) Evaluating sustainability of using ICT solutions in smart cities—methodology requirements. In: Hilty M, Aebischer B, Andersson G, Lohmann W (eds) ICT4S 2013: proceedings of the first international conference on information and communication technologies for sustainability. Switzerland, Zurich, pp 184–191

McCormick BH, De Fanti TA, Brown MD (1987) Visualization in scientific computing. Comput Graph 21(6)

Malczewski J (1999) GIS and multicriteria decision analysis. Wiley, New York

Marceau J (2008) Introduction: Innovation in the city and innovative cities. Innov Manage Policy Practice 10(2–3):136–145

Mingers J, Rosenhead J (2004) Problem structuring methods in action. Eur J Oper Res 152:530–554

Montibeller G, Belton V, Ackermann F, Ensslin L (2008) Reasoning maps for decision aid: an integrated approach for problem-structuring and multi-criteria evaluation. J Oper Res Soc 59:575–589

Neuhaus F (2011) Twitter data—seeking spatial pattern. Retrieved January 09, 2015, from UrbanTick: http://urbantick.blogspot.it/2011/03/twitter-data-seeking-spatial-pattern.html?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed:+urbantick+(urbanTick)

Pensa S, Masala E, Lami IM, Rosa A (2014) Seeing is knowing: data exploration as a support to planning. Proc ICE Civil Eng 167(5):3–8

Pensa S, Masala E (2014) InViTo: an interactive visualisation tool to support spatial decision processes. In: Pinto NN, Tenedorio JA, Antunes AP, Cladera JR (eds) Technologies for urban and spatial planning: virtual cities and territories. IGI Global Book, Hershey, PA, pp 135–153

Resch B, Summa A, Sagl G, Zeile P, Exner JP (2014) Urban emotions—geo-semantic emotion extraction from technical sensors, Human sensors and crowd sourced data. German Research Foundation (DFG—Deutsche Forschungsgemeinschaft), Heidelberg

Rittel HWJ, Webber M (1973) Dilemmas in a general theory of planning. Policy Sci 4:155–169

te Brömmelstroet MC (2010) Equip the warrior instead of manning the equipment: land use and transport planning support in the Netherlands. J Transp Land Use 3:25–41

Toppeta D (2010) The smart city vision: how innovation and ICT can build smart, "Livable", Sustainable cities. The Innovation Knowledge Foundation. Available at http://www.thinkinnovation.org/file/research/23/en/Toppeta_Report_005_2010.pdf

United Nations (2012) The future we want, Cities, fact sheet for the Rio United National Conference on Sustainable Development, Rio de Janeiro, Brazil, June 20–22, 2012, Accessible at http://www.un.org/en/sustainablefuture/pdf/Rio+20_FS_Cities.pdf

Vonk G, Geertman S, Schot P (2005) Bottlenecks blocking widespread usage of planning support systems. Environ Planning A 37(5):909–924

Weber EP, Khademian AM (2008) Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. Public Adm Rev 68(2):334–349

Washburn D, Sindhu U, Balaouras S, Dines RA, Hayes NM, Nelson LE (2010) Helping CIOs understand "Smart City" initiatives: defining the smart city, its drivers, and the role of the CIO. Forrester Research Inc, Cambridge, MA

White L (2006) Evaluating problem-structuring methods: developing an approach to show the value and effectiveness of PSMs. J Operational Res Soc 57(7):842–855

B.I.M. Models and Evaluations

Giovanna Acampa, Fabiana Forte and Pierfrancesco De Paola

Abstract The new Italian Procurement Code—L.D. n. 50, 2016—implementing the 2014 European Union Directive, introduced BIM (Building Information Modeling) as an innovative approach to digitalize the construction sector. The recent Decree n. 560 of December 1st 2017 defines the methods and schedule for the gradual introduction of the BIM for the design, execution and management of construction works. BIM procedures involve a radical change in the design approach that goes from the graphical representation to the simulation of a process, both in the field of new constructions and in the field of Cultural Heritage conservation. In this perspective the article shows the results of a survey carried out on historic buildings. It aimed at verifying how much the modeling has remained confined to a low level of development (LOD A, according to the UNI 11337 standard is linked to a merely symbolic level) and those who have gone further by integrating specific and detailed information that allow real time to evaluate the sustainability of different alternatives. The article, which represents a first step of an ongoing research, starting from the regulatory framework of the BIM in Italy, highlights its potential (Sect. 1); the issue of the evaluation is deepened (Sect. 2), with particular reference to the 5D-BIM Project cost management and to the Heritage Building Information Modeling (HBIM).

Keywords BIM models · Evaluation · Design

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1 BIM in Italy: Regulatory Framework and the Potential in the Construction Sector

The new Italian Procurement Code—Legislative Decree n. 50, 2016—implementing the 2014 European Union Directive, reorganizes completely the regulatory framework regarding public contracts relating to works, services and supplies. One of the main innovations is the «rationalization of the design activities and the connected verifications through the progressive use of specific electronic methods and tools as that of modeling for building and infrastructures» (art. 23, Design Levels, subsection 1, letter h). Both for new works and for renewal and requalification interventions or variations, the Contracting Authorities may require the use of these specific electronic methods and tools (art. 23, subsection 13). The implementing decree establishes manners and times, making mandatory the use of the BIM (Building Information Modeling) starting from 2019 (Ministerial Decree 560/2017).

Although several definitions of BIM. Exist (introduced a long time ago in USA and in other European countries), it can be briefly defined as a virtual environment able to store all the information on the architectural design, on the specifications of the used products, on the logistics, on the sequence of interventions to carry out the construction and on the costs for the accomplishment, management and maintenance of the work (CRESME 2017). This "platform" allows to share knowledge and to communicate among the several stakeholders involved in the whole Life Cycle of the building. In this perspective the "evaluation process" becomes crucial and is complex to carry out (Forte 2015).

On one hand, the evaluation should enhance the quality of the decisional process—technical and political-, related to both resources allocation (monetary, human, territorial, etc.) and effects or impacts. On the other, the evaluation influences the efficiency of all the planning, and guarantees that the resources to be deployed in the implementation are used rationally.

In the Italian system of public works one of the main problems is the production time and the costs. The 2014 Report by the Italian Department for the Economic Development and Cohesion (DPS), concerning the times and costs of the infrastructure investments, highlights that the time to complete works is very long and delays are frequently associated with an increase in costs. According to the report, if the interventions for an amount lower to 100 million of Euro are completed in 2,9 years on average, the works for an amount greater than 100 million Euro, take more than 14 years. Specifically, the weight of "crossing times" (the time necessary to pass from a procedural stage to the next one) is particularly significant (DPS 2014).

This framework emphasizes another typical problem in the Italian system of production of public works: the low focus on the design phase (Fattinnanzi et al. 2018).

As shown in Fig. 1, within the whole Life Cycle of the building (planning, concept, design; construction; use and maintenance) the early stage of design has a very high potential to influence the full life cycle and its costs, while this potential decreases during the Life Cycle.

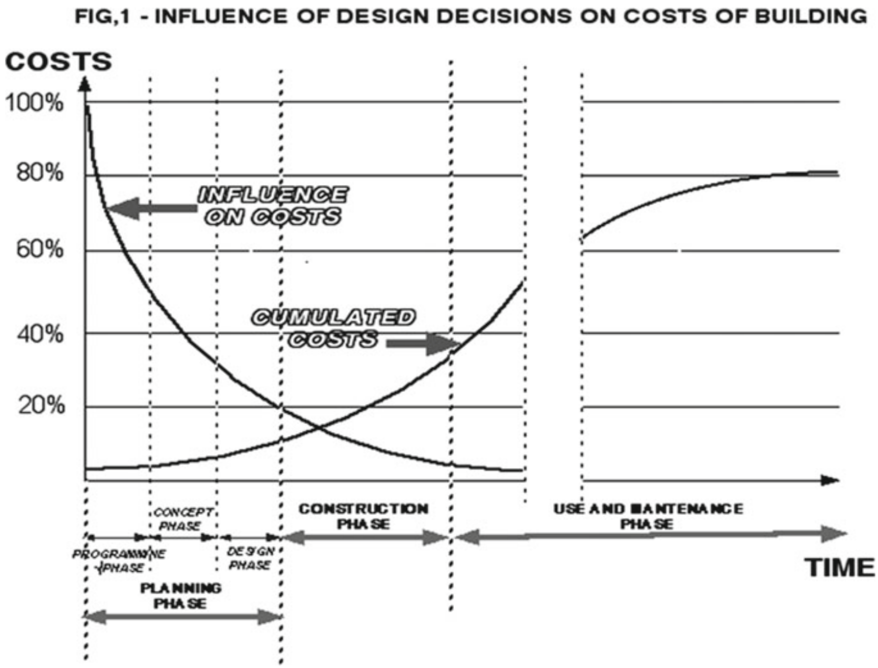


Fig. 1 Influence of design decisions on the life cycle costs. (*Source* Forte 2015)

In that same phase a huge amount of information has to be processed quickly and crucial decisions must be taken. About 75% of the costs of the building are already fixed during the planning/design phase and, in this same phase, it is possible to introduce improvements. Furthermore, from this point of view there are several advantages in the use of the BIM model: higher efficiency and productivity, shorter downtime, lower costs, a more rigorous and coherent control of the project. Besides, a project conceived following the BIM approach, enables the Contracting Authority to have a virtual elaboration of the Life Cycle of the building and thus, it is easier to monitor the obsolescence of materials and to better plan the maintenance.

Regarding the trend in the use of BIM in the public competitive procurements, it is interesting to highlight what emerges from the recent OICE Report (2018): although actually the BIM competitions cover a minimal share of the entire public demand—only 1.4% in number on the total for architecture and engineering services and the 2.5% in value-, 2017 marked a turning point because the competitions have tripled: from 26 competitions on 2016 to 86 on 2017 (in the 2015 were only 4). A meaningful increase of 70%, probably due to the approval of the BIM Decree (Ministerial Decree no. 560/2017). With reference to the subdivision for typology of intervention, the 2017 BIM competitions in 2017 anticipate a trend which all the design sector will have to address: the renewal and requalification interventions on the existing built environment. (OICE—Confindustria 2017).

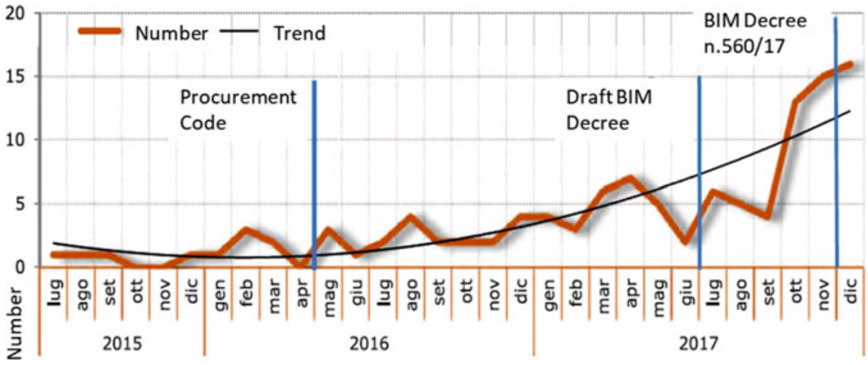


Fig. 2 Monthly trends of the number of the BIM competitions. (*Source* Report OICE BIM 2017)

The new Italian Procurement Code (Cape III, art. 146–151) regulates also the procurements in the sector of Cultural Heritage. In order to implement the Code, the Regulation no. 154 (2017) was adopted by MiBACT (Ministry for Cultural Heritage and Activities and Tourism). Even if it does not refer to it explicitly, the introduction of the Historic BIM (HBIM) for the "design, execution and management" in the process of conservation and enhancement (Forte 2016), has become unavoidable also in the field of Cultural Heritage, although in Italy it is still an emerging sector (as in the section 2.3 of the article).

In Italy the protection and the management of Cultural Heritage is regulated by the Italian Code on the Cultural and Landscape Heritage (L.D. n. 42/2004, art. 106). Its Article 29 establishes that the conservation of the cultural heritage is ensured by means of a consistent, co-ordinated and "programmed" activity of study, prevention, maintenance and restoration.

Therefore, each activity must be carefully co-ordinated and programmed with the others so that all the interventions complement each other in the overall conservation process, addressing the entire life cycle of the cultural asset. In this perspective the use of the HBIM could bring significant advantages (Fig. 2).

Especially regarding monuments restoration, where "unexpected" events are even more frequent compared to an ordinary building site, HBIM seems the most effective methodology to implement: a more precise knowledge of the status quo, is crucial to take for the most correct choices of intervention; the control of the time and the cost and indeed, the planning of the subsequent maintenance actions.

2 BIM and Evaluations

2.1 Introduction

The novel methodologies to draft projects using advanced technologies and electronic tools, dictate an update in architects' profession. Designers and evaluators dealing with architectural works, must absorb the rationale that defines the new way of dealing with the building process; in order not to be left out of this unstoppable process they are called to make their contribution (Acampa et al. 2018a).

In the field of restoration and maintenance of historic buildings, the first step for HBIM (Heritage Building Information Modeling) is to build a 3D model that simulates the building. In this perspective, the survey techniques can no longer be linked only to the geometric and dimensional characteristics of the building itself, but must also include qualitative and performance information of all its technical and architectural elements.

The model's effectiveness, however, will depend not only on the amount of information collected for each element, but also on the knowledge that the designer has of construction technologies. The added value linked to his professional experience is essential for identifying the required restoration and maintenance interventions. In fact, the more the virtual model will adhere to reality, the more reliable will be the selection of the design alternative which, at certain costs, will optimize the quality performance of the technical elements over time.

Applying BIM methodologies on buildings of cultural historical interest is not trivial, as their variety and complexity often makes harder to figure out all the parts of which they are made of. The model must start from the comprehension and analytical graphic rendering of all its parts.

The studies carried out and published in recent years, show how up to now HBIM has been used above all for the graphic restitution of buildings, as it was a CAD system, and therefore exploiting at the minimum its potential.

2.2 5D-BIM Project Cost Management

Designing in BIM means overturning the logic to which we have been accustomed, in fact we must move from the graphic representation of the work to its simulation.

The change, which is now unavoidable, given the rules set by the new legislation on public procurement, brings with it some important methodological consequences.

Up to now, design was carried out in subsequent phases: from the more general design, with a scale of representation that framed the work at territorial level, to the more detailed one through a step-by-step procedure.

In the building process the design and construction phases used to be substantially different. The design phase could be considered completed even at preliminary level and, relying on integrated contracts, design choices and construction details were deferred to the phase in which the work itself was carried out. Even if the designer got to the stage of conceiving the executive design, he often referred to generic constructive details not traceable within the project (Jodice et al. 2001).

The widespread inability of designers to assess the economic and production consequences of their choices, and also the ineffectiveness of the tools used to control costs, left a very wide decision-making margin for the contractors. The consequence was increase in time and costs against poor quality. Practically, quantity surveying was used to establish the cost of work once design choices had already been made, and was drawn up following a business logic linked to work orders carried out on site. It was not a tool to compare costs and productivity of different technical elements and therefore useful for making design choices (Acampa et al. 2018b).

Now, with the BIM design, we can no longer disregard the feasibility of the details, the 3D model is no longer an "attractive representation" that at the end of the project gives to non-professionals an idea of the envelope, but it is as if it were a "general rehearsal".

The virtual model is obtained in fact from the aggregation of elements belonging to repositories, just as the work is the result of the assembly of technical elements. The cost related to its construction is the product between the physical quantities of its elements and the costs of building them. Each element has a specific role and can be made with different technologies, and its costs will differ depending on breakdown of the products composing it and on the construction procedures.

The total cost of the work will therefore be a function of the parametric cost of each technical element, and it will include, in addition to construction costs, the maintenance costs incurred over a specific period and the disposal costs (Fattinnanzi 2011, 2012).

This technological revolution can be an opportunity to reconsider the tools and timing of the computation. Building Information Modeling provides both opportunities and challenges for the project cost management profession (Smith 2016) as it does not focus only on 3D modeling but it is also defined by further dimensions (Fig. 3).

For example, the UNI 11337, the Italian BIM standard, in parts 5 and 6, requires specifying 7 dimensions:

- methods for planning management (4D-Programming);
- methods for economic data management (5D-Computations, appraisals and evaluations);
- methods for information management (6D-Use, management, maintenance and disposal);
- methods to manage externalities (7D—Social, economic and environmental sustainability).

and encodes information on the elements in repositories, LOD (Level of Development/Detail/Definition), with letters from A to G and for each letter it defines graphical characteristics (LOG Level of Geometry) and attributes (LOI Level of

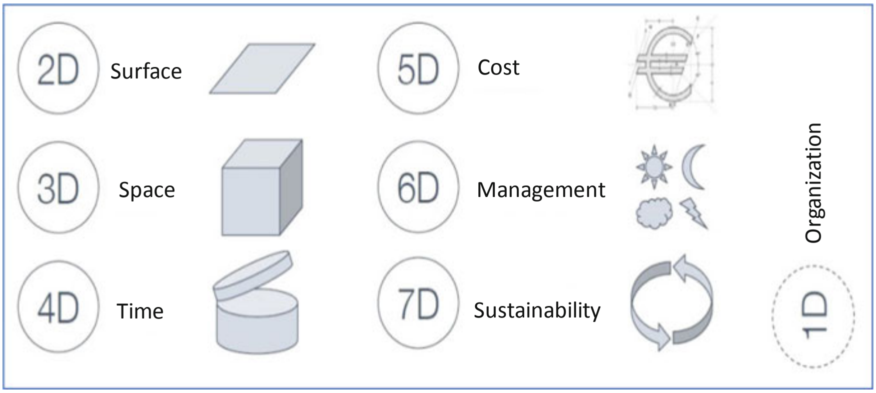
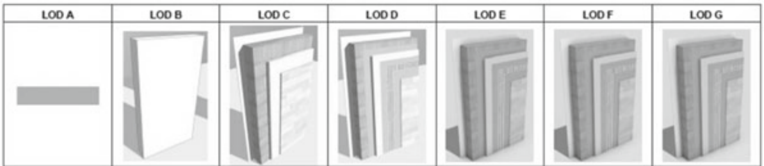


Fig. 3 BIM dimensions. (*Source* Alberto Pavan, UNI 11337-2017)



	LOD A	LOD B	LOD C	LOD D	LOD E	LOD F	LOD G
Geometry of Vertical or pseudo-vertical architectural element	Element represented by a 2D symbol	Generic solid for representation of vertical or pseudo-vertical architectural element with shape, thickness and approximate	Element was represented with dimensions calculated according to the technical regulation	Element represented by a solid with real dimensions. Modeled stratigraphies	Element represented by a solid with real dimensions. Including stratigraphies specific data on materials and finishes.	Wall object	Wall object
Object	2D graphic	3D solid	Structured 3D solid	Complex 3D solid	Complex 3D solid	Solid complete wall	Solid wall
Characteristics	Approximate positioning	Simple overall dimensions	Thickness, length, width, volume, definition of materials	Definition of detailed stratigraphies thicknesses, structure, insulation, inner tube	Internal and external finishing type, internal and external finishing surface	Maintenance manual, Classification (UNI 8290, CSI, etc.), Product certification	Maintenance data

Fig. 4 Level of development (modified by Alberto Pavan, UNI 11337-2017)

Information) of the elements. The choice of coding LODs with letters, unlike numbers as in UK[1] or USA,[2] shows how UNI's LODs, that replace the scale concept of graphic representation, have been adapted to the Italian reality (Fig. 4).

In the fifth dimension, the computation will be carried out according to the parametric impact that components have on the project (Xu 2017); this change, compared to actual practice, will impact also on price lists. Starting to control costs from the

[1]In UK, directive PAS 1192-2 (focused on information management for the delivery phase of construction projects using Building Information Modeling) specifies two components for the Level of Definition: Level of detail (LOD), regarding the graphic content of the models, Level of information (LOI), regarding the no-graphic content of the models.

[2]The American Institute of Architects (AIA) published Document G202-2013 Project Building Information Modeling Protocol. The Level of Development LOD identify the specific minimum content requirements.

design phase, it will certainly lead to optimize them as demonstrated also by an analysis carried out in 2013 on 35 selected cases (Bryde et al. 2013).

2.3 Evaluation in the Heritage Building Information Modeling

In Italy, given also the land use reduction policies in force, maintenance and restoration of buildings have attracted renewed interest and along with that, the analysis of the elements' degradation and of the maintenance costs necessary to contain the phenomena. In BIM models this means that we will refer above all to LOD level F and LOD level G.

The levels from A to E are not significant in the restoration and recovery of buildings except for some simplifications, while it is only in level F that the objects virtually show the reality as measured by means of surveys at the place of the intervention (as-built). In level F, in fact, the quantitative and qualitative characteristics are specific to the individual elements. Furthermore, for each individual element, management, maintenance and/or repair interventions are defined and is described how they should to be carried out over a period of time. In level G, the model shows the actual state of the elements along with the dynamic and updated virtualization of past and possible future interventions. Any type of intervention is noted, and levels of degradation are monitored and updated. The procedure is very complex due both to the heterogeneity of the elements and the types of degradation that depend on multiple causes. The causes of degradation can indeed be intrinsic, linked to the location, to constructional defects, materials or construction technologies; or extrinsic linked to the action of time and use. The effects may bring to physical, chemical, surface or structural alterations. Considering the degradation of an asset as a result of the degradation processes of its elements, the cost of recovering buildings of historical interest will be the sum of the costs necessary to eliminate the deterioration in all the elements involved, to bring the building back to an appropriate level of performance. Case-studies are very complex and still very few researches have dealt with BIM models for restoration while most stop at 3D level.

A review of the literature related to the BIM, shows that 131 contributions were published from 2007 to 2018, but only 20 have to do with interventions on buildings of historical interest (HBIM), all recently published. Of these 20, half is by Italian authors, not surprisingly—given the vast artistic and cultural heritage of the country (see Table 1 and Fig. 5).

The papers dealing with the computational part (5D BIM) outnumber HBIM papers and most of them were written by non-Italian authors. It is significant. No one in Italy is dealing with historical building modeling. It is an opportunity to open a new interesting line of research.

Table 1 Flow Publications

Journals				
	Journals	Main Topics	Impact Factor [a]	Number of Selected Publications
1	Journal of Cultural Heritage	Material science, Multidisciplinary	1.838 (JCR)	8
2	International Journal of Architectural Heritage	Construction & Building Technology	1.053 (JCR)	3
3	Advanced Engineering Informatics	Computer Science, AI	2.680 (JCR)	2
4	Automation in Construction	Construction & Building Technology	2.919 (JCR)	12
5	Computer-Aided Civil and Infrastructure Engineering	Construction & Building Technology	5.786 (JCR)	1
6	Studies in Conservation	Analytical	0.578 (JCR)	1
7	International Journal of Project Management	Management	4.034 (JCR)	1
8	Structural Survey	Buildings and Construction	0.28 (SJR)	2
9	Procedia Engineering	Engineering	0.74 (CiteScore)	1
10	International Journal of Architectural Computing	Computer-aided Architectural design	0.122 (SJR)	2
11	ISPRS Journal of Photogrammetry and Remote Sensing	Remote sensing	6.387 (JCR)	23
12	Survey Review	Remote sensing	0.929 (JCR)	5
13	Computers in Industry	Computer Science	2.691 (JCR)	1
14	Digital Applications in Archaeology and Cultural Heritage	3D digital models of the cultural heritage	0.252 (SJR)	3
15	DISEGNARE CON	Heritage Architecture	–	3

(continued)

Table 1 (continued)

Journals				
	Journals	Main Topics	Impact Factor [a]	Number of Selected Publications
16	Journal of Computing in Civil Engineering	Computer Science, Engineering	2.310 (JCR)	1
17	Computers Environment and Urban Systems	Environmental Science	2.659 (JCR)	1
18	Information and Software Technology	Information Systems, Software Engineering, Graphics	2.694 (JCR)	1
19	WIT Transactions on The Built Environment	Buildings and Construction	0.12 (SJR)	4
20	Science China Information Sciences	Engineering, Material Science	1.719 (JCR)	1
21	Archives of Computational Methods in Engineering	Computer Science, Interdisciplinary Applications	5.061 (JCR)	1
22	Journal of Information Technology in Construction	Buildings and Construction	0.352 (SJR)	2
23	Leadership and Management in Engineering	Civil and Structural Engineering	0.144 (SJR)	1
24	Virtual Archaeology Review	Conservation, Documentation, 3D surveying	–	2
25	International Journal of Building Pathology and Adaptation	Buildings and Construction	0.82 (Scopus)	1
26	Built Environment Project and Asset Management	Design and Construction management	1.07 (Scopus)	1
27	CSE-City Safety Energy	–	–	1
28	SCIRES-IT-SCIentific RESearch and Information Technology	Cultural and environmental Heritage documentation	–	2

(continued)

Table 1 (continued)

Conference Proceedings		
1	Annual Conference of the Association for Computer Aided Design in Architecture	1
2	eCAADe Conference	1
3	ICB World Building Congress	1
4	International Conference on Computing in Civil and Building Engineering	2
5	International Conference on Big Data (Big Data) IEEE	1
6	Digital Heritage International Congress (DigitalHeritage) IEEE	7
7	CIB W78 Conference	1
8	International Building Control Conference	1
9	International Conference on Virtual Systems and Multimedia	2
10	International Scientific Committee for Documentation of Cultural Heritage (CIPA)	2
11	International Symposium on Automation and Robotics in Construction (ISARC)	1
12	Digital Documentation International Conference	1
13	EuroMed	1
14	International Conference of Science and Computation ICCSA	1
Books and Internet Sources		
1	Recording, Documentation, and Information Management for the Conservation of Heritage Places	1
2	Heritage Building Information Modelling	1
3	Computational Modeling of Objects Presented in Images	1
4	Handbook of Research on Emerging Technologies for Digital Preservation and Information Modeling	1
5	BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors	1
1	ClearEdge 3D	1
2	IMAGINiT	1
3	Graphisoft	1
4	Tekla	1
5	MicroStation	1
6	BuildingSMART	3
7	Autodesk	1
8	DAYSIM	1
9	SKETCHUP	1
10	DURAARK	1
11	Innovmetric	1
12	Meshlab	1
	Regulations	2

[a] Impact Factor according to: (JCR) *InCites Journal Citation Reports*, (SJR) *Scimago Journal and Country Rank, CiteScore and Scopus*

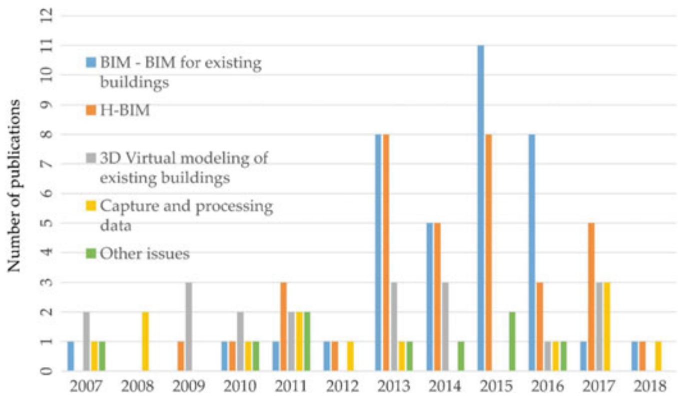


Fig. 5 Most used approaches for the publications in Table 1

3 Conclusions

BIM is evolving significantly in the field of management and documentation of cultural heritage. However, the virtual reconstruction procedure of historical-cultural heritage is not an easy task, because the objects to model consist of components whose heterogeneous, complex, and irregular characteristics and morphologies are often not represented in the BIM software repositories.

The planning and management of conservation and restoration projects could be improved by having access to the virtual model of a historical monument. 3D laser scanners and photogrammetry are used, along with historical bibliographical analysis, to capture the geometry and identity of the analyzed buildings. The complexity and irregularity of the shapes characterizing historical buildings, and the lack of intelligent algorithms to fully automate the virtual modeling, make the constructive process of parametric components a significantly time-consuming process.

This review has shown that there is still much to do in this domain, where more research and development should be carried out to address the ongoing progress of BIM platforms and their relationship to architectural heritage. Future research could focus on the development of useful tools for creating different kinds of element arrays, to create shape recognition algorithms to automate the parametric reconstruction of entire buildings, to create a universal and free-access H-BIM repository containing all the information useful for all those involved in architectural heritage issues.

References

Acampa G, Napoli G, Giuffrida S (2018a) La disciplina estimativa in Italia,—Identità, conoscenza, prospettive in Valori e Valutazioni. Teorie e Esperienze, n. 20

Acampa G, Bona N, Grasso M, Ticali D (2018b) BIM: building Information Modeling for infrastructure. In: En: AIP conference proceedings, 140008

Bryde D, Broquetas M, Volm JM (2013) The project benefits of Building Information Modeling (BIM). Int J Project Manage 31

CRESME (2017) L'architetto nella città del futuro. Scenari di trasformazione del mercato e della professione. Cresme Ricerche, Architetti Roma Edizione, Roma

DPS (2017) Dipartimento per lo Sviluppo e la Coesione Economica. I tempi di attuazione e di spesa delle opere pubbliche, Rapporto

Fattinnanzi E (2011) La valutazione della qualità e dei costi nei progetti residenziali. Il brevetto SISCo (prima parte). Valori e Valutazioni. Teorie e Esperienze, n. 7. Roma, DEI

Fattinnanzi E (2012) La valutazione della qualità e dei costi nei progetti residenziali. Il brevetto SISCo (seconda parte). Valori e Valutazioni. Teorie e Esperienze, n. 8. Roma, DEI

Fattinnanzi E, Acampa G, Forte F, Rocca F (2018) The overall quality assessment in an architecture project. In: Journal of SIEV—Italian Real Estate Appraisal and Investment Decision Society—Valori e Valutazioni, theories and experiences, n. 21. Dei, Roma

Forte F (2017) Appraisal and evaluation in the production of works for the transformation of the contemporary city. In: Stanghellini S, Morano P, Bottero M, Oppio A (eds) Appraisal: from theory to practice. Results of SIEV 2015. Green Energy and Technology, Springer

Forte F (2018) Historic, artistic and cultural patrimony for a "Habitable City": incentives for care", cap.19. In: Mondini G, Fattinnanzi E, Oppio A, Bottero M, Stanghellini S, (eds) Green energy and technology, integrated evaluation for the management of contemporary cities, Results of SIEV 2016. Springer

Jodice M, Gori P, Pacciani I, Bosi F, Capasso E, Frugiuele S (2001) La legge 109 sul pubblico appalto e la gestione dei finanziamenti CEE per gli interventi sul Patrimonio storico-culturale della Toscana. In: Floridia A. (a cura di) Beni Culturali in Toscana. Politiche, esperienze, strumenti. Milano, Franco Angeli

OICE—Confindustria (2017) Rapporto sulle gare BIM 2017 per opere pubbliche. Analisi del mercato e delle gare. Roma

Smith P (2016) Project cost management with 5D BIM. Procedia Soc Behav Sci 226:193–200

Xu J (2017) Research on application of BIM 5D Technology. Central grand project. Procedia Eng 174

Integrated Assessments and Energy Retrofit: The Contribution of the Energy Center Lab of the Politecnico di Torino

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Abstract Traditionally, local energy planning has been carried out following a sectorial approach, neglecting the long-term effects of energy policies, not considering social and environmental elements and omitting important actors involved. More innovative approaches lead to consider evaluation models able to take into account the full range of impacts generated at the level of utilities, end-users and society in general. This chapter aims to provide a reflection on the role of assessment tools in decision-making processes related to energy retrofit operations at architectural and urban level, presenting a series of recent and innovative experiments developed in the joined research group of the Energy Center Lab at Politecnico di Torino (Italy). Different techniques were applied to real case studies to provide an answer to concrete evaluation problems in the energy field. The results of the various applications show that the proposed valuation techniques offer useful tools to support local energy planning processes according to integrated energy-economic models.

Keywords Energy planning · Decision-making · Co-benefit · KPI · Extra-economic impact

1 Introduction

Most of the energy related activities take place in cities, that are recognised as the main engines of world economy. Despite cities cover only the 2% of lands globally, they are responsible for 70% of world primary energy consumptions and greenhouse gas emissions. Moreover, half of the world's population lives in cities, and this number is expected to rise to 75% by 2050. This massive urban growth makes the future of our economies, climate and energy supply increasingly challenging, requiring to rethink our development model and our cities. Accordingly, the European Union has

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drawn up a transition plan towards a low-carbon economy, through the publication, in 2011, of the document “A Roadmap for moving to competitive low carbon economy in 2050” (European Commission 2011). Its objective is to reduce emissions by 80% to 2050 compared to 1990, with intermediate targets of decreasing of 25% to 2020, 40% to 2030 and 60% to 2040. In this strategic framework, all the sectors will have to participate in the transition according to their technological and economic potential. Among urban sectors, buildings are relevant, since they are responsible for 40% of the final energy demand and for about 36% of carbon dioxide gas emissions in Europe (BPIE 2011). Thus, in order to increase the urban energy performance a building stock renovation is needed, that allows to reconfigure its demand and supply. Indeed, buildings are expected to reduce their emissions by 90% to 2050 compared to 1990 (European Commission 2011). To reach this ambitious target, the EU issued the Energy Performance of Building Directive—EBPD (European Commission 2002). After having introduced a common standard for calculating the energy performance of buildings, EPDB has been reviewed with the approval of Directive 2010/31/EU or EPBD recast (European Commission 2010), which introduced the concept of near/Net Zero Energy Building (nZEB and NZEB). The innovation brought by this first revision of the Directive consisted in the introduction of a new metric to evaluate possible interventions on buildings, measuring the optimal level of cost in relation to the expected energy benefit. The cost-optimal level can be defined as the level of performance of a building that brings to the lowest cost on the useful economic life of the building and it is evaluated according to a methodology called cost-optimal analysis. The cost-optimal methodology is based on the evaluation of the primary energy consumption of a building under different hypotheses of retrofit and of the overall cost of the corresponding interventions, namely the global cost. The latter represents a financial indicator defined as the sum of the current values of the cost items that are needed throughout the entire life cycle of the building (European Committee for Standardization 2017). The introduction of the concept of cost-optimal has been a symptom of the need to include financial assessment in the definition of national energy performance targets in buildings. Its identification allows a building design and construction suitable for the market.

Besides the introduction of financial requirements in energy efficiency targets definition, the current debate on the legislative package “Clean Energy for all Europeans” testifies the growing attention to socio-economic aspects and the need to integrate non-technical parameters in energy planning. The new revised EPBD (European Commission 2018) tries to promote the spreading of Information and Communication Technologies (ICT) in buildings, proposing new metrics to measure buildings technological readiness to capture users’ needs and grid requirements, catching the potential of ICT market and the capability of ICT solutions to improve living condition and occupants’ satisfaction in buildings. The vision proposed by this new EPBD is in line with the ongoing evolution of the energy system, which is transforming from a centralized, fossil-fuel-based, highly-energy-consuming system to an energy efficient, more decentralized, renewable-energy-based and interdependent one, in a framework where the buildings are expected to have an active role as energy hubs and as part of a wider environment, where the system, the buildings and the occupants communicate and interact (BPIE 2016). As a consequence, the attention of researchers needs to be moved to new scales of evaluation, adopting an integrated approach and enlarging the perspective from the single building one to the district or city level, considering the system occupants-building-grid as a whole.

Starting from different innovative experiments developed in the joined research group of the Energy Center Lab of the Politecnico di Torino (Italy), the aim of this chapter is to give an overview of possible evaluation methods, providing a reflection on their role in the framework just depicted and as assessment tools in decision-making processes related to energy retrofit operations at architectural and urban level.

In Sect. 2 methods are theoretically introduced, while Sect. 3 provide some application results. Finally, policy and market implication of their deployment are reported (Sect. 4) as well as final remarks (Sect. 5).

2 Energy and Economic Evaluations to Support Decision-Making Process

On the basis of such references, this section proposes an overview of the methods employed in the Energy Center Lab works that integrated different assessment approaches to evaluate the economic performance of energy investments at different application scale. The Energy Center Initiative sprang from the commitment of Municipality of Torino, Piedmont Region and Politecnico di Torino, with the support of Compagnia di San Paolo and Fondazione CRT, to strengthen the cooperation between political, scientific and business actors through the construction of a physical headquarter where they could collaborate on R&D themes related to energy (Borchiellini et al. 2017).

Figure 1 provides a synopsis of various cost and benefit items that can be included in sustainable energy decision-making (Bisello et al. 2017; Wang et al. 2009).

2.1 Life Cycle Cost Approach

In the economic-estimative scenario of energy investments, numerous approaches have been developed that have incorporated the objectives and principles of Life Cycle Thinking (Strantzali and Aravossis 2016). The methods extend the evaluation to the entire life cycle of the assets under examination (Dell'Anna et al. 2019). The life cycle is crucial for decision-making processes in the presence of alternative technological options, at different production/construction scales (single material, single component, systems at the building-plant scale) or at different territorial levels (scale of projects complex transformation, district scale, urban scale) (Fregonara et al. 2018). In particular, the most consolidated approaches are Life Cycle Costing (LCC)

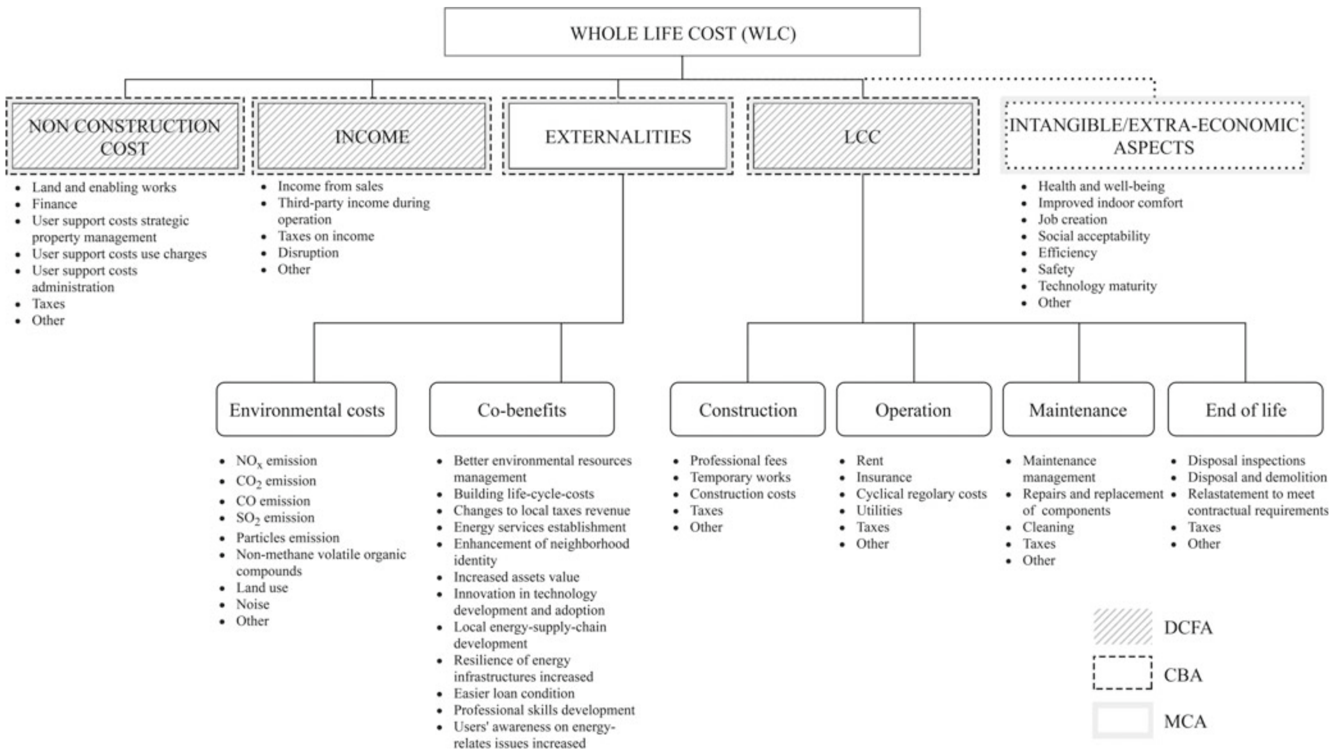

Fig. 1 Evaluation techniques applied in energy decision problems

and Life Cycle Assessment (LCA) (Fregonara 2015). If the LCC (ISO Standard 15686: 2008–5) considers only direct monetary costs incurring during the whole life cycle of a building or building system, the LCA method (ISO 14040/44: 2006) introduces the environmental impacts costs in the equation of economic performance.

2.2 Externalities Estimation

In recent years, as part of the feasibility assessment of energy projects, there is a progressive tendency to incorporate extrinsic variables, co-benefits, in addition to the economic parameters directly linked to the project (European Commission 2014). In particular, the concept of co-benefit has been recently introduced and is commonly used to define any positive impact of a policy, program or project, which is next to the primary objective (Bisello and Vettorato 2018; Ferreira et al. 2017; Ürge-Vorsatz et al. 2014). In general, monetization of co-benefits is possible using different techniques related to specific categories: existing market analysis, revealed preferences (RPs), stated preferences (SPs) and benefit transfer. Direct costs and benefits, such as savings in bills, can be easily quantified referring to existing market. On the other hand, when intangible impacts come into play, estimating them with a monetary value is really difficult. In particular, the methods of RPs indirectly deduct the values relating to a good or service from information observed by an existing market, connected to the asset in question. The two most common techniques in this area are the Travel Cost Method and the Hedonic Price Method (HPM). When market conditions are not available, it is possible to create a hypothetical scenario, a fictitious market, asking people how they would behave if that scenario were real expressing their willingness to pay (WTP). The SP methods mostly applied for this purpose are the Contingent Valuation Method (CVM) and the Choice Experiment (CE) (Bisello et al. 2017; Bottero et al. 2014).

2.3 Evaluation Frameworks

Energy interventions require the decision-maker to consider a series of technical, economic, environmental and social impacts in the assessment phase (Wang et al. 2009). In recent literature, importance has been given to the development of tools to support energy issues at the district (Nearly Zero Energy District, NZED) and urban (Post-Carbon Cities, PCC) scale. The evaluation techniques in support of the decision in the energy field useful for the comparison of different alternatives are divided into two large families: single-parameter analysis of cash flows (Discounted Cash Flow Analysis, DCFA; Cost-Benefit Analysis, CBA), and multi-criteria analysis (MCA). The DCF technique is mainly applied in the private sector, and is based on the estimate of profitability in the analysis of cash flows by determining the current value of the revenue generated by an investment (Prizzon 2001). The profitability of the project is calculated by the difference between the sales revenue and the costs incurred for the realization of the project during the life cycle. As stated by the European Commission (2014), the DCF is not enough, however, to evaluate projects of a public nature, given the number of stakeholders that come into play. To evaluate large-scale projects, it is necessary to evaluate the usefulness of the intervention for the community in general through CBA technique. Compared to the DCF, in the CBA, the economic benefits and the positive externalities generated by the project come in the revenue side (Bottero et al. 2019). Both methods generate two synthetic indicators that indicate the financial and economic profitability of the project analyzed; Net Present Value (NPV), Internal Rate of Return (IRR). The main limitation of single-parameter methods is that all impacts must be converted into monetary terms. To meet this limit, innovative approaches have emerged that allow us to include purely monetary and non-monetary effects in the evaluation. MCAs are based on the examination of alternatives based on a set of criteria, of various kinds, and with sometimes conflicting objectives. MCAs can offer decision support in four different ways; choice, finding the best alternative; ranking, classification of alternatives based on an order; sorting, classification of alternatives in groups; description, identification of the main distinguishing features of the alternatives (Roy 1985).

3 Results from Studies Towards Post-Carbon Cities

Starting from the methodological background described in Sect. 2, the present section illustrates different applications that exemplify the evaluation techniques above described by putting evidence the results obtained with reference o the initial settings.

3.1 Cost-Optimal Methodology for the Design of a NZEB

Since in 2010 the EPBD recast introduced the cost-optimal methodology as the evaluation tool able to find a balance between energy performance and financial sustainability in promoting energy efficiency in buildings, many researches focused on this evaluation approach. The cost-optimal methodology is based on the evaluation of the primary energy consumption caused by the building under different hypothesis of energy retrofit and the global cost of the corresponding interventions, calculated according to a life cycle cost approach as the sum of the present values of all item costs occurring in the calculation period. Barthelmes et al. (2016) tested this methodology as a decision tool in the design process for a single-family house. In particular, they compared 16 design alternatives, calculating the related energy performances through dynamic simulations (i.e., models developed in EnergyPlus), and the global costs on a 30 years base. The cost optimal level, namely the energy performance that

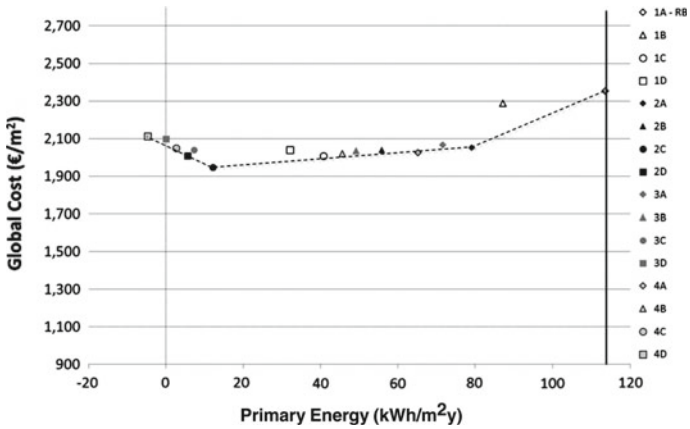

Fig. 2 Cost-optimal graph for the evaluation of 16 alternative energy scenarios for the design of a single-family house. *Source* Barthelmes et al. (2016)

leads to the lowest cost during the building estimated economic lifetime, corresponds to less than 20 kWh/m^{2}y of primary energy consumption and is characterized by a global cost of 1947 €/m^2 (Fig. 2). None of the other alternatives guarantees a further increase of the energy performance concurrently to a global cost decrease, while in many cases, solutions with similar global cost to the cost-optimal one, have poorer energy performance (e.g. Global cost equal to 2008 €/m^2 and more than 40 kWh/m^{2}y of primary energy consumption), demonstrating the effectiveness of this evaluation approach in defining the best alternative.

3.2 *Cost-Optimality and Urban Energy Planning*

Moving from the analysis of a single building to the urban scale requires to consider the spatial distribution of the variables under investigation by using specific tools such as GIS. Under this perspective, Delmastro et al. (2016) applied the cost-optimal analysis to some Reference Buildings (RBs) representative of the residential building stock of a district in Turin to qualitatively investigate the suitable range level of energy performance to be promoted. In particular, starting from a GIS-based analysis, they clustered the existing residential building stock according to geometrical characteristics and period of constructions. Attributing a RB label to each building and geo-referring some available energy monitored data, they have been able to characterize the stock in terms of energy consumption, defining a reference energy performance for each RB class. Finally, performing energy simulations of 4 different retrofit scenarios at RBs level and calculating the related global costs enabled the application of a cost-optimal analysis on the district. According to the authors, results

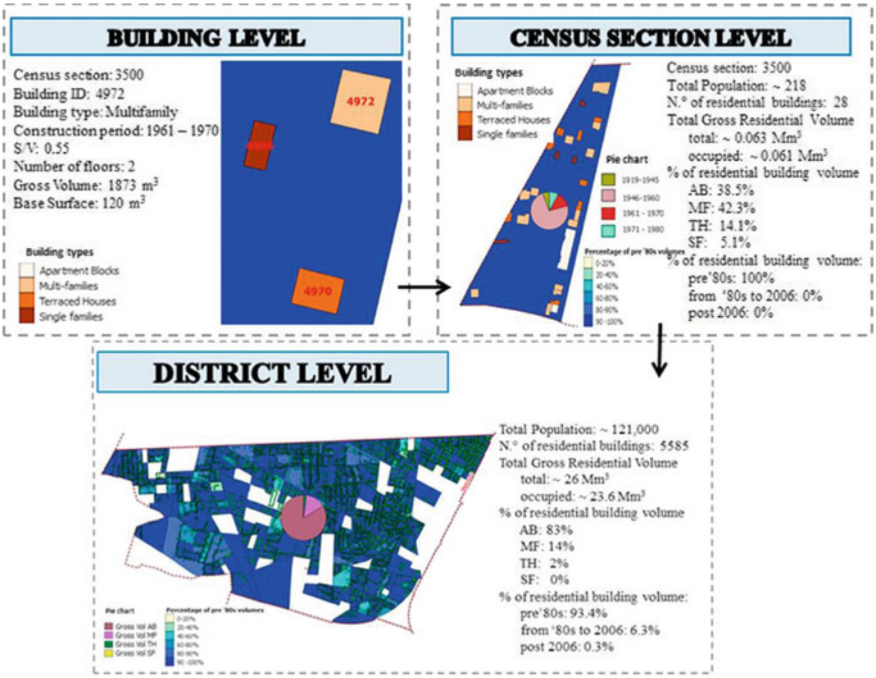

Fig. 3 Characterization (total heated volume and surface, surface to volume ratio etc.) and classification (in terms of distribution in Reference Building classes) of the building stock through GIS-based tools. Example of application on a district in Turin. *Source* Delmastro et al. (2016)

confirm that the proposed methodology can be a decision-making tool in supporting design strategies and retrofit costs identification on long-term horizons (Fig. 3).

3.3 A Spatial Hedonic Price Model for the City of Turin

Bottero et al. (2018) integrate a spatial econometric model with the Hedonic Price Method (HPM) with the aim of evaluating the households' willingness to pay for the energy performance of buildings in the city of Turin (Italy). Generally speaking, HPM starts from the market prices of real estate and thus such as to estimate the implicit prices of the individual characteristics of the asset, the energy class and energy consumption. Compared to the traditional approach, the spatial model proposed in this study aims to evaluate the spatial autocorrelation that exists between transactions (Bonifaci and Copiello 2015). A pilot sample of three-year sale observations (2016–2018) was used to construct seven evaluation models based to ordinary least square model (OLS), spatial autoregressive model (SAR), and spatial error model (SEM) on a large data-set of around 15,000. The results indicated the presence of

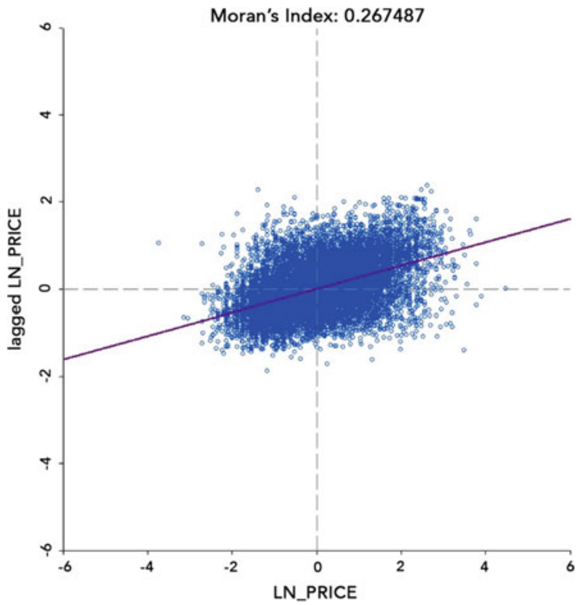

Fig. 4 Spatial autocorrelation index of sample's transaction prices of apartment properties in Turin, Italy. The logarithmic house prices are on the horizontal axis, and their spatially lagged counterparts on the vertical axis. The points' distribution in the I and III quadrants indicates the presence of a spatial autocorrelation between transactions. *Source* Bottero et al. (2018)

spatial lag and spatial error types of autocorrelation and highlighted the need to carefully check the coherence between the spatial and the econometric approach (Fig. 4). Moreover, a positive WTP for green building comes out from the econometric model.

3.4 A Bidding Game to Estimate the Health Benefit from Energy Investment

Commonly, the benefits of energy efficiency programs are expressed in terms of economic payback. Multiple studies have highlighted the impacts in human health coming from emissions reduction, indoor air quality increase, and visual, acoustic and thermal comfort improvement (Maidment et al. 2014). Quantifying health benefits of energy efficiency programs therefore requires epidemiological approaches. Despite this, there is a general lack of data based on studies that investigate the impact on human health and well-being of the energy retrofit. To close the gap, Becchio et al. (2018a) propose an interdisciplinary approach that combines Contingent Valuation Method (CVM), specifically a Bidding Game (Fig. 5), and economic analysis to determine the WTP of owners and tenants to enjoy high level of comfort conditions in the house. A significant positive WTP for energy measures improvements are sug-

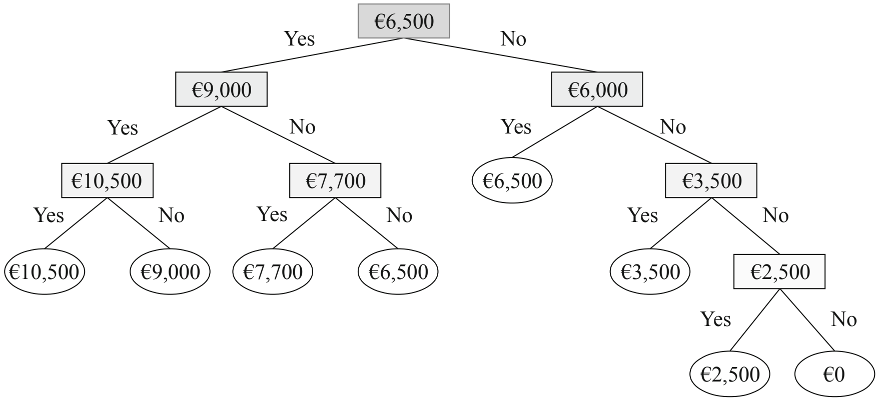

Fig. 5 Bidding game algorithm used in the application of the CVM for estimating the benefits related to indoor comfort conditions. *Source* Becchio et al. (2018a)

gested by the results, estimating an annual perceived comfort benefit for households equal to 6.79 €/m^{2}year.

3.5 A CVM to Measure Customers' WTP for High Comfort Conditions in Hotels

Another sector characterized by a strong consumption of energy is the accommodation facilities one. In this context, hotels are a category of interesting buildings to consider in the challenge of the low-carbon transition. Buso et al. (2017) have developed a research based on an interdisciplinary approach that considers a joint energy-economic perspective to evaluate the WTP of the guests for high comfort conditions in an assumed hotel room. Considering an econometric model based on the method of the contingent evaluation, a questionnaire was formulated. From the 244 obtained responses it emerged that, on average, respondents are willing to pay 14% more than the room rate, about 11.5 €/(room*night), to enjoy comfortable indoor conditions. A parallel energy simulation analysis on a real Reference Hotel (RH) located in Turin suggested that additional operating costs for improvement of indoor comfort conditions (I and II Category) are lower than the WTP declared by the respondents (Fig. 6).

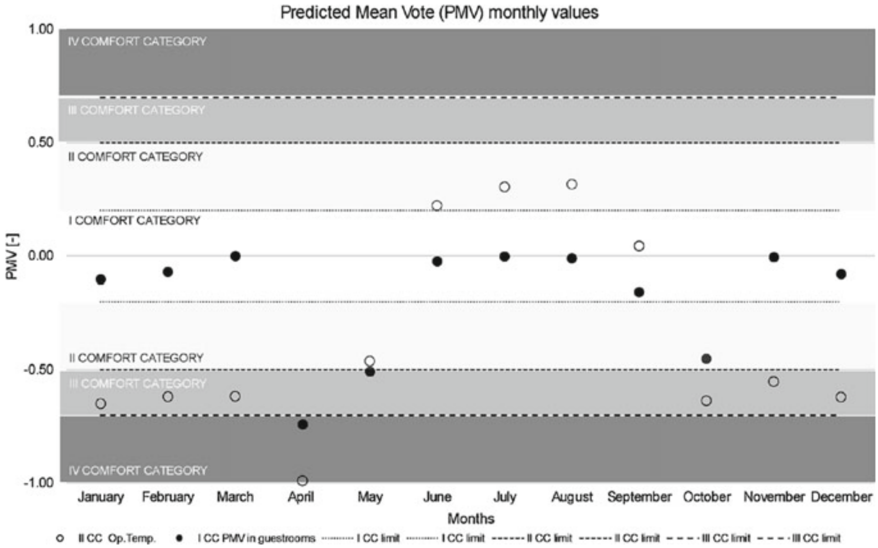

Fig. 6 Average monthly values of PMV (Predicted Mean Vote) for a typical guestrooms thermal zone of the RH according to two thermostat settings; white points represent the PMV value when setting the thermostat according to the requirements of the II category of comfort; while the black points show the monthly values of the PMV, when setting the I comfort category. The comfort level of the second model is higher in most of the year. *Source* Buso et al. (2017)

3.6 A CBA-Based Model to Rank Alternative Solutions for a NZED

After an analysis based purely on the evaluation of the energy and environmental performance of an energy retrofit project for a district located in Turin (Fig. 7), Becchio et al. (2018b) propose a model based on the CBA to be able to evaluate alternative scenarios including the full range of co-benefits generated. After a careful review of the literature, the impacts to be considered have been selected, quantified, and then monetised, so that they can be included in the evaluation framework. From this study, it is possible to highlight that certain design choices can significantly reduce the impact on the environment and CO_2 emissions, through the use of renewable sources to meet the demand for heating and electricity, and generate an amount of benefits in favour of society (increase in jobs, real estate value growth) in line with the European objective of decarbonisation.

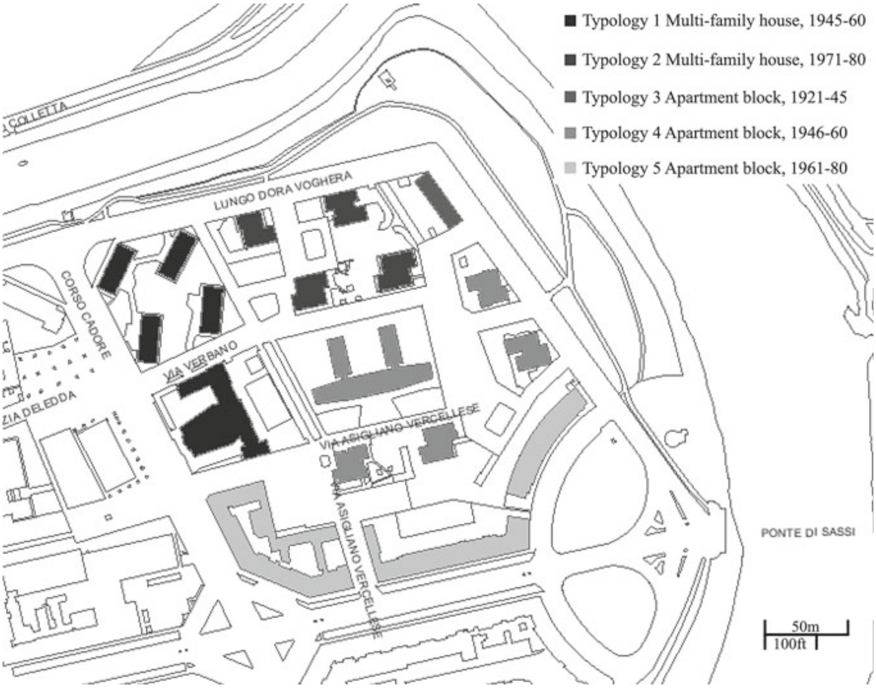

Fig. 7 Reference district selected for NZED design. The figure shows the typology classification of buildings according to the TABULA database (Ballarini et al. 2014). *Source* Becchio et al. (2018b)

3.7 District Energy Solutions Evaluated Through a MCA Model

In the field of preliminary assessments at the district level, Becchio et al. (2017a) solve a multidimensional decision-problem through the MCA method. In detail, starting from a real case study in the city of Turin (Italy), the PROMETHEE multicriteria method is used to compare four alternative strategies for the creation of a new NZED (Brans et al. 1986). An expert group composed of specialists in energy, economics and the environment were convened to structure the decision problem and to discuss and validate the results obtained from the analysis. The results show the advantages of using multi-criteria methods for this particular problem at the district scale where different actors come into play, and the impacts generated are characterized by different dimensions (Fig. 8).

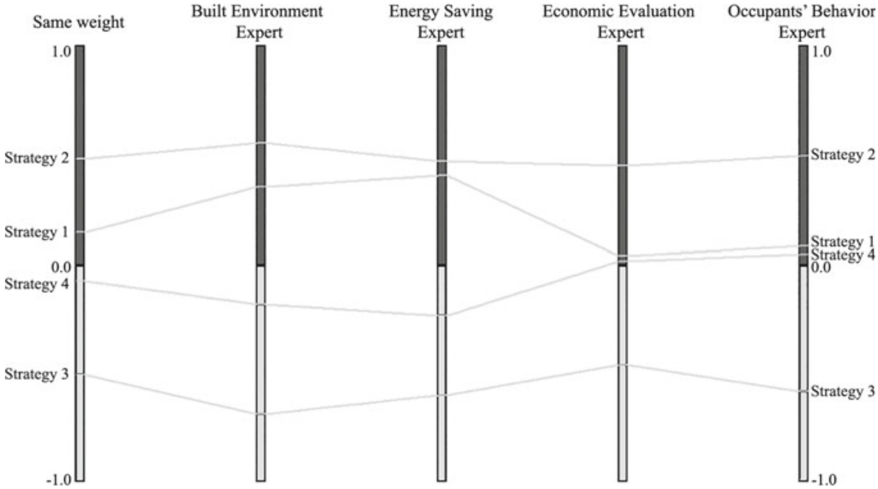

Fig. 8 Ranking of the alternative scenarios for the NZED according to experts' opinion. *Source* Becchio et al. (2017a)

3.8 Investigating GWHP at Urban Scale with an Integrated Model

With the aim of providing an assessment tool able to guide public administrations in low carbon energy planning, Becchio et al. (2017b) proposed an integrated model to assess the energy, economic and environmental impacts of alternative energy scenarios. The model was tested on a real case study, the historic centre of Livorno Ferraris (Italy) to evaluate two alternative scenarios (A and B) that implement the use of low-enthalpy geothermal heat pumps (GWHP) at urban level (Fig. 9). The study demonstrates how an easy and intuitive decision-support system able to consider the different economic and environmental aspects involved in the problems of energy decision could become a useful tool to assist public administrations at the local level.

Fig. 9 GWHP abstraction and reinjection wells locations, for scenarios A and B. *Source* (Becchio et al. 2017b)

3.9 The End-Users' Lifestyle Impacts Captured by a CBA Model

Energy consumption is influenced by many factors not always taken into account in the calculation of energy performance, leading to a significant discrepancy between the planned and real energy consumptions. Many studies have identified the user behaviour as a potential cause of this inconsistency. Becchio et al. (2019) have experimented a new method of economic evaluation of the energy performance of buildings. In this application, the combination of different values of variables, such as heating and cooling temperature setpoints, ventilation, lighting and equipment has allowed us to determine different lifestyles according to user habits: a low consumer (LC), a standard consumer (AC), a waste consumer (HC). To study the family composition, the behaviors of a young couple (A) and an elderly couple (B) were analyzed. The behaviors of these users were joined with a building in pre-retrofit (RB) and post-retrofit (P2C) phases giving rise to 9 alternative scenarios. CBA application allowed to capture the impacts generated by these behavioural factors for a real building located in Turin. In detail, the different lifestyles were analyzed considering invest-

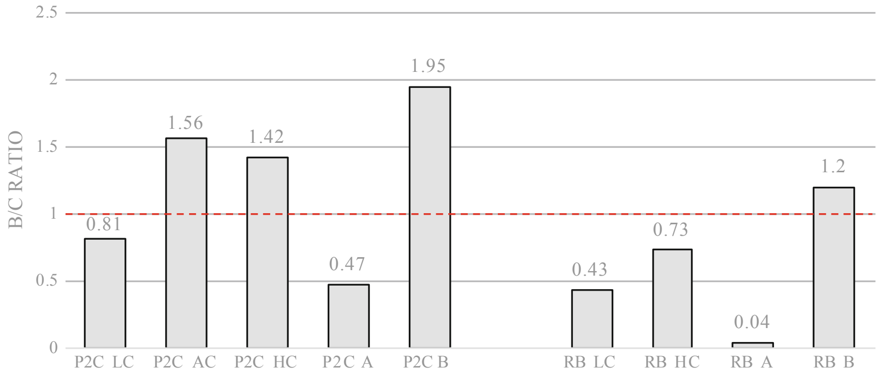

Fig. 10 B/C ratio of the different users' lifestyle. *Source* Becchio et al. (2019)

ment and operational costs, and benefits related to energy saving, GHG emissions, indoor thermal comfort and water saving. To summarize the overall value of each lifestyle, the benefit-cost ratio (B/C) is used as indicator. As shown in Fig. 10, the best configuration is represented by the retrofitted building combined by an elderly couple lifestyle (P2CB) characterized by a high-energy use for space heating and cooling, but a low electricity consumption, given by the little number of used devices.

3.10 Prioritize Retrofit Actions Thanks to Simplified Evaluation Tools

Simplified evaluation tools to properly convey political attentions and intervention resources are required. Accordingly, Vergerio et al. (2018) proposed a methodology to support public administrations in defining local energy policies on building where, before deploying the most proper economic assessment in relation to the stakeholder objectives, a graphical tool (i.e. quadrant-chart) is introduced. This tool was used in a few previous studies (Cerutti et al. 2009; Delmastro et al. 2015) and it can provide an effective overview of the performance of each building in relation to the whole sample according of previously defined indicators (related to energy, environment or financial domain). The graphic space is divided into four quadrants, which describe different performance conditions (I for the best performance, IV for the worst one) and priority of interventions on buildings (I for no intervention, IV for first intervention priority), which are represented by dots.

A preliminary application of the tool to a sample of single-building schools in Turin highlighted how 11 schools out of 184 are the most critical ones. Indeed, they are responsible for the 12% of total primary energy consumptions of the analized stock and equivalent carbon dioxide emissions. Thus, conveying further evaluation

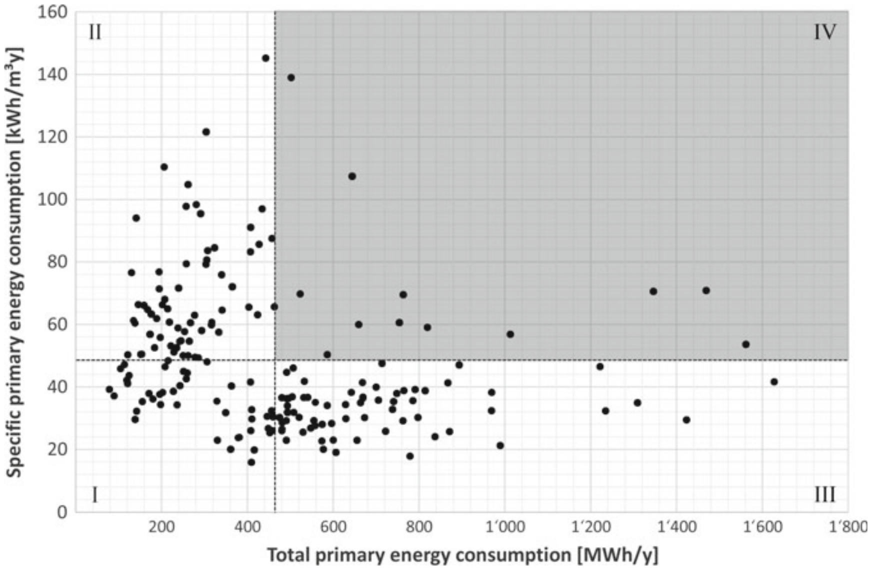

Fig. 11 Quadrant-chart related to primary energy consumptions as a decision-making tool. Example of application to 184 schools in Turin. *Source* Vergerio et al. (2018)

efforts to define possible EEMs through cost-optimal analysis or CBA approach for those buildings can be an effective and promising task (Fig. 11).

4 Policy and Market Implications

The application of the evaluation tools presented in previous sections seems to have particular importance in the domain of the definition of energy policies both at building and at the urban scale.

Defining energy efficiency measures at building level through cost-optimal analysis allows to design buildings that are suitable for the market, identifying also the market of green investors, who renounce to the energy and financial performances balance in order to obtain excellent energy performance. On the contrary, ranking alternative strategies of building retrofit through CBA or MCA application permits to disclose and then exploit their potential indirect or external benefits. The inclusion of co-benefits in the evaluation process of alternative technological solution for buildings (e.g. better air quality guaranteed by alternative HVAC systems) can really influence future market evolution.

Besides impacts related to the building level, district and urban dimensions are of particular interests. Indeed, the urbanization process is putting cities at the centre of the debate on energy efficiency and sustainability. Mention has to be made to the fact that the urban areas represent an innovative research topic according to the European energy policies, which are encouraging the development of decarbonisation scenarios for reducing environmental impacts. Accordingly, the European Parliament developed the concept of Post-Carbon Cities, that shifted the zero-energy concept from buildings (NZEB) to urban districts (NZED) and, more generally, to urban boundaries, in order to achieve new types of cities that are low-carbon, environmentally and economically sustainable. This challenging task requires for innovative evaluation metrics and tools. In this context, integrated approaches to the energy planning are particularly interesting for their capability to capture urban complexity, reflected by the coexistence of different stakeholders with conflicting objectives. In this sense, MCA approach permits to analyse alternative transformation pathways including stakeholders' preferences. The learning process that MCA application encourages, contribute also in rising stakeholders' confidence and awareness in the evaluation results. Moreover, simplified evaluation tools give an important contribution in rationalizing the evaluation efforts and, more importantly for policy makers, financial resources, whose allocation could be better managed.

5 Conclusions

The aim of this chapter is to provide a reflection on the role of assessment tools in decision-making processes related to energy retrofit operations both at building and urban level. To reach this purpose, different evaluation metrics are presented, and innovative experiments developed in a joined research group of Politecnico di Torino are reported. In particular, the importance of cost-based approach adopting a life cycle thinking is discussed citing LCC, LCA and the introduction of cost-optimal analysis in the EPBD recast. Its application as decision-support tools both in building design and urban energy efficiency interventions planning is reported. However, as the current debate on the legislative package "Clean Energy for all Europeans" testifies, there is a growing attention for socio-economic aspects and for the need to integrate non-technical parameters in energy-related evaluation problems. Indeed, the introduction of co-benefits can really influence the evaluation results. Co-benefits or externalities are used to define any positive impact of a policy or project on society or, more in general, at macro-economic level. Co-benefits related to property price increase and thermal comfort improvement are quantified and monetized in the applications proposed at single building level, using revealed (i.e. HPM) or stated preferences (i.e. CVM) techniques to estimate owner's or occupant's willingness to pay (WTP) to achieve those benefits. Furthermore, the effectiveness of CBA application at district level in capturing social benefits related to energy retrofit interventions or to different behavioral patterns is demonstrated. Besides CBA, MCA can be seen as a valuable tool in supporting the decision-process, having the advantage to overcome the CBA limitation of requiring the monetization of all the impacts, and being able to consider the opinion of different stakeholders.

In this end, the evaluation methods discussed in the present work proved to be effective in offering to the decision-makers integrated tools able to take into account the complexity of the problems under investigation. In future, other studies could be developed in order to further provide critical reasoning about the appropriateness, coherence and effectiveness of the methodologies proposed. Future perspectives of the research involve the investigation of the issue related to the evaluation of the indoor comfort guaranteed by energy efficiency measures. Indeed, attention to the end users and to the human-centred approach in energy problems is becoming increasingly important. The study of further lifestyles profiles is a key topic of the research carried out by the Energy Center Lab. Moreover, further developments will be devoted to the integration of the evaluation tools with GIS in order to produce thematic maps able to visualize analysis and to communicate to the different stakeholders.

References

Barthelmes VM, Becchio C, Bottero M, Corgnati SP (2016) Cost-optimal analysis for the definition of energy design strategies: the case of a nearly-zero energy building. Valori e Valutazioni 21:61–76

Ballarini I, Corgnati SP, Corrado V (2014) Use of reference buildings to assess the energy saving potentials of the residential building stock: the experience of TABULA project. Energy Policy 68:273–284

Becchio C, Bertoncini M, Boggio A, et al (2019) The impact of users' lifestyle in zero-energy and emission buildings: an application of cost-benefit analysis. In: Calabrò F, Della Spina L, Bevilacqua C (eds) New metropolitan perspectives. Springer International Publishing, Cham, pp 123–131

Becchio C, Bottero M, Corgnati SP, Dell'Anna F (2017a) A MCDA-based approach for evaluating alternative requalification strategies for a net-zero energy district (NZED). In: Zopounidis C, Doumpos M (eds) Multiple criteria decision making. Springer International Publishing, Cham, pp 189–211

Becchio C, Bottero MC, Casasso A et al (2017b) Energy, economic and environmental modelling for supporting strategic local planning. Procedia Eng 205:35–42

Becchio C, Bottero MC, Corgnati SP, Dell'Anna F (2018) Evaluating health benefits of urban energy retrofitting: an application for the city of Turin. In: Bisello A, Vettorato D, Laconte P, Costa S (eds) Smart and sustainable planning for cities and regions. Springer International Publishing, Cham, pp 281–304

Becchio C, Bottero MC, Corgnati SP, Dell'Anna F (2018b) Decision making for sustainable urban energy planning: an integrated evaluation framework of alternative solutions for a NZED (Net Zero-Energy District) in Turin. Land use Policy 78:803–817

Bisello A, Grilli G, Balest J et al (2017) Co-benefits of smart and sustainable energy district projects: an overview of economic assessment methodologies. In: Bisello A, Vettorato D, Stephens R, Elisei P (eds) Smart and sustainable planning for cities and regions: results of SSPCR 2015. Springer International Publishing, Cham, pp 127–164

Bisello A, Vettorato D (2018) Multiple benefits of smart urban energy transition. In: urban energy transition. Elsevier, pp 467–490

Bonifaci P, Copiello S (2015) Price premium for buildings energy efficiency: empirical findings from a hedonic model. Valori e valutazioni 14:5–15

Borchiellini R, Corgnati S, Becchio C et al (2017) The energy center initiative at Politecnico di Torino: practical experiences on energy efficiency measures in the municipality of Torino. Int J Heat Technol 35:196–204
Bottero MC, Bravi M, Dell'Anna F, Mondini G (2018) Valuing building energy efficient through hedonic prices method: are spatial effects relevant? Valori e Valutazioni 21:27–40
Bottero M, Comino E, Dell'Anna F, Dominici L, Rosso M (2019) Strategic assessment and economic evaluation: the case study of Yanzhou Island (China). sustainability 11(4):1076
Bottero MC, Ferretti V, Mondini G (2014) Economia ed estimo dei beni culturali e ambientali. In: Roscelli R (ed) Manuale di estimo. UTET, Novara, pp 323–361
Brans JP, Vincke P, Mareschal B (1986) How to select and how to rank projects: the Promethee method. Eur J Oper Res 24:228–238
Building Performance Institute Europe (BPIE) (2011) Europe's buildings under the microscope. In: A country-by-country review of the energy performance of buildings
Building Performance Institute Europe (BPIE) (2016) Smart buildings in a decarbonised energy system. 10 principles to deliver real benefits for Europe's citizens
Buso T, Dell'Anna F, Becchio C et al (2017) Of comfort and cost: examining indoor comfort conditions and guests' valuations in Italian hotel rooms. Energy Res Soc Sci 32:94–111
Cerutti A, Corgnati SP, Rollino L (2009) Actual heating consumption of Italian public buildings: results from an experimental campaign, 4th IBPC Istanbul. Istanbul
Dell'Anna F, Vergerio G, Corgnati S, Mondini G (2019) A new price list for retrofit intervention evaluation on some archetypical buildings. Valori e Valutazioni 22:3–17
Delmastro C, Mutani G, Corgnati SP (2016) A supporting method for selecting cost-optimal energy retrofit policies for residential buildings at the urban scale. Energy Policy 99:42–56
Delmastro C, Mutani G, Schranz L (2015) Advantages of coupling a woody biomass cogeneration plant with a district heating network for a sustainable built environment: a case study in Luserna San Giovanni (Torino, Italy). Energy Procedia 78:794–799
European Commission (2002) Directive 2002/91/CE, Energy performance of building directive (EPBD), Bruxelles
European Commission (2010) Directive 2010/31/UE, Energy performance of building directive recast (EPBD recast), 2010. Bruxelles
European Commission (2011) A Roadmap for moving to a competitive low carbon economy in 2050. Available at: https://ec.europa.eu/clima/policies/strategies/2050_en#tab-0-0. Last Access January 2019
European Commission (2014) Guide to cost-benefit analysis of investment projects. Publications Office of the European Union
European Commission (2018) Directive 2018/844/UE, Energy performance of building directive 2nd Recast (new EPBD). Bruxelles
European Committee for Standardization (2017) EN 15459-1:2017, Energy performance of buildings—economic evaluation procedure for energy systems in buildings—Part 1: calculation procedures, Module M1-14, Annex D
Ferreira M, Almeida M, Rodrigues A (2017) Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target. Energy Build 152:587–601
Fregonara E (2015) Valutazione sostenibilità progetto. Life cycle thinking e indirizzi internazionali. Franco Angeli, Milan
Fregonara E, Carbonaro C, Pasquarella O (2018) LCC analysis to evaluate the economic sustainability of technological scenarios on the district scale. Valori e Valutazioni 21:59–74
Maidment CD, Jones CR, Webb TL et al (2014) The impact of household energy efficiency measures on health: a meta-analysis. Energy Policy 65:583–593
Prizzon F (2001) Gli investimenti immobiliari. Celid, Turin
Roy B (1985) Méthodologie Multicritère d'Aide à la Décision. Economica, Paris
Strantzali E, Aravossis K (2016) Decision making in renewable energy investments: a review. Renew Sustain Energy Rev 55:885–898

Ürge-Vorsatz D, Herrero ST, Dubash NK, Lecocq F (2014) Measuring the co-benefits of climate change mitigation. Annu Rev Environ Resour 39:549–582

Vergerio G, Becchio C, Delmastro C et al (2018) A decision-making process to support public administrations in defining local energy policies. Therm Sci Eng Prog 6:398–409

Wang JJ, Jing YY, Zhang CF, Zhao JH (2009) Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renew Sustain Energy Rev 13(9):2263–2278

Urban Problems and Patterns of Change: The Analysis of a Downgraded Industrial Area in Turin

Marta Bottero, Caterina Caprioli and Mauro Berta

Abstract As it is well known, in Western countries cities are experiencing negative effects due to decentralization and deindustrialization, that have brought economic crisis and urban decline. In order to contrast such decline, urban regeneration is getting more and more important in the current political agenda. In fact, urban regeneration means not only building-restoration operations, but also programs aiming at eliminating social decline, increasing the quality of life of the inhabitants, supporting the valorization of cultural resources, protecting the environmental system, bringing economic development, and so on. Urban regeneration looks at urban areas as complex and dynamic systems, in which different processes (physical, social, environmental and economic) drive the transition and the generation of important changes. This paper aims to reflect on urban problems and regeneration operations, focusing in particular on the role of evaluation tools for supporting decision-making in this context. Starting from the analysis of a real case study related to a critical area in the city of Turin, the article will propose different evaluation tools able to produce a complete picture of the problem and to define possible long-term visions for the requalification of the site.

Keywords Evaluation tools · SWOT analysis · Stakeholders analysis · Brownfield · Urban regeneration

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1 Introduction

Nowadays, when dealing with the theme of urban transformation and planning, we have to comply with many aspects increasingly important and urgent. Cities are the main place of attraction for technological, economic and socio-cultural development (Kourtit and Nijkamp 2018). However, the negative effects of some present and past dynamics significantly influence the current situation of cities. On one hand, the growing population levels are causing major urban sprawl in some parts of the world and, consequently, uncontrolled planning (Jaeger et al. 2010a). On the other hand, the results of the contemporary uncontrolled urban growth (Jaeger et al. 2010b) has produced major urban sprawl in large parts of the territory, which is now apparently getting slower but still widespread diffused. In addition, it is known that cities worldwide are responsible for more than 70% of energy-related emissions (Thring 1977) and 60–80% of final energy use is consumed there (Torabi Moghadam et al. 2017). The United Nations predict also that by 2050 over 70% of the world population will live in urban areas (Brockerhoff and Nations 1998).

In order to answer these problems, in the last few years, different urban paradigms have been proposed to achieve sustainable performances, such as the smart city model (Santangelo et al. 2013) or the concept of eco-districts and sustainable neighbourhoods (Choguill 2008; Luederitz et al. 2013).

In that context, public space and its planning represent an important occasion in this transition, not only to improve the quality of the urban environment but also to generate social cohesion (Madanipour 2013). Some urban projects, such as the requalification of the Porto Vecchio in Genoa (Italy) or of the Clyde Waterfront in Glasgow (UK) have focused strictly on public spaces, as a driver of image and changes in the quality of life of urban areas with significant implications for its revitalization and regeneration (Lecroart 2007). The quality of the urban environment in deprived neighbourhoods and the building of high-level public spaces lead to fairer and more democratic cities, in which equal treatment and investment do not mean displacement and gentrification (Madanipour 2013).

This paper aims at investigating the complexity involved in urban regeneration, focusing in particular on the role of evaluation tools for supporting decision-making processes. Starting from the case of the area of Basse di Stura, a former industrial area now abandoned in the city of Turin (Northern Italy) the article illustrates a multi-level methodological approach for supporting the construction of future transformation scenarios for the site.

2 Evaluation Methods and Tools for Urban Regeneration

As already said, urban regeneration refers to complex processes where physical transformations are strongly linked to social, economic, environmental and institutional elements. In that context, it is essential to use appropriate decision support tools able to take into account the full variety of dimensions of the problem and to include needs, expectations and values of all parties involved.

In the past, the methods and techniques most commonly used for the evaluation of urban projects were based on monetary approaches able to define both the financial and the economic convenience (e.g. Discounted Cash-Flow Analysis (DCFA) or Cost-Benefits Analysis (CBA)). Later on, in parallel with the spread of the sustainability concept (Imperatives 1987; Meadows et al. 2004; Randers 2012), other evaluation methods have been established. These methods are able to consider other aspects from a more intangible and extra-economic point of view and to include the participation of different stakeholders (Brandon and Lombardi 2010). Figure 1 shows the main techniques existing in literature for the evaluation of urban transformation projects.

Fig. 1 Techniques for the evaluation of urban transformation projects. Adapted from Polt and Vonortas (2006)

However, for addressing the complexity of urban transformations, the use of a single approach is not sufficient to consider all the issues involved.

The present study explores the combination of SWOT Analysis and Stakeholders Analysis, in order to define the possible strategies for the area of Basse di Stura.

3 The Area of Basse di Stura in Turin (Italy)

3.1 Presentation of the Case Study

Basse di Stura is a large area of 150 ha located in the Northern part of the city of Turin (Fig. 2). Its name Basse comes from the high difference in the level of the ground between the riverbed of the Stura stream and the roads that surround the area. In fact, except for the Stura stream the other boundaries are made of infrastructures. This set of infrastructures underlines the relevant role of the area in terms of accessibility for the metropolitan city, but it generates at the same time a zone with heavy traffic and it cuts the territory in many autonomous, and mostly isolated "islands". Moreover, in the Northern part of the area temporary illegal nomad camps are settled.

Its geographical location at the edge of the city has determined the functions that are in there and the ones located in the past. Originally, all spaces were occupied by rural functions: the extensive agricultural fields and the presence of the Stura stream encouraged the development of farmhouses. This rural dimension was recently lost because of high pollution of land generated by the past heavy factories and the illegal disposal of industrial waste. Even today, a huge number of factories and car dealerships occupy the area, showing its still industrial dimension. Both these conditions (the persistence of a residual rural activity and the still present industrial functions) underline that we are in a boundary area, between the urban and rural conditions, where the most pollutant, unhealthy and generally inconvenient activities were gradually moved.

3.2 Regulatory Framework

In the last years, local public administration has expressed its interest in respect to this area for the natural potentialities of this site and for its strategical location. In particular, its position bordering the municipalities of Venaria Reale, Borgaro Torinese and Settimo Torinese is particularly important because different policies proposed by local authorities are geographically connected to Basse di Stura. Three of them are strictly related to environmental issues: the project Tangenziale Verde (Green Bypass), Torino Città d'Acque (Torino City of Water) and Corona Verde (Green Crown). They all share the same main objective to create new green areas, with an ambition of strengthening and connecting the existing ones. In addition, these

Fig. 2 Location of the area under investigation (Basse di Stura)

projects provide for the implementation of cycle paths at a large-scale, from Turin to the other municipalities of the metropolitan city.

Another occasion for Basse di Stura is related to the infrastructural project of the second line of the Turin underground (Comune di Torino—Divisione Infrastrutture e Mobilità 2008). Based on the preliminary studies of the route, the Rebaudengo area, which is about 1.5 km away from Basse di Stura, is supposed to be the northern terminal of the line. The relative proximity of this infrastructure could be an important occasion for the area, that, unlike the current situation, could be easily connected to the other parts of the city.

To understand some relevant dynamics of the area, the analysis of the regulatory framework was necessary. The Basse di Stura area, in fact, required a deep investigation not only of the Municipal Plan (Comune di Torino 2006) but also of other regulatory instruments from national to local level.

Until 2013, the area was one of the contaminated sites classified as of national interest (SIN = Sito di Interesse Nazionale) by the Italian Ministry of Environment and Sea. The extent of the area, its environmental relevance, the proximity of residential areas with a high density of population, the high level of soil contamination caused by the illegal disposal of industrial waste, the vulnerability of the groundwater and of the watercourse had meant that the area was included in this list for its high environmental and health risks. After 2013, the administration competence of the area passed, first, to the Regione Piemonte and then to the Municipality of Turin.

The Municipal Plan represents the main document to understand most of the dynamics and the future visions of this area, at least those provided by the Municipality. Its directives, however, are faced with other plans:

– the Regional Territorial Plan that provides for the transformation of the area to create advanced productive and tertiary functions;
– the Landscape Regional Plan for an integration with the Corona Verde project (mentioned in the previous paragraph);
– the Coordination Plan of the Turin Metropolitan area;
– the Plan for the Po river basin;
– the Hydrogeological Risk Plan.

In the Municipal Plan, the Basse di Stura area is indicated as an urban and fluvial park (P17) with a small buildable surface (around 0.10 sqm (gross floor area)/sqm (territorial area)). Despite this constructible surface, no operation was started on the area, that remained in the same condition. In fact, the potentiality of the area has to cope with two kind of relevant problems: the high level of soil contamination and the limits prescribed by the Hydrogeological Risk Plan that prevent any construction in a large portion of the area. That led to an *impasse* caused by the not competitiveness of the remediation for the owners compared to the possibility to build a small surface in a not well-defined area.

Due to the complex situation of Basse di Stura, a specific plan was drafted for the overall area: the executive plan for the environmental requalification (Comune di Torino 2003), which identifies in depth the necessary environmental remediation and the requalification actions.

3.3 Description of the Main Characteristics of the Area

The previous paragraphs showed some potentialities and limits of the Basse di Stura area. However, some dynamics do not emerge from the analysis of plans and laws. The aim of this section is to summarize the main elements that characterize the case study. Then, Fig. 3 gives a graphical representation and localization of these characteristics, useful for the comprehension of the last sections of the paper.

Ground Level
The area has a difference in level of about 5 m from south to north, as a result of the natural effect of the Stura stream proximity, but also of the anthropic actions. The lower zones are characterized by a visual separation from the other parts and this separation is accentuated also by different uses.

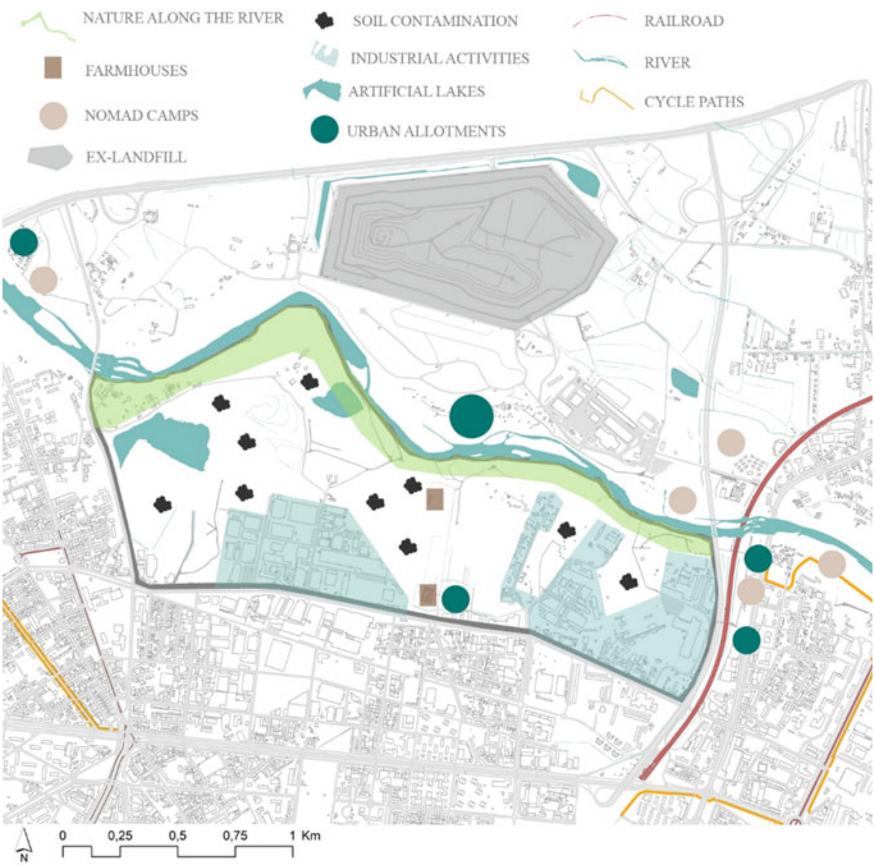

Fig. 3 Main characteristics of Basse di Stura area

Rural Dimension, Farmhouses and Urban Allotments
The intensive past agricultural activities are evident in a network of canals for the water supply and in the presence of farmhouses, already existing even though their original agricultural role was totally or partially lost. Cascina la Città (1699), La Ressia (1840) and La Fossata (1683) are the most relevant and nearest to our case study, but also others are located not far from Basse di Stura.Nowadays, traces of this rural dimension are visible in the illegal urban allotments located in the residual spaces among infrastructures (Spinelli 2013).

Natural Elements
The Stura stream and the recent agricultural past have led a variety of flora and fauna in Basse di Stura: resident or migrating bird species, amphibians and mammals, tree and shrub species (willows, poplars, etc.) and agricultural crops (corn, barley, wheat, Phytolacca, artemisia, etc.) (Spinelli 2013).

Industrial Activities, Landfills and Soil Contamination
The rural dimension of the area started to fail after the construction of the first industries around the 50s, which gradually stole lands and workers from agricultural activities. In the 70s, the construction of Via Reiss Romoli marked the definitive change of the uses of the area (Laboratorio di ricerca storica sulla periferia urbana della zona nord-ovest di Torino 2001). Nowadays, also due to the crisis of the industrial sector that has taken place in Turin, the activities are limited.

The current condition of the area is the result of different anthropic interventions that, since the beginning of this century, have changed its original state:

- the aggregates quarrying (that generated several quarry lakes).
- the construction of industrial sites (along with the Stura: Area Tesksid ex Rifometal, concrete factories; at the margins: ex-Rockwood, Stureco, an incinerator in the Fenice area, now disposed).
- the location of some industrial landfills partly connected to plants in Basse di Stura (Rifometal landfill) and partly to the production activities outside the area (Altopiano Deltasider, Cimi Montubi area and tanks, Solfatara landfill, AMIAT landfill). In addition, during the seventies, industrial waste was disposed into the abandoned quarries.

All these activities are highly incompatible with the function of the urban park planned by the municipal plan: for that reason, massive remediation is required (Arpa Piemonte 2011).

Landowners
Different are the owners in Basse di Stura. This represents a not easy element for the success of the Municipality objective. In addition, in some cases, the result of the high level of soil contamination is not attributable to the current owners. And for this reason, they refuse to pay the costs of remediation.

Nomad Camps
Many nomads live along the Stura banks, creating informal camps and slums. They live in caravans and shacks, accessible from uneasy paths among plants. Most of these settlements are not authorized and was born in long and narrow strips of land with some health and hygienic problems.

4 Multi-methodological Approach

As mentioned before, this paper proposes a multi-level methodology for supporting the decision process concerning the transformation of the area (Fig. 4). The first phase of the analysis, the problem framing, is devoted to structuring the problem, defining critical aspects and uncertainty elements. The second phase is devoted to the identification of possible scenarios for the transformation project.

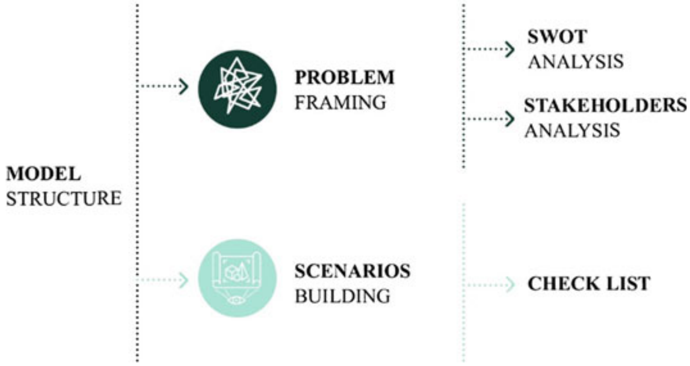

Fig. 4 Structure of our multi-level methodology

4.1 Application of the SWOT Analysis

The SWOT analysis is a tool able to support choice processes in a structural and rational way during the decision-making process. This technique allows underlining strengths, weaknesses, opportunities and threats of the specific element under investigation. In fact, thanks to this approach, it is possible to highlight the main internal and external characteristics and to develop coherent strategies based on the real context of analysis. The most common graphical representation of a SWOT is the 2 × 2 matrix, in which the four sections contain respectively the strengths, weaknesses, opportunities and threats. In this paper, a different design of the SWOT is developed, that allow to analyse each element in Basse di Stura both from a natural and from an anthropic point of view (Figs. 5 and 6).

4.2 Development of the Stakeholders Analysis

In order to understand what happened or what can happen in a decisional process, a question that we have to ask is about who has contributed or could contribute to its development and outcome by adopting relevant behaviours (Dente 2014).

In fact, every stakeholder is motivated by some particular interest related to their goals, values or preferences, which will determine their support or rejection of a strategy. Table 1 shows all stakeholders interested in the Basse di Stura project and underlines for each of them the competence level, the resources they carry out and the types of actors they are.

It has to be noticed that different methods have been used for the development of the stakeholders' analysis. For example, institutional analysis, performed mainly on legislative or administrative documents, has been applied for the examination of those stakeholders referring to large organizations, such as the European Union, the

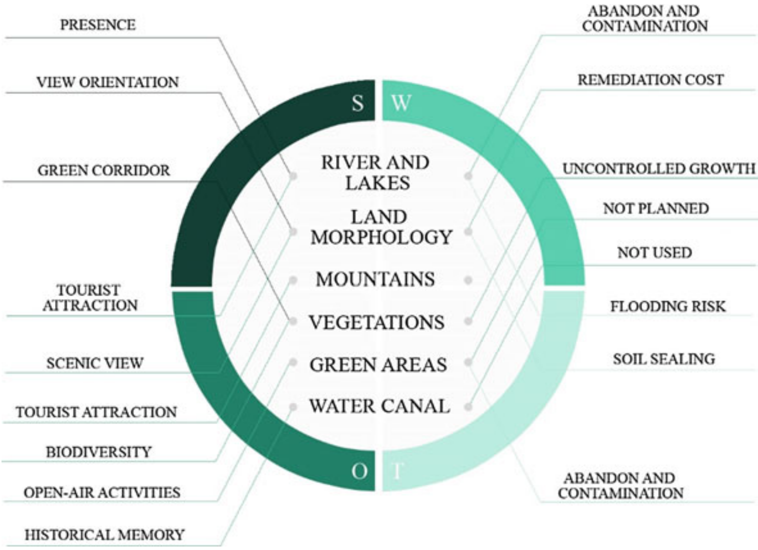

Fig. 5 SWOT analysis for the natural elements

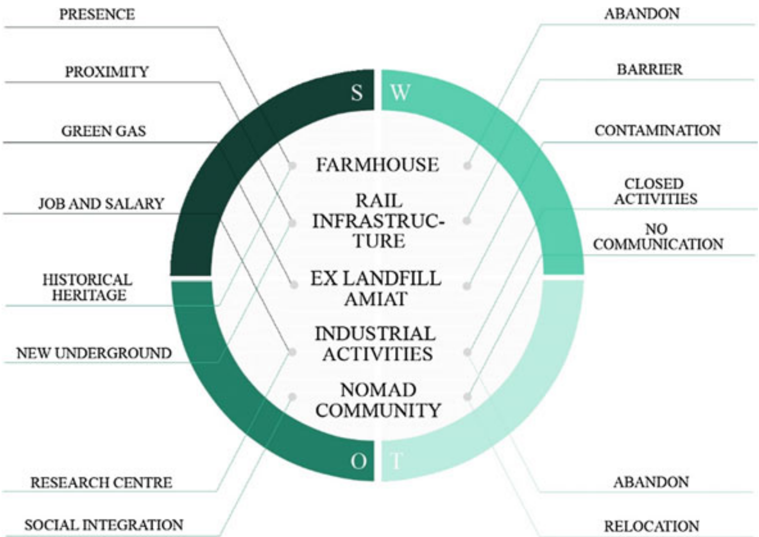

Fig. 6 SWOT analysis for the anthropic elements

Table 1 Types, resources, levels of each stakeholder

Stakeholders	Levels	Resources	Types
EU (European Union)	International	Economic	Political, bureaucrats
Italy govern	National	Legal, political, economic	Political, bureaucrats
Piedmont region	Regional	Legal, cognitive, political, economic	Political, bureaucrats
ARPA (environmental agency)	Regional	Legal	Bureaucrats, expert
Designers (architects, planners…)	National, regional, municipal, local	Cognitive, economic	Expert
Big landlords (Poste, Italgas)	National	Legal, political, cognitive, economic	Special interest
Investors	National, regional, municipal, local	Economic	Special interest
Metropolitan city of Turin	Municipal	Legal, cognitive, political, economic	Political, bureaucrats
Municipality of Turin	Municipal	Legal, cognitive, political, economic	Political, bureaucrats
Neighbourhood municipalities	Municipal	Legal, cognitive, political, economic	Political, bureaucrats
AMIAT (Municipal waste management company)	Municipal	Cognitive	Special interest
GTT (transport agency)	Municipal	Political	Special interest
Environmental groups	Local	Cognitive, political	General interest
Small landlords	Local	Cognitive	Special interest
Local commercial activities	Local	Cognitive	Special interest
Citizens	Local	Cognitive	Special interest
Nomad community	Local	Cognitive	Special interest
Owners of industrial activities	Local	Economic, cognitive	Special interest
Juventus FC	Municipal	Economic	Special interest

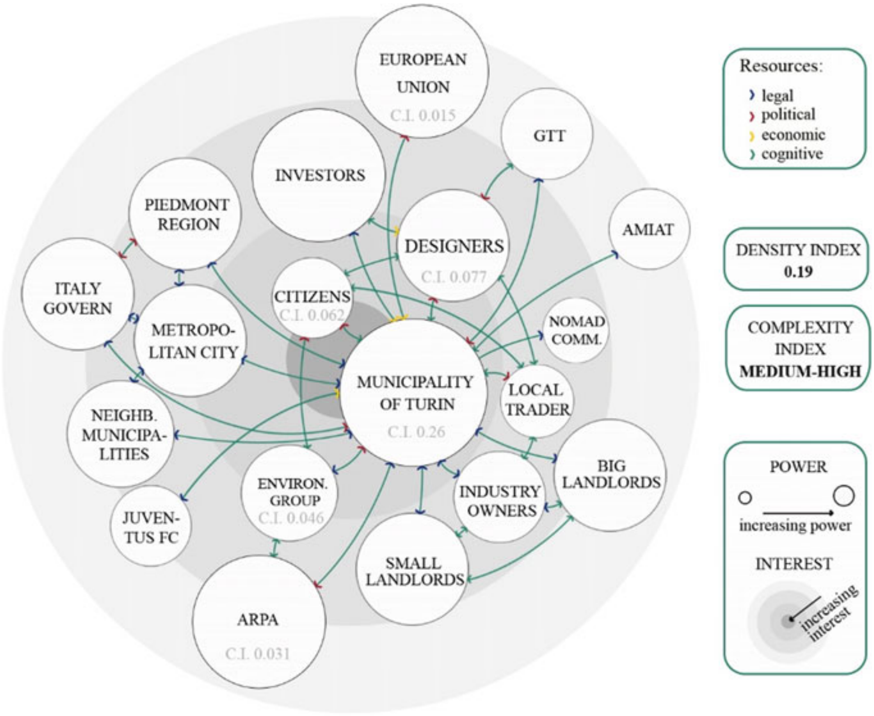

Fig. 7 Stakeholders map for the Basse di Stura case study

national government, and the region. For other categories of stakeholders, such as the municipality, citizens and local agencies, personal interviews and questionnaires have been developed in order to connect their preferences.

For this case study, a specific stakeholders technique was developed, the Social Network Analysis (Marin and Mayntz 1991; Rhodes 1998). This approach is particularly suitable to highlight the stakeholders influences thanks to the network representation in which each stakeholder has different ties with others. These connections and relations can affect the overall performance of the decision network. According to this approach, it is possible to visually understand the size and the form of the network. Figure 7 shows the stakeholders network for the present case study. The nodes are the stakeholders, listed in Table 1, while the arrows are the connections among them. The dimension of the circles is related to the power of the stakeholders, while the proximity to the centre is the stakeholders' interest in respect to the transformation of the area.

In addition, according to this method, the calculation of specific indexes helps in the comprehension of the dynamics that regulate the network (Berta et al. 2018): the density index, the complexity index and the centrality of the network index.

The density index underlines the intensity of relations between actors of a decision-making process, as represented in the following Eq. (1):

$$D = \frac{\sum \mathrm{K}_i}{(n^2 - n)} \tag{1}$$

where D is the density index varying between 0 and 1, n is the number of actors and K_i is the number of all relations. In this case study, the density value is quite low, i.e. 0.19. However, the level of complexity is quite high, because the competence levels of the actors are very different (from the international level to the local) such as the types of stakeholders they are (from politician to expert, from bureaucrat to special interest).

Finally, the centrality index underlines the level of monopolizing relation of each stakeholder with the others, through the following Eq. (2):

$$C = \frac{k_i}{\sum K_i} \tag{2}$$

where C is the centrality index that varies between 0 and 1 and k_i is the number of relations of each actor. In this case study, the most central actor of the process is the Municipality of Turin with 17 relations (centrality index equals to 0.26). It is not surprising because the city of Turin is the main promoter of the process. Instead, the others have a lower capacity of directing the process. In fact, all of them have from a maximum of 5 relations (such as the designers) to a minimum of 1 (such as the nomad community or the waste management company). However, the transformation is not possible without the help of many of these actors. As mentioned before, many economic and legal problems affected the area. For this reason, a decision process able to take into account all parties interested in the project and capable of catching the needs of the area is needed. In that context, a multi-level methodology seems to be a promising strategy to support the decision process and the definition of strategies, thanks to the definition of present values and the way to preserve and improve them.

4.3 New Functions for Basse di Stura

The construction of the SWOT analysis and the consideration of values and preferences emerging from the stakeholders' analysis allowed a deep understanding of the area and a preliminary definition of the possible future scenarios. In this sense, as mentioned in Sect. 2, the goal of this study was to explore alternative solutions that, starting from the primary use of the area defined by the Municipality, i.e. an urban park, offer the reason to pursue a so complex project.

In this sense, five different strategies were defined for the area:

– social and educational activities;
– activities in nature;

Table 2 Description of the possible strategies

Strategies	Description
Social and educational activities	The area could offer a variety of educational and social activities, from a farm school to a social centre, which could attract both the neighbourhood inhabitants and Turin citizens
Nature activities	The area could have different activities related to nature thanks to the characteristics of the area and its closeness to the river, such as a birdwatching area or a horse farm
Experimental activities	The industrial past of the area and its dimension could be suitable to locate an experimental area with research centres and experimental activities such as soil phytoremediation and bio-energies areas
Sports activities	The large dimension of the area and its closeness to the river could be suitable to host different sport activities, such as soccer, tennis, basketball fields or cycle paths and fitness trails
Organised sites	The area could offer a variety of organised sites, from the most traditional ones for a park (such as children play grounds or dog parks) to the most unusual ones (such as organized beaches along the river)

– experimental activities;
– sports activities;
– organised sites.

In Table 2 the different strategies were listed and each of them was described to better clarify the possible vision for Basse di Stura.

5 Discussion and Conclusions

In the recent period of crisis, the urban development depends largely on the ability of cities of reinventing themselves. In this sense, abandoned buildings, underdeveloped areas, downgraded districts and, more generally, urban voids constitute an important opportunity for rethinking territorial functions, systematizing the different interests and values and creating positive synergies among public and private actors.

Under this perspective, urban regeneration has not to be seen only from the point of view of the physical requalification of buildings, as it represents an important transformation processes able to address the problem of soil consumption by reusing existing abandoned infrastructures, to lead the involvement and the co-operation among the different actors and social groups and to respond to the new social needs of the population, thus stimulating innovative urban policies. Following this reasoning, urban regeneration provides a link between the various components of the urban system, including both the hardware (buildings, infrastructures, physical elements …) and the software (social dynamics, identity and cultural elements, economic forces …) (Bodano et al. 2015; Bentivegna 2016; Mondini 2016).

In the light of the aforementioned considerations, the study presented in the paper seems to be adequate to disentangle the different aspects of the regeneration, that go from urban elements to socio-economic aspects. The combined use of SWOT Analysis and Stakeholders Analysis is suitable for considering the different key factors of the operation and it constitutes a solid basis for the definition of the guidelines for the operation.

One of the leading factors of this work has been the will of keeping tightly connected the two phases of the scenarios building (i.e. the outline of different physical alternatives for the masterplan) and of the evaluation of these scenarios. The evaluation activity is seen neither as a consequence nor as a preparatory work, but it grows constantly with the design activity, affecting its assumptions and its results in a continuous feed-back.

Another important element of innovation of the present work is related to the use of a formal approach to support the design of alternatives solutions for a complex decision-making process (Colorni and Tsoukiàs 2013).

As a future perspective, it would be interesting investigate the use of the stated/revealed preferences methods, such as for example the method of Choice Experiments (Haaijer 1999; Louviere et al. 2010), for the design of the alternative requalification projects.

Future developments of the study may then explore the integration of stated/revealed preferences methods with Geographic Information System (GIS). The creation of specific thematic maps could support the visualisation and the communication of the results of the evaluation model (Bottero et al. 2018).

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References

Arpa Piemonte (2011) Relazione Conclusiva delle attività di caratterizzazione del SIN Basse di Stura

Bentivegna V (2016) Dialogo e trasparenza nei processi decisionali. Valori Valut 17:25–28

Berta M, Bottero M, Ferretti V (2018) A mixed methods approach for the integration of urban design and economic evaluation: industrial heritage and urban regeneration in China. Environ Plan B Urban Analyt City Sci 45:208–232. https://doi.org/10.1177/0265813516669139

Bodano F, Sabatino S, Talarico A (2015) Ambiti di valutazione per interventi di social housing. In: CELID (ed) Social Housing Modelli e processi integrati per valutare la sostenibilità. Torino

Bottero M, Bravi M, Dell'Anna F, Mondini G (2018) Valuing buildings energy efficiency through Hedonic Prices method: are spatial effects relevant? Valori Valut 21:27–39

Brandon PS, Lombardi P (2010) Evaluating sustainable development in the built environment. Wiley-Blackwell
Brockerhoff M, United Nations (1998) World urbanization prospects: the 1996 revision. Popul Dev Rev 24:883. https://doi.org/10.2307/2808041
Choguill CL (2008) Developing sustainable neighbourhoods. Habitat Int. https://doi.org/10.1016/j.habitatint.2007.06.007
Colorni A, Tsoukiàs A (2013) What is a decision problem? Preliminary statements. Springer, Berlin, Heidelberg, pp 139–153
Comune di Torino (2003) Deliberazione del Consiglio Comunale 20 Ottobre 2003 (proposta dalla G.C. 4 giugno 2003), Oggetto: Parco Basse di Stura p 17, Piano Esecutivo di recupero ambientale—appro-vazione. http://www.comune.torino.it/delibere/2003/2003_03688.html. Accessed 28 Nov 2018
Comune di Torino (2006) Piano Regolatore Generale di Torino—Norme Urbanistico Edilizie di Attuazione (NUEA) Volume I. http://www.comune.torino.it/ediliziaprivata/prgc//10_tavole/V07_variantetesto_coordinato_var_100.pdf. Accessed 28 Nov 2018
Comune di Torino—Divisione Infrastrutture e Mobilità (2008) Linea 2 Metro—Studio di Fattibilità. http://www.comune.torino.it/trasporti/bm~doc/dossierlinea2completo-2.pdf. Accessed 28 Nov 2018
Dente B (2014) Understanding policy decisions. SpringerBriefs in applied sciences and technology. Springer International Publishing, Cham, pp 1–27
Haaijer ME (1999) Modeling conjoint choice experiments with the probit model
Imperatives S (1987) Report of the world commission on environment and development: our common future towards sustainable development 2. Part II. Common challenges population and human resources, vol 4. Oxford, UK; Oslo, Norway
Jaeger JAG, Bertiller R, Schwick C et al (2010a) Urban permeation of landscapes and sprawl per capita: new measures of urban sprawl. Ecol Indic 10:427–441. https://doi.org/10.1016/j.ecolind.2009.07.010
Jaeger JAG, Bertiller R, Schwick C, Kienast F (2010b) Suitability criteria for measures of urban sprawl. Ecol Indic 10:397–406. https://doi.org/10.1016/j.ecolind.2009.07.007
Kourtit K, Nijkamp P (2018) Big data dashboards as smart decision support tools for i–cities—an experiment on stockholm. Land use policy 71:24–35. https://doi.org/10.1016/j.landusepol.2017.10.019
Laboratorio di ricerca storica sulla periferia urbana della zona nord-ovest di Torino (2001) Soggetti e problemi di storia della zona nord-ovest di Torino dal 1890 al 1956: Lucento, Madonna di Campagna e Borgo Vittoria—MuseoTorino. http://www.museotorino.it/view/s/c9d1cd87a53248ce8a6aa516d66fd14f. Accessed 11 Jan 2019
Lecroart P (2007) Large-scale urban development projects in Europe drivers of change. Chief Exec
Louviere JJ, Flynn TN, Carson RT (2010) Discrete choice experiments are not conjoint analysis. J Choice Model. 3:57–72. https://doi.org/10.1016/S1755-5345(13)70014-9
Luederitz C, Lang DJ, Von Wehrden H (2013) A systematic review of guiding principles for sustainable urban neighborhood development. Landsc, Urban Plan
Madanipour A (2013) Public space and the challenges of urban transformation in Europe. Routledge
Marin B, Mayntz R (1991) Policy networks. Empirical evidence and theoretical considerations. Campus
Meadows DH, Randers J, Meadows DL, Randers J (2004) The limits to growth : the 30-year update. Chelsea Green Publishing Company
Mondini G (2016) Valutazioni integrate per la gestione delle nuove sfide sociali. Valori Valut 17:15–17
Polt W, Vonortas N (2006) IST evaluation and monitoring
Randers J (2012) 2052 : a global forecast for the next forty years. Chelsea Green Pub
Rhodes RAW (1998) Understanding govenance: policy networks, governance, reflexivity and accountability. Public Adm. https://doi.org/10.1111/1467-9299.00107

Santangelo M, Aru S, Pollio A (2013) Smart city. Ibridazioni, innovazioni e inerzie nelle città contemporanee, Carocci Ed. Roma

Spinelli Q (2013) Torino, Stura. Scenari per una diversa urbanità. Politecnico di Torino

Thring MW (1977) World energy outlook. electron. Power 23:329. https://doi.org/10.1049/ep.1977.0180

Torabi Moghadam S, Delmastro C, Corgnati SP, Lombardi P (2017) Urban energy planning procedure for sustainable development in the built environment: A review of available spatial approaches. J Clean Prod 165:811–827. https://doi.org/10.1016/j.jclepro.2017.07.142

Cost-Risk Analysis for Supporting Urban Regeneration Technological Projects

Elena Fregonara, Diego Giuseppe Ferrando and Corrado Carbonaro

Abstract The aim of this paper is to propose a methodology for supporting decision making processes in urban regeneration projects. Focus is posed on economic–environmental sustainability evaluation of building retrofit projects, at district scale, in presence of risk and uncertainty. An application of a conjoint Probability Analysis with Life-Cycle Cost Analysis (LCCA) is proposed for selecting the preferable solution between technological alternative scenarios with different energy production systems. The model input (cost drivers) and model output (Global Cost) are expressed in stochastic terms. A complex project is proposed as a case-study: a social-housing district in a town in Northern Italy.

Keywords Economic–energy sustainability · Life cycle cost analysis · Risk analysis · Stochastic global cost · Urban regeneration projects

1 Introduction

A crucial issue in the scientific debate is to define methodologies able to orient public authorities and private developers involved in investment decisions, particularly in the case of building projects directed to economic-energy-environmental sustainability. This applies both to the case of new building interventions, and to the case of existing heritage retrofit projects, involving complex decision-making processes towards sustainable cities.

The issue results particularly delicate in case of complex urban regeneration projects, when a shift from the building scale to the territorial scale is required. For example, in case of retrofit project dealing with an urban district, or an urban

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segment characterized by homogeneous building types and infrastructural equipment. In every case, it is essential to consider the specific location of the project: the territorial characteristics, the infrastructure equipment, the socio-economic context.

Shifting from the building to the district/urban scale, the degree of complexity grows: for example, for the presence of different energy sources or systems. These growing complexity must be internalized into the evaluation, in order to define methodologies directed to support territorial government activities and the definition of policies, coherent with the regulations on energy consumptions (i.e. Directive 2018/844/EU of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency), able to guarantee the required performance requisites and financially sustainable.

In the case of energy retrofit/new buildings interventions, the choice between technological options represents a particularly important step in decision-making processes, and, more largely, in policy making and land government activities. Technological options represent different potential impacts in terms of environmental and economic sustainability, requiring appropriate evaluation approaches able to consider these impacts simultaneously, and able to conciliate the results of economic and environmental analysis, often very different (Fregonara et al. 2017).

The problem is even more complex if we consider the presence of risk and uncertainty components, which characterizes every building project. Introducing flexibility to the project design phase, and associating the input/output variables of the projects to their probability, is seen as the key to present a concrete support for calibrating policies and investment decisions (Pereira et al. 2014; Jafari et al. 2014).

Thus, the aim of this paper is to propose a methodology for supporting decision-making processes, when in presence of different project solutions, since the early design stages, and considering the presence of risk and uncertainty as a "structural component" of complex projects (urban transformation, retrofit of existing heritage, new-building interventions, etc.). Focus is posed on the cost component, considering that the recent scientific literature is implementing Life-Cycle Cost Analysis—LCCA (as defined in the Standard ISO 15686–5:2008—Buildings and constructed assets—Service-life planning, Part 5: Life-Cycle Costing), with risk management approaches, to provide a more robust forecast of future costs of a building project.

Coherently, the regulatory documents about LCCA, and other fundamental documents as the report produced by Davis Langdon Management Consulting directed to formulate a common LCCA methodology (Langdon 2007), emphasize the usefulness of risk analysis in the evaluation of projects' economic sustainability.

Assuming the classification proposed by Boussabaine and Kirkham (2004), in this work a quantitative risk analysis technique is proposed: the probabilistic approach founded on the use of Probabilistic Distribution Functions (PDFs) and simulation techniques. Specifically, in this paper the Global Cost, which represents the core of LCCA (Standard EN 15459:2007 and Guidelines accompanying the Commission Delegated Regulation (EU) No 244/2012), is calculated in terms of stochastic Global Cost through the Probability Analysis approach.

As a case-study a complex project is proposed: a social-housing district in a small town in Northern Italy. he case was part of the European “Concerto AL Piano” project, developed as part of the “Concerto” programme, co-funded by the European Commission’s Directorate General for Energy and Transport, in the September 2007—August 2013 period—Coordinator Prof. Roberto Pagani, Politecnico di Torino. The “Concerto AL Piano” project was directed to trigger urban regeneration processes on a building and district scale, thanks to the energy and environmental implementation of the existing heritage, through energy retrofit and new high sustainability buildings. The main strategy of the project was the integration of efficient energy technologies at building and neighbourhood scale, maximizing the production and the efficiency of the whole urban district, considered as a single urban organism (Pagani et al. 2016).

Assuming the premises and the results of previous researches (see Sect. 2), the analysis presented in this study demonstrates that, even in risk and uncertainty conditions, the alternative energy production technologies are able to perturb significantly the results of the analysis. The costs related to the options are influenced mainly by the efficiency of the systems and by the energy supply cost amounts, and secondly by the financial aspects and initial investment costs.

These results confirm the importance of choices between technological options on a territorial scale, particularly in regeneration projects and investment decision-making processes. Furthermore, the results suggest relying on generation systems whose power source is more stable in prices: the design decisions should therefore be directed towards technologies that use local sources with high availability such as solar energy (especially in the countries of Southern Europe): inexhaustible, free and not subject to any price fluctuation. In this way, the dependence on the supply of electricity, often subject to significant market fluctuations, could be reduced.

With these premises, the article is articulated as follows. In Sect. 2 the methodological background is illustrated. In Sect. 3 the case study is presented. In Sect. 4 the results of the methodology application are presented Sect. 5 discusses the work, and Sect. 6 concludes.

2 Methodological Background

An application of risk analysis in conjunction with LCCA is proposed for selecting the preferable alternative among technological options, at the district scale.

It is assumed that there is a presence of risk and uncertainty in cost estimating, both in the input variable estimates (Life Cycle Cost Estimates—LCCEs) and in the technical performance of the LCCA. Operatively, it is proposed the Probability Analysis approach, which is solved through stochastic simulation and the Monte Carlo Method (MCM). According to the approach, risk and uncertainty in model input are modelled as stochastic variables or “stochastic relevant cost drivers” (Department of Energy 2014). Coherently, model output (LCCA quantitative indicators) are calculated in stochastic terms (Fregonara and Ferrando 2018; Fregonara et al. 2018a).

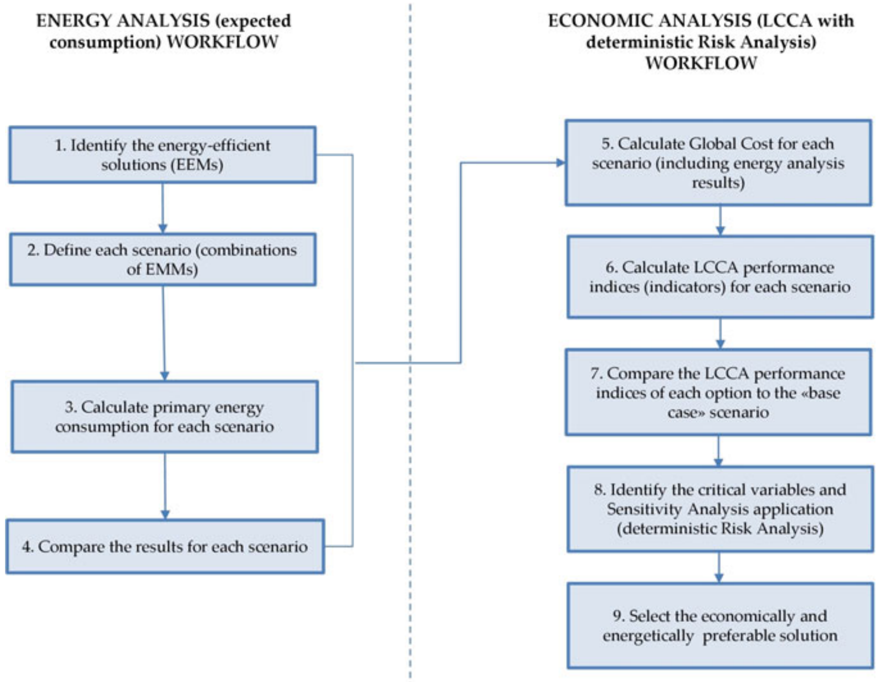
This work starts from the methodology illustrated in a recent study (Fregonara et al. 2018b) which aim was to explore the LCCA on the district scale, considering that the greatest part of LCCA applications is related to the building scale. Thus, the extensibility of the LCCA approach from the individual building to urban segments was tested. The research was based on the analysis of different technological scenarios compatible with the energy performance requirements, in order to identify the preferable one in terms of economic sustainability, and to compare technological shapes limited to building scale equipment and interventions for shared energy infrastructure equipment on the district scale (Pagani et al. 2016). It was assumed that "the integration between local energy production technologies (district heating by gas cogeneration, photovoltaic, solar heating energy) is preferable to project solutions aimed at maximising the recourse to specific energy generation technologies, viewed separately. An integration of sources which can simultaneously ensure a simple management and control" (Fregonara et al. 2018b, p. 59). The results highlighted the potential offered by switching from the single building scale to the territorial sub-segment one in the simultaneous presence of several energy sources.

With the purpose of comparing alternative technical solutions—six scenarios—to assess the relative differences in terms of their life-cycle costs and to select the preferable solutions from both an energy and an economic viewpoint, the methodology was developed according to a two-phase process: analysis of the expected energy consumption, and economic analysis.

The analysis of the expected energy consumption was articulated in the following steps (see Scheme 1—left side): (1) identification of energy-efficient solutions (or Energy Efficiency Measures—EEMs) to improve the energy performance of the building envelope and the building energy system; (2) definition of different scenarios based on combinations of alternative technological solutions (EEMs); (3) calculation of primary energy consumption for each scenario, related to the heating, domestic hot water and electricity use, following calculation of requirements for winter air-conditioning, production of domestic hot water and electricity for domestic use; (4) comparison of the technological scenarios in relation to the relevant expected energy consumption.

Afterwards, the economic analysis was conducted according to the following steps (see Scheme 1—right side): (5) calculation of the Life Cycle Cost for each scenario, in terms of Global Cost, incorporating the results of the analysis of expected energy consumption; (6) calculation of the economic performance indices through the Life Cycle Cost Analysis approach; (7) comparison of the economic indicators of the alternative scenarios to the "basic scenario"; (8) identification of critical variables and development of the Sensitivity Analysis (deterministic); (9) identification of the preferable solution from both an energy and an economic viewpoint.

In details, the step (5) of the economic analysis was developed through the LCCA approach as described in the Standard ISO 15686–5:2008—Part 5, and to the Global Cost calculation defined in the Standard EN 15459:2007, and to the Guidelines accompanying the Commission Delegated Regulation (EU) No 244/2012, following the Directive 2010/31/EU–EPBD recast. The results of the LCCA application were expressed through performance indices (or quantitative indicators): Net Present Value



Scheme 1 Energy and economic analyses: integrated methodology with deterministic risk analysis

(NPV), Savings to Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR), Simple Pay-back Period (SPB), Discounted Pay-back Period (DPB). The input data on costs related to each option considered, and the financial input data were assumed.

The Global Cost calculation was based on Eq. (1):

$$C_G(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \cdot R_d(i) \right) - V_{f,\tau}(j) \right] \quad (1)$$

where $C_{G(\tau)}$ represents the global cost, referred to starting year τ_0; C_I represents the initial investment costs; $C_{a,i}(j)$ represents the annual cost during year i of component j, including the annual running costs (energy costs, operational costs, maintenance costs) and periodic replacement costs; $R_d(i)$ represents the discount factor during the year i; $V_{f,\tau}(j)$ represents the residual value of the component j at the end of the calculation period, referred to the starting year.

Similarly to the previous research experience, in this study the Global Cost formula expressed in Eq. (1) is assumed, and a simplified application is implemented, according to Eq. (2):

$$C_G = C_I + \sum_{t=0}^{N} \frac{Co + Cm}{(1 + r)^t} \tag{2}$$

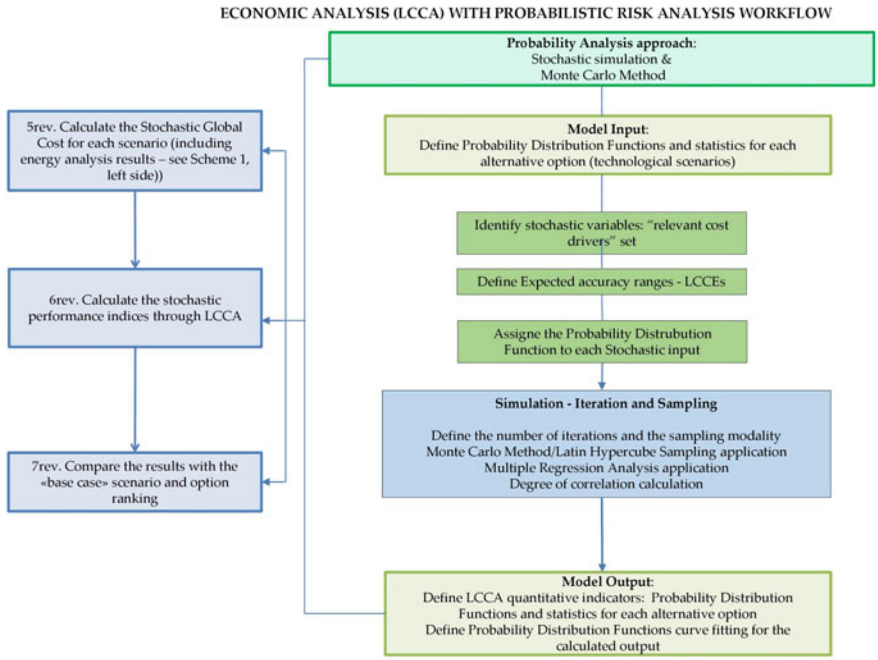
where C_G represents the cost in the life cycle (or Global Cost); C_I represents the initial investment costs; C_o represents the operating and energy costs; C_m represents the maintenance costs, t stands for the year in which the costs arise and N stands for the number of years within the timespan taken into account for the application; r represents the discount rate.

A methodological development of the steps (5–9) of the economic analysis is now proposed, for including risk and uncertainty in the LCCA application, shifting from a deterministic to a probabilistic approach. The aim of the developed methodology is to quantify the risk through a quantitative Risk Analysis, resolved through the Probability Analysis approach and the simulation method. This implies the definition of PDFs functional forms, founded on random number generation, both for model input and for model output.

Thus, it is firstly necessary to identify the most relevant variables (risky or uncertain variables) and their PDFs, and then, to isolate and to quantify the marginal contribution of each of them to the results. The most relevant variables, or relevant cost drivers, related to the cost items characterized by risk or uncertainty are expressed in terms of stochastic variables. These represent the critical input variables, able to influence the evaluation of economic–financial and energy–environmental sustainability. Similarly, the model output is calculated in terms of stochastic Global Cost, as in Eq. (3):

$$\hat{C}_G = \hat{C}_I + \sum_{t=0}^{N} \frac{\hat{C}_o + \hat{C}_m}{\left(1 + \hat{r}\right)^t} \tag{3}$$

where $\hat{C}_G$ is the stochastic Life-Cycle Cost, $\hat{C}_I$ is the stochastic investment cost, $\hat{C}_o$ is the stochastic operating and energy cost, $\hat{C}_m$ is the stochastic maintenance cost, t is the year in which the cost occurred, N is the number of years of the period considered for the analysis, $\hat{r}$ is the stochastic discount rate. In summary, the steps of the revised methodology, as illustrated in Scheme 2, are: (5rev) Global Cost calculation for each scenario, according to the stochastic approach expressed in Eq. (3), and including the expected energy consumption analysis results; (6rev) stochastic performance indices calculation, through LCCA; (7rev) comparison of the LCCA results with the "base case" scenario indicators, and ranking of the options (this last step corresponds to the step 9 of the previous methodology). Notice that each step is developed by means of the Probability Analysis, which is in turn developed according to the workflow illustrated in Scheme 2, right side. The Probability Analysis approach (which substitutes the step 8 of the previous methodology), is articulated according to the following passages (see Scheme 2, right side):



Scheme 2 LCCA with quantitative risk analysis workflow

Model Input Definition:

- identification of the set of "relevant cost drivers", or critical inputs, to be expressed as stochastic variables. Different confidence levels of the estimates, or "expected accuracy ranges", are determined in relation to the different cost items. Being the costs referred to the life cycle of the components, the "expected accuracy ranges" are expressed in terms of LCCEs (Department of Energy 2014);
- assignment of the PDF to each stochastic input variable, and the identification of the relative probability distribution parameters. The triangular distribution is considered the most used PDF to represent the uncertain variables present in the real estate investments (Maio et al. 2000; Rosato et al. 2016). Therefore, this step consists in the assignment of minimum, maximum, and point estimate values for each variable;
- Iteration and Sampling resolved through MCM. A number of iterations and a sampling modality are fixed: the simulation is conducted through the software @Risk (release 7.5 by Palisade Corporation), through a Monte Carlo Method application with 100,000 iterations, with a Latin Hypercube Sampling modality;
- running the simulation and production of the Regression Analysis in order to quantify the effect of the input variables on the output value. The marginal coefficients of the dependent variables against the independent variable (Global Cost) are calculated. Tornado graphs and spider graphs support this step. Specifically;

– Multivariate Stepwise Regression Analysis application. The Global Cost is taken as the dependent variable in the regression equation. The marginal coefficients are calculated for each input variable for measuring the sensitivity of the output variable with respect to each of them;
– degree of correlation calculation, by coefficients of correlation between the output values and each set of input value samples. This step is solved through the rank correlation analysis, and through Spearman's correlation coefficients calculation.

Model Output Definition:

– output calculation in terms of the PDFs and statistics (minimum value, maximum value, standard deviation, Skewness, Kurtosis, etc.) for each option;
– Probability Distribution Functions curve fitting, for the calculated output.

In summary, the economic analysis resolved jointly with the quantitative risk analysis is articulated as in the following Scheme:

3 Case Study

A complex project is selected as a case-study for the application of the methodology: a social-housing district in a small town near Turin, in Northern Italy. It consists in a social-housing complex of 11 building with 299 dwellings. The retrofit project is produced according to an integrated approach, shared among all the stakeholders involved (municipality, practitioners, institutions, citizens, enterprises). It foresees interventions at the building scale (envelop and heating systems), and at the district level, introducing a combined heat and power "Distric Heating", fuelled by gas cogenerator.

The case-study was treated in a European Project "Concerto AL Piano" mentioned in introduction. The project aims at demonstrating the economic and social benefits in investing in energy saving and renewable energy in urban regeneration. The project includes a mix of interventions: the renovation of existing social housing, the construction of residential new eco-buildings and the provision of a cogeneration district heating, integrated in the urban environment.

One of the most important investigation line in the Concerto projects was the evaluation costs of the urban sustainability: each European technical reports contained the technical performances in relation to the technological cost evaluation. For the European consortia participating in the Concerto projects was fundamental to answer to the following questions: "Is the technological retrofit of buildings economically viable? Is the choice of envelope technologies and renewable source systems amortizable over time? Which systems are more widely applicable in relation to building types and you have costs? In these perspectives the Concerto Al Piano project investigated the retrofit of the Social housing districts, characterized by a widespread typology in the Italian and European urban peripheries. This case study can therefore provide valuable information on the choices of technologies to

Fig. 1 The case-study: Concerto AL Piano project area; public housing buildings before and after retrofit

be adopted in relation to the investment risk for the redevelopment of a public or private property portfolio (Figure 1).

Making reference to the previous research step illustrated in (Fregonara et al. 2018b), in this work the Scenario 3 and the Scenario 6 are considered, being representative respectively of the base–case solution and of the preferable solution in economic and energy terms. Considering the system configuration for energy production of the two scenarios, these are renamed here as "Concerto AL Piano" scenario and "Integrated Solar" scenario. The Concerto AL Piano scenario represents the solution concretely carried out in Alessandria, in which the widespread solar technologies is accompanied by the district heating systems with a gas cogenerator. The Integrated Solar scenario is based on a simulation in which all the district's energy needs are satisfied with heat pumps powered by photovoltaic technology.

Table 1 summarizes the technological characteristics of the two scenarios.

4 Application and Results

Assuming the methodology illustrated in Sect. 2, and the case-study illustrated in Sect. 3, the following results are obtained.

4.1 Model Input: Stochastic Variables

As a first step, the relevant cost drivers (critical variables) are identified and, for each of them, an expected accuracy range is fixed. This last represents the confidence percentage, being defined on the basis of experts' opinions. The cost items and the

Table 1 The "Concerto AL Piano" and "Integrated Solar" scenarios: technological characteristics

Scenarios		Technological integration at the neighborhood level			Heat pumps	Cogeneration system	Solar thermal system	Photovoltaic system
Energy source					Solar power	Natural gas	Solar power	Solar power
Concerto AL Piano scenario	New	YES—District energy cogeneration CHP and solar technologies	0.22 0.21 0.20	1.60	–	Remaining shares of DHW and El demand	60% DHW demand	31% El demand
	Re-new		0.29 (0.92) 0.32	2.00		100% El and DHW demands	–	–
Integrated Solar scenario	New	YES—solar technologies on public neighborhood surface	0.22 0.21 0.20	1.60	100% heating and DHW demand	–	–	100% El demand of Heat pumps
	Re-new		0.29 (0.92) 0.32	2.00				

Table 2 The cost drivers, the relative data sources and expected accuracy ranges

Cost driver	Source	Expected accuracy range	
		Low (%)	High (%)
Initial investment costs			
– Provision and installation of buildings insulation	Concerto AL Piano data (2014)	−10	+30
– Provision and installation of cogeneration system	Concerto AL Piano data (2014)	−10	+10
– Provision and installation of photovoltaic system	www.Energia.it (April 2017 data)	−10	+10
Annual running and maintenance costs			
– Heating and DHW supply cost	ARERA[a] 1st quarter 2018	−10	+10
– Electric power supply cost	ARERA[a] 1st quarter 2018 (daily single rate)	−20	+20
– Cogeneration system efficiency	Expert opinion	−10	+10
– Photovoltaic system efficiency	Expert opinion	−25	+25
– Cogeneration system maintenance	www.Confindustria.it (April 2017 data)	−10	+20
– Photovoltaic system maintenance	www.Confindustria.it (April 2017 data)	−10	+10

[a]ARERA: Italian regulatory authority for energy networks and environment

relative expected accuracy ranges are summarized in Table 2, with reference to the sources adopted for cost items definition.

Notice that the initial investment costs are expressed in terms of total cost amounts, whilst the maintenance costs are expressed as yearly or periodic cost amounts; supply costs are expressed as parametric cost amounts. Finally, the systems' efficiency is represented through a coefficient, which value is assumed equal to 1 when the system efficiency is optimal.

In Table 3, the range of values for each cost item is defined. These values—Low Range Value, Point Estimate, and High Range Value—represent the distribution parameters, for defining a triangular distribution. About the Discount rate, the range of the values is defined on the basis of specific considerations, assuming the indications of the official documents (EN ISO 15459:2007). Furthermore, a 20 years lifespan is assumed for the LCCA application.

In Table 4 the PDFs obtained by processing the input data (Monte Carlo simulation output) are presented, specifying the triangular distributions calculated for each cost item, and the elementary statistics (minimum, maximum, and mean values; 5 and 95% percentiles).

The graphical representation of the probability distributions presented in Table 4 in three cases—Provision and installation of building insulation, Cogeneration system maintenance and Discount rate—, presents a triangular distribution with asymmetry

Table 3 The cost drivers and relative probability distribution parameters

Cost driver	Unit	Low range	Point estimate	High range
Initial investment costs				
– Provision and installation of buildings insulation	€	2,473,250.61	2,748,056.23	3,572,473.00
– Provision and installation of cogeneration system	€	1,928,752.65	2,143,058.51	2,357,364.36
– Provision and installation of photovoltaic system	€	4,381,941.29	4,868,823.66	5,355,706.02
Periodic running and maintenance costs				
– Heating and DHW supply cost	€/KWh	0.09	0.11	0.12
– Electric power supply cost	€/KWh	0.20	0.25	0.30
– Cogeneration system efficiency	Points	0.90	1.00	1.10
– Photovoltaic system efficiency	Points	0.75	1.00	1.25
– Cogeneration system maintenance	€/year	40,604.79	45,166.43	54,139.72
– Photovoltaic system maintenance	€/year	65,799.72	73,110.80	80,421.88
Discount rate	%	1.25	1.39	2.50

in the left. This denotes that the two different technological systems are subject to a higher probability of cost increasing, and analogously the Discount rate is subject to a higher probability of value increasing. In all the other cases, the triangular distributions are symmetric.

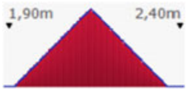
4.2 Model Output: Stochastic Simulation

As defined in Sect. 2, after defining the input values the Monte Carlo Method is applied for calculating, in stochastic terms, the output values for the Global Cost. Figure 2 presents the results considering the Concerto AL Piano and Integrated Solar scenarios. The PDFs graphics present a similar shape, being based on similar input data distributions. The relative minimum, mean, maximum values, and standard deviation values are indicated in the Figure. Comparing the output of the two alternative scenarios, higher costs emerge for the Concerto AL Piano scenario: this is due above all to higher periodic running costs.

Figures 3 and 4 illustrate the simulation results. Specifically, the Tornado graphs represent graphically the effects of the inputs on the output mean, and the Spearman correlation coefficients express the correlation between the output (Global Cost) and the sampled values for each input distribution.

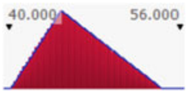
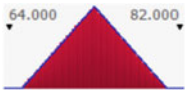
In the premise, it must be considered that the results reflect the cost entities and the relative distributions over time. Specifically, the Concerto AL Piano scenario

Table 4 The cost drivers and probability distribution values in Concerto AL Piano scenario and Integrated Solar scenario

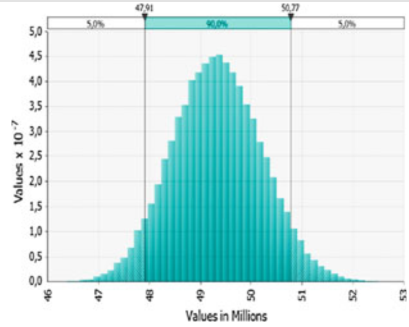
Cost Driver	Graph	Min	Mean	Max	5%	95%
Provision and installation of buildings insulation		2,474,786	2,931,260	3,570,548	2,596,146	3,359,609
Provision and installation of cogeneration system		1,929,592	2,143,059	2,356,448	1,996,517	2,289,595
Provision and installation of photovoltaic system		4,383,530	4,868,824	5,353,721	4,535,897	5,201,725
Heating and DHW supply cost		0.10	0.11	0.12	0.10	0.12
Electric power supply cost		0.20	0.25	0.30	0.22	0.28
Cogeneration system efficiency		0.9003096	1	1.099746	0.9316221	1.068374

(continued)

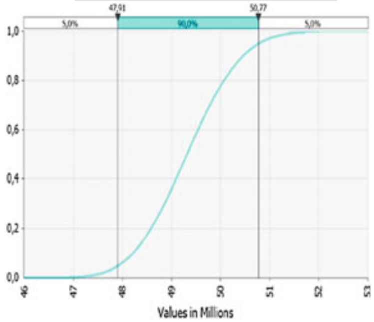
Table 4 (continued)

Cost Driver	Graph	Min	Mean	Max	5%	95%
Photovoltaic system efficiency		0.7507739	1	1.24907	0.8290527	1.170938
Cogeneration system maintenance		40,619	46,620	54,126	42,352	51,668
Photovoltaic system maintenance		65,817	73,111	80,397	68,112	78,110
Discount rate (%)		1.3	1.7	2.5	1.3	2.2

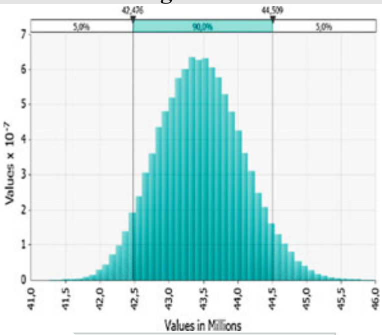
Concerto AL Piano



Statistics	
Minimum	46.098.373
Maximum	52.634.423
Mean	49.325.533
Std Dev	870.445
Variance	7,57674E+11
Skewness	0,071138604
Kurtosis	2,859273035
Median	49.314.917
Mode	49.348.571
Left X	47.907.170
Left P	5%
Right X	50.773.958
Right P	95%



Integrated Solar



Statistics	
Minimum	41.263.631
Maximum	45.975.373
Mean	43.462.102
Std Dev	616.110
Variance	3,79591E+11
Skewness	0,15404508
Kurtosis	2,867811911
Median	43.448.404
Mode	43.328.686
Left X	42.476.419
Left P	5%
Right X	44.508.577
Right P	95%

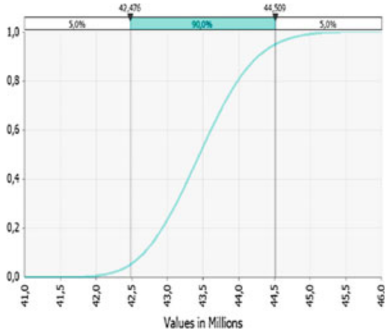


Fig. 2 The output probability distribution function, probability density function, and statistics for the Concerto AL Piano scenario and Integrated Solar scenario

presents lower initial investment costs, but higher running costs, in terms of energy consumption during time.

Comparing the Regression Analysis application results, the following considerations emerge:

– for both scenarios, the energy efficiency is the variable able to produce the largest perturbation on the output, followed by the energy cost variation, respectively for

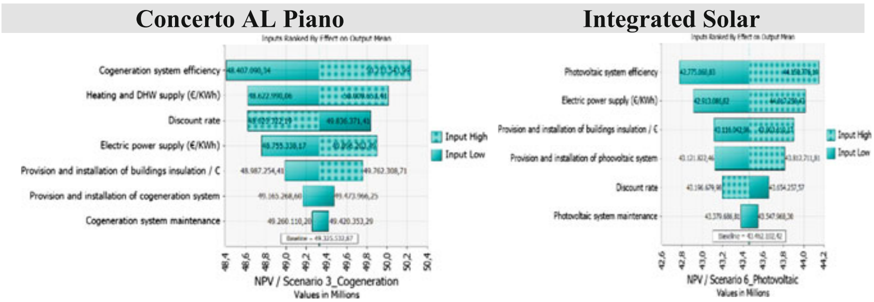


Fig. 3 The inputs ranked by the effect on the output mean, the Concerto AL Piano and Integrated Solar scenarios

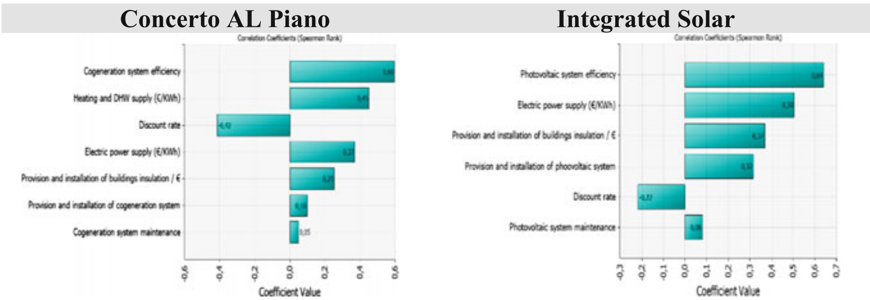


Fig. 4 The Spearman correlation coefficients for the Concerto AL Piano and Integrated Solar scenarios

the Heating and DHW in the Concerto AL Piano scenario and for the electric power for the Integrated Solar scenario;

– the Discount rate is particularly significant in differentiating the two scenarios: in fact, it results the third variable in terms of impact on the Concerto AL Piano scenario, whilst it is relatively significant on the Integrated Solar scenario (in fifth place in the ranking). In fact, the higher periodic costs for the energy production in the Concerto AL Piano scenario, submitted to the discounting procedure, produce a more relevant effect;
– among the initial investment costs, the building insulation cost results in both scenarios the variable with the higher impact on the output (fifth in the Concerto AL Piano scenario and third in the Integrated Solar scenario). This is evidently due to the large uncertainty range assumed for the variable;
– in both cases the maintenance variable has a small influence on the results (in seventh place in the ranking for the Concerto AL Piano scenario and in sixth place in the ranking for the Integrated Solar scenario).

The Spider Graphs presented in Fig. 5 confirm the negative effect of the discount rate, whilst the results of the other variables denote positive trends in every case, with a limited difference.

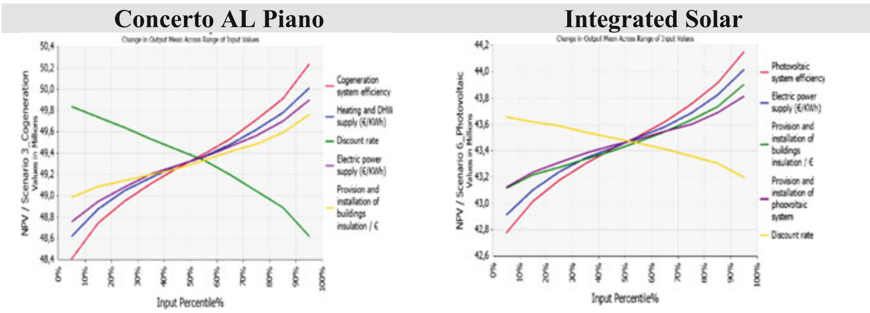


Fig. 5 The Spider Graphs for the Concerto AL Piano and Integrated Solar scenarios

Table 5 The output values of Gc for the Concerto AL Piano and Integrated Solar scenarios: the probability distribution function and statistics

Output	Graph	Min	Mean	Max	5%	95%
Gc Concerto AL Piano		€ 46,098,370	€ 49,325,530	€ 52,634,420	€ 47,907,170	€ 50,773,960
Gc Integrated Solar		€ 41,263,630	€ 43,462,100	€ 45,975,370	€ 42,476,420	€ 44,508,580

The analysis is concluded by comparing the simulation output results, as reported in Tables 5, for the two scenarios respectively.

In Fig. 6, the Probability Density Function curve fitting for Stochastic CG presents the Beta distribution as the best fit for both scenarios. This result is coherent with the literature about the uncertainty components treatment, specifically considering the stochastic costs variables (Johnson 1997; Fente 1999).

5 Discussion

According to the authors, this study has the merit to show the importance of applying, jointly, energy analysis and economic analysis considering risk/uncertainty effects in the whole evaluation process. The operative modality proposed represents a preferable alternative as respect to the application of energy analysis and economic analysis developed separately, considering that the results (in terms of options ranking) could be very different. Furthermore, the methodology is able to include risk and uncertainty components related to both input data and to the application process.

The analysis above illustrated indicates that the system efficiency, in conjunction with the energy costs variation, are the crucial variables: when affected by uncertainty,

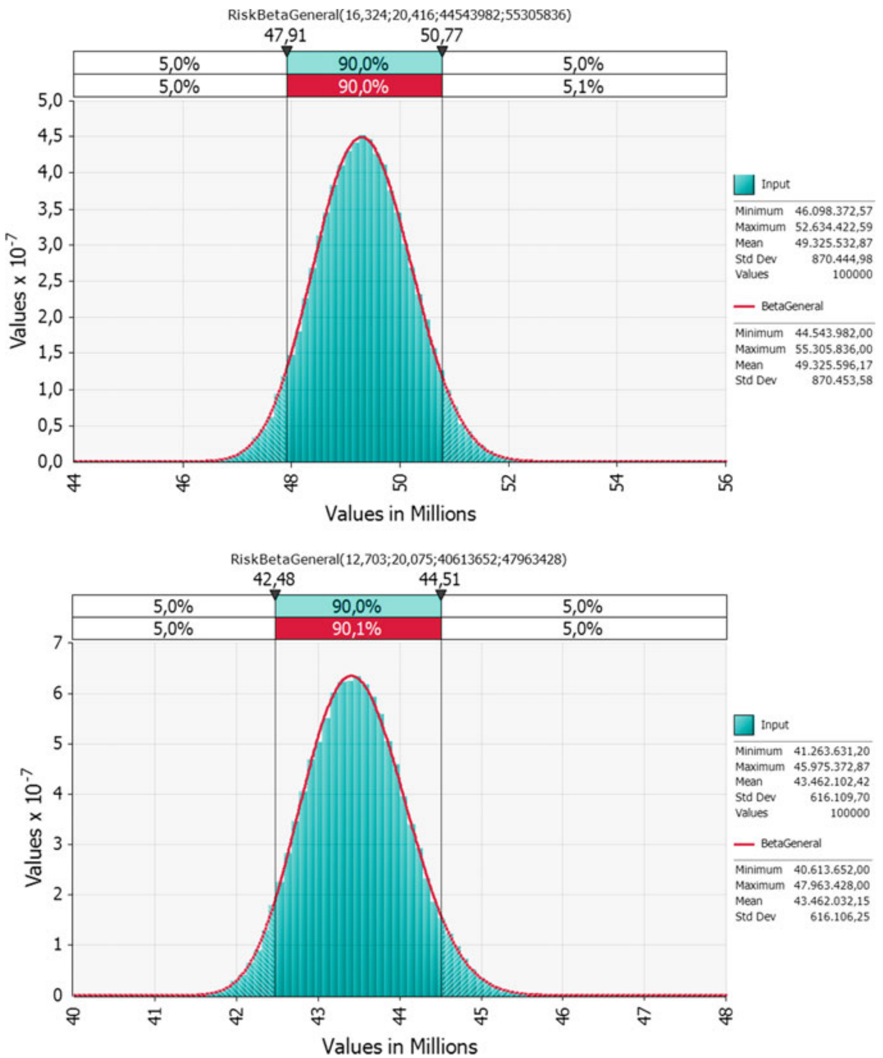


Fig. 6 Probability density function curve fitting for Stochastic $C_{G,}$ Concerto AL Piano and Integrated Solar scenarios

these variables are able to determine the most relevant effects on the final results. Investment costs have a relative effect, specifically the maintenance ones, whilst the discount rate affects particularly on the option with higher yearly costs.

In general, by introducing flexibility into the analysis can put in evidence the potential effects of uncertainty: risk and uncertainty are conceived as an opportunity in terms of profitability for investors, and, in urban regeneration interventions, as the opportunity to activate urban policies in practice.

Furthermore, the results of the analysis suggest relying on generation systems whose power source is certain and stable in prices: higher energy sources and price fluctuations make investment risk higher. In this sense, the design choices should therefore be directed towards technologies that use local sources with high availability such as solar energy. In this sense we report the example of Concerto AL Piano, in which in the first phase of the project it was decided to feed the biomass district cogeneration plant, to maximize the environmental sustainability of the redevelopment intervention. The uncertainty of biomass prices, especially between 2009 and 2012, constituted a considerable uncertainty for investors, which, combined with technical choices, led to the use of natural gas as a source of power.

Therefore, considering the two most significant indicators of the analysis, it is clear that the integration of several energy sources is a winning strategy over the years to ensure the absorption of the price change of fuels and energy: having available more technologies based on different sources, it is possible, depending on the time, maximize the use of one or the other, depending on the contingent prices of the energy market.

The study presented in the paper must be considered as a first result of a research on progress, that the authors are going to develop further starting from the limitations of present outcomes. The main limits are:

- concerning the economic analysis, the assumption on the PDFs are based on the experts' opinions and on the general knowledge on topic. This implies a certain degree of subjectivity, that could be reduced by introducing more empirical data, obtained through in depth and punctual market researches, or through the application of supporting tools as the Delphi Method;
- similarly, financial data assumed in the study are general data that could be better calibrated respect each specific item considered in the application (discount rate, data on costs, etc.);
- as concern the time assumptions, the entire time horizon of the LCCA application could be better defined, on the basis of empirical evidence, and, furthermore, it was not considered in stochastic terms, coherently with the other input. Similarly, the time ranges of maintenance interventions were not considered;
- finally, about the energy analysis, the same considerations expressed in the first point can be highlighted.

6 Conclusions

In this paper, a methodology was proposed for supporting decision making in new buildings or in retrofitting design activities at the district scale, assuming a life-cycle perspective and sustainable design principles. The focus was on the evaluation of the economic–environmental sustainability, considering the presence of the risk and uncertainty components in both cost-estimating and technical performance. According to these aims, an application of the Life-Cycle Cost Analysis in conjunction with a Risk Analysis was proposed to select the preferred choice from alternative technological options, related to different energy production systems.

Specifically, the risk analysis was solved through the probability analysis approach, which was developed by the following steps: identification of the set of "relevant cost drivers" expressed as stochastic input variables and the definition of the relative expected accuracy ranges; assignment of the Probability Distribution Function to each stochastic input variable and the identification of the relative probability distribution parameters; iteration and sampling through the Monte Carlo method; running of the simulation and production of regression analysis; output calculation for each alternative option and Probability Distribution Function curve fitting for the calculated output. The methodology was applied on a retrofit project for a social-housing district in a town in Northern Italy. The purpose was the selection of the preferable solution between technological alternative scenarios concerning different energy production systems.

The results give full evidence of the input variables uncertainty to significantly perturb the model output, giving the possibility to define more precisely the profitability ranges, and, consequently, to explicit the potential impacts of uncertainty on policy-making. In this sense, the proposed methodology could be developed, through more extensive experimentations, as a tool to support public and private subjects, operating at urban/district level, in deciding among alternative energy production systems and energy efficiency interventions, and, meanwhile, improving the use of renewable energy sources.

References

Boussabaine A, Kirkham R (2004) Whole life-cycle costing: risk and risk responses. Blackwell Publishing, pp 56–83, 142–162

Davis Langdon Management Consulting (2007) Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology—final methodology. Available online: http://ec.europa.eu/enterprise/sectors/construction/studies/life-cycle-costing_en.htm. Accessed on January 2019

Department of Energy (DOE) (2014) Life cycle cost handbook guidance for life cycle cost estimate and life cycle cost analysis. Washington DC, USA

European Commission (2010) Directive 2010/31/EU, energy performance of building directive recast (EPBD recast), 2010, Bruxelles

European Commission (2018) Directive 2018/844/EU of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, 2018, Bruxelles

European Committee for Standardization (CEN). Standard EN ISO 15459:2007. Energy performance of buildings—economic evaluation procedure for energy systems in buildings; European Committee for Standardization, 2007, Bruxelles

European Parliament, Guidelines Accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 Supplementing Directive 2010/31/EU, European Parliament, 2012, Brussels

Fente J, Knutson K, Schexnayder C (1999) Defining a beta distribution function for construction simulation. In: Proceedings of the 1999 winter simulation conference, Phoenix, AZ, USA, 5–8 Dec 1999

Fregonara E, Ferrando DG (2018) How to model uncertain service life and durability of components in life cycle cost analysis applications? The stochastic approach to the factor method. Sustainability 10(10):3642

Fregonara E, Giordano R, Ferrando DG, Pattono S (2017) Economic-environmental indicators to support investment decisions: a focus on the buildings' end-of-life stage. Buildings 7(3):1–20

Fregonara E, Ferrando DG, Pattono S (2018a) Economic-environmental sustainability in building projects: introducing risk and uncertainty in LCCE and LCCA. Sustainability 10(6):1901

Fregonara E, Carbonaro C, Pasquarella O (2018b) LCC Analysis to evaluate the economic sustainability of technological scenarios on the district scale. J Valori Valut 21:59–74

International Organization for Standardization. ISO 15686:2008 (2008) Buildings and constructed assets—service-life planning—Part 5: Life Cycle Costing; ISO/TC 59/CS 14; International organization for standardization: Geneva, Switzerland

Jafari A, Valentin V, Russell M (2014) Probabilistic life cycle cost model for sustainable housing retrofit decision-making. In: International conference on computing in civil and building engineering, Orlando, Fl, USA, pp 1925–1933

Johnson D (1997) The triangular distribution as a proxy for the beta distribution in risk analysis. The Statistician 46:387–398

Maio C, Schexnayder C, Knutson K, Weber S (2000) Probability distribution function for construction simulation. J Constr Eng Manage 126–4:285–292

Pagani R, Savio L, Carbonaro C, Boonstra C, De Oliveira Fernandes E (2016) Concerto AL Piano. Sustainable urban transformations. Franco Angeli, Milano, pp 1–171

Pereira EJDS, Pinho JT, Galhardo MAB, Macêdo WN (2014) Methodology of risk analysis by Monte Carlo Method applied to power generation with renewable energy. Renew Energ 69:347–355

Rosato P, Valcovich E, Stival CA, Berto R, Cechet G (2016) Le coperture piane con inverdimento estensivo su edifici esistenti. Parte Seconda—Aspetti economici. Valori Valut Teorie Esper 16:5–27

Technological, Axiological and Praxeological Coordination in the Energy-Environmental Equalization of the Strategic Old Town Renovation Programs

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Abstract This contribution deals with the energy-environmental interventions to be encouraged and subsidized over the implementation of the Detailed Renovation Program of Ragusa Superiore, Italy. It proposes a global economic-evaluative strategic planning pattern supporting decision-making in developing a specific energy-environmental equalization program. Starting from the huge database of the GIS describing the Architectural Units forming the old town's urban fabric, the pattern features each of them with several architectural and energy attributes, so that each of them can be sorted among the different Categories of Intervention, ranging from the conservative to the transformative ones. Furthermore, the energy characteristics of all the AUs of the sample have been modelled in order to calculate the energy performance to be improved. The combination of architectural and energy characteristics provides the profile of each AU according to which the pattern associates to it the appropriate CI and calculates the related cost and real estate market price surplus to be used for the equalization. By releasing the constraint according to which an AU is sorted to a specific CI, the pattern is able to design several global strategies that can be ranked by performing a MAVT model.

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1 Introduction

The arise of the energy-environmental issue in construction has affected the sector of the redevelopment of historic urban fabrics subject to restrictive rules on building envelopes and roofs. A set of critical issues concerning the stiffness, fragility and delicacy of the valuable architectural and urban heritage (Berardi 2013; Elgert 2018) are highlighted, as well as the incompatibility between the energy retrofit works and the characteristics of the building (Menassa 2011).

Detailed planning tools for historic centres, generally define the eligible interventions on each architectural unit (AU) by assigning them a category of intervention (CI), and, as regards the energy-environmental issue, impose constraints on systems, finishes, fixtures in presence of traditional roofing, quality of the decorations, exposed walls, etc.

This contribution is part of a more extensive study concerning the old town of Ragusa, and proposes a model integrating the analysis of the characteristics of the building fabric (Conte and Monno 2012), the evaluation of the architectural attributes and energy performance, the project, as for the attribution of the CI to each AU.

The model, therefore, aims to integrate the implementing rules for building works by extending the traditional intervention categories so as to take into account the compatibility between energy profile and architectural characterization.

The relation between energy-environmental and urban-landscape issues (Carter and Robert 2017; Giuffrida et al. 2018) is the common field of the technological, axiological and praxeological determinations. The technological performances cannot be considered values in themselves if a preference profile hasn't been outlined; otherwise, preferences need to be projected over the individual interest horizon and connected to the greater good that is related to "ought"; societal determinations, in turn, cannot be separated from natural constraints that encourage new development prospects by stimulating the creativity of the social system as a whole.

2 Materials

Ragusa is the capital of the southernmost province of Italy and one of the eight cities in south-eastern Sicily that, in 2002, were registered in the UNESCO World Heritage List by virtue of the innovation of their urban planning systems and the architectural value of their late baroque monuments.

Fundamental to the renewal that characterizes the urban structure and the current image of the historical centre, is the reconstruction process that began after the earthquake, in 1693, that destroyed Ragusa and all the major centres of Val di Noto

(Valente 2001), one of the three administrative districts in which Sicily had been divided since the Muslim age. The reconstruction provided an opportunity for the expansion of the city, whose original nucleus was rebuilt by the clergy and the landed gentry, while the emerging bourgeoisie succeeded in locating themself in the adjacent “Patro” hill where Ragusa Superiore rises (Caruso and Perra 1994).

The “new city” was built over a regular grid pattern of rectangular blocks, hinged on two main axes. Its construction, continued for over two and a half centuries from east to west.

The urban fabric is characterized by very different types of blocks and buildings; on the east side, a square grid of 90-m^2 blocks, where remarkable buildings of the new bourgeoisie and other monuments are located; on the west side, the urban fabric is fragmented into smaller blocks, which are in turn divided into small lots, some time 20-m^2 areas. In such areas more recent and poorer buildings are located.

The Detailed Plan of the historical centre of Ragusa, approved on 23/11/2012 (Departmental Decree no. 278/DRU) (Municipality of Ragusa 2010) involves 8600 Architectural Units. This planning tool rules the building works concerning the urban fabrics of both Ragusa Ibla and Ragusa Superiore. The database of the Geographic Information System, provides dimensional, typological, material, and broad technical-constructive information, that have been selected, unified, integrated, re-elaborated, and coordinated in the prospect of a generative strategic planning model (Haley 1997).

The model concerns a sample of 1788 AU (Fig. 1), aggregated into 118 blocks between Via Roma and C.so Mazzini. Each AU is described according to 16 characteristics, organized into four groups in a database with 940 fields distributed among 30 linked spread sheets; the contents of the latter are largely derived by transforming the data into meaningful units of information and, subsequently, in attributes and evaluations aimed at the sorting the AUs between the different Categories of Intervention.

3 Methods

3.1 Technological, Axiological and Praxeological Coordination

The energy issue is one of the most relevant scopes concerned by the assessment science, strongly connected with the relationship between social system and environment, involving the dualities present/future, stocks/streams, values/interests, that mostly affect the dense urban areas.

It therefore involves the entire cognitive spectrum of value judgments involved in the technological, axiological and praxeological coordination.

The technological coordination concerns the general state of the building fabric. The material, constructive and performance qualities are part of it, including

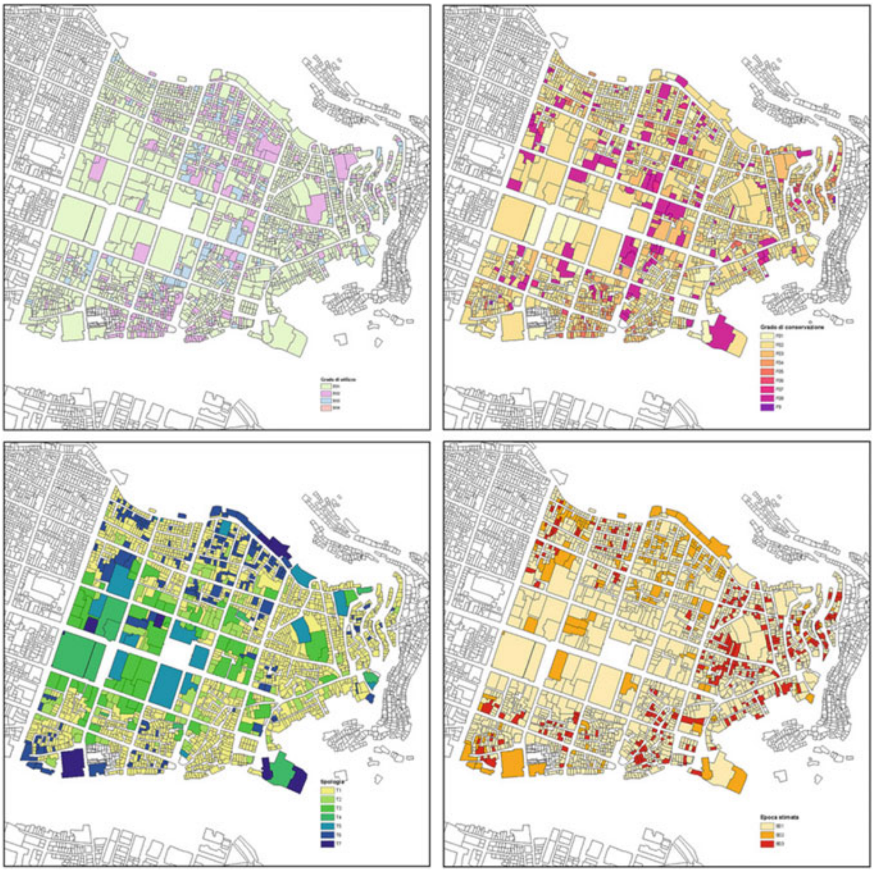

Fig. 1 The sample and some of the early analyses concerning usage, conservation degree, typologies and age of the AUs comprised in the studied area

the energy-environmental profile. The technological coordination is related to the sphere of "being able to", in the sense of the possibilities bounded by natural and artificial (tools) constraints, which the shape of the built environment depends on. This coordination generally concerns "facts" as described by observation and comparison. The sphere of judgment is involved in "factual judgments", mainly referred to the scientific truth.

The axiological coordination concerns the value of the architectural heritage as selected and promoted by the individual intentionality. This coordination includes the architectural aspects in a general sense, neither excluding nor opposing to the economic ones. According to the concept of (real estate) capital asset, the architectural heritage combines qualitative and quantitative values converging to the ability to provide a stream of monetary and non-monetary utilities, and an expected increase in value prospect.

The axiological coordination is related to the sphere of "willing" enveloping the cultural and emotional stimuli to the individual acting. This type of coordination generally concerns values as well as the sphere of judgment is involved in "value judgments", mainly stating the axiological truth concerning the order of preferences.

The axiological coordination concerns the set of determinations (choices and decisions) that settle the social order of the human capital, and the shape of the urban capital; the latter envelopes the motivational premises (the multiple points of view) in a unitary decision context (the vanishing point). They refer to the practical aspect "what to do?", to "normativity", therefore, giving rise and shape to the political-administrative action; furthermore this coordination involves the decision-making attitude as for two aspects (somehow opposite), creativity and responsibility.

The praxeological coordination concerns the sphere of "ought", the original condition of the organized communities whose internal relationships make them unitary subjects. In such a dimension the redistributive policies, overarching the personal and short-term interests, support the common development mediating between the compliance with a natural order and the possibility of a cultural order. The natural order refers to the most urgent environmental issues in a perspective of intergenerational solidarity, sometimes considered as an abstraction. The cultural order is based on a broad intra-generational solidarity. This coordination typically involves "decision" that gives a normative shape to the merit associated to the different options in their relation with the common good. The judgment sphere involved is the "judgment of merit", which accomplishes the ethical truth.

3.2 An Energy-Environmental Equalization Pattern

The urban planning approach based on the public-private agreement is nowadays involving all the branches of the urban redevelopment, encouraging the "interscalar" modeling that extends the analysis and valuation pattern "form object to land" (Giuffrida and Trovato 2017).

The sustainability of an urban renovation/development program (Sullivan et al. 2014; Della Spina et al. 2017) can be considered depending on: the equalization of the advantages gained by the households involved, that is achieved if the energy and economic surplus coming from the building development is fairly redistributed. It is well known that the historical urban fabrics renovation programs are mostly unprofitable, then a more general program including energy retrofit can improve the amount of both tangible and intangible benefits, on the one hand due to the government fiscal subsidies, on the other hand due to the recent development of REITs and the flexibility of technologies based on the electrical source (ISO 2008; Olsen and Chen 2003), that are more suitable for mostly no flexible buildings.

Furthermore, due to the heterogeneity of the urban heritage, more inequalities about energy retrofit options opportunities arise related to the urban-landscape constraints that do not affect all buildings in the same way.

Such inequality concerns also the Category of Intervention attributed, given that valuable buildings are supposed to be conserved, whereas poor architectural quality buildings are allowed to be transformed, and in some cases also to be increased in cubage; on the other side, the architectural and urban-landscape quality, that is assumed as a public good, needs to be preserved.

The proposed tool includes and coordinates quantitative and qualitative terms of values within a generative strategic planning model designed to connect valuation and planning functions.

The basic tool of the model is the well-known "residual value" appraisal criterion, according to which the surplus exceeding the fair profit coming from a transformation can be calculated as follows:

$$v_0 = v_f - k - f^* - \pi \tag{1}$$

$$\pi = r(v_t + k + f^*) \tag{2}$$

$$r = \left(w + r'\right)\left[\left(1 + w + r'\right)^n - 1\right]/\mathrm{w} \tag{3}$$

$$f^* = \left\{v_f - [(v_t + k)(1 + r)]\right\}/(1 + r) \tag{4}$$

$$v_f = (s \cdot i)/\bar{h}\bar{p};\ \ k = (s \cdot i)/\bar{h}\bar{k} \tag{5}$$

$$\beta = \left[v_t\bar{h}(1 + r)\right]/s\left[\bar{p} - \bar{k}(1 + r)\right] \tag{6}$$

where: v_0 is the current real estate value of the properties involved in the detailed plan; v_f is the value of the properties at the end of the development process; k is the building cost including ordinary permission fees; f^* indicates the surplus over the normal profit that can be transformed in extraordinary permission fees; r is the overall profit rate concerning each loan time span; w is the weighted average cost of capital (WACC); r' is the annual profit rate for risk and organization of the promoter (likely the householder) and it was made explicit as for it can be bargained if municipality assumes individual profitability as a significant incentive; n is the loan time span (years); β is the cubage ratio of the permitted cubage increase that municipality can permit in order to increase the global profitability of the plan, thus implementing a more transformative renovation strategy; $\bar{h}$ is the weighted average height of the new properties allowed; s is the surface area where the cubage increase is permitted; $\bar{p}$ is the weighted average market price of the increased real estate surface area; $\bar{k}$ is the weighted average unit building cost of the increased real estate surface area.

Consequently the objective of the Detailed Plan is to maximize the quantitative and qualitative wealth that can be created by sorting the AUs among the differently conservative or transformative CI, the former less profitable but more sustainable, vice versa the latter. A more transformative strategy mostly involving the less valuable AUs allows municipality to extract taxes to subside the preservation of the more valuable ones, but at the same time the global urban landscape quality decays. Conversely, a mostly conservative strategy, preserving the *status quo* as for the urban landscape characterized by low cubage, could discourage householders of the low valuable AU from developing their own properties.

In this methodological framework, the energy-environmental improvement of the urban fabric is one of the aspects that must be taken into account in the description of the quality profile of the buildings, and consequently in the overall renovation program, and the corresponding equalization measures (Della Spina et al. 2015).

3.3 Primary Energy Demand Calculation

The general database provided us with the basic information about the constructive, material and geometric features of the AUs of the urban fabric, used to calculate the primary energy demand for each of them (Gagliano et al. 2013, 2017). The following formula doesn't take into account the free contributions:

$$Q_h = 0.024 \cdot DD \cdot (H_T + H_V) \tag{7}$$

where: H_T is the global coefficient of heat exchange by transmission, (W/K); H_V is the global coefficient of heat exchange for ventilation (W/K); DD are the degree days of the city in which the building is located.

$$H_T = \sum_{1}^{n} S_i \cdot U_i \tag{8}$$

where: S_i (m^2) is the extent of the ith external envelope that enclose the heated gross volume. The surfaces to other rooms heated at the same temperature are not considered; U_i (W/m^2 K) is the thermal transmittance of the building

$$H_V = 0.34 \cdot V_n \tag{9}$$

where: n is the number of air changes, equal to 0.5 times/h; V_n is the net volume of the climate-controlled room, that can be considered 70% of the gross volume.

$$EP_i = (Q_h/S_n)/\eta_g \tag{10}$$

where: Q_h (kW h) is the thermal energy demand of the building; S_n (m^2) is the net surface area of the building; η_g is the overall average seasonal energy efficiency of the building (ISO 2007).

3.4 *The Strategic Planning Pattern*

The strategic planning model within which the valuation of the energy retrofit performances are framed, articulates the circular sequence "analysis-valuation-project", the *knowledge/action* process whose heuristic and logic coherence guarantees consequentiality and transparency of the decisional path (Fig. 2).

Analysis identifies the AUs as the "minimal information bearer units" by describing them reporting their dimensional, geometric and material component; the further qualities are selected and represented as attributes in the prospect of the following stage.

Valuation defines the semantic linkages between attributes and their qualitative and monetary multiple values, represented as the multidimensional value associated to each AU.

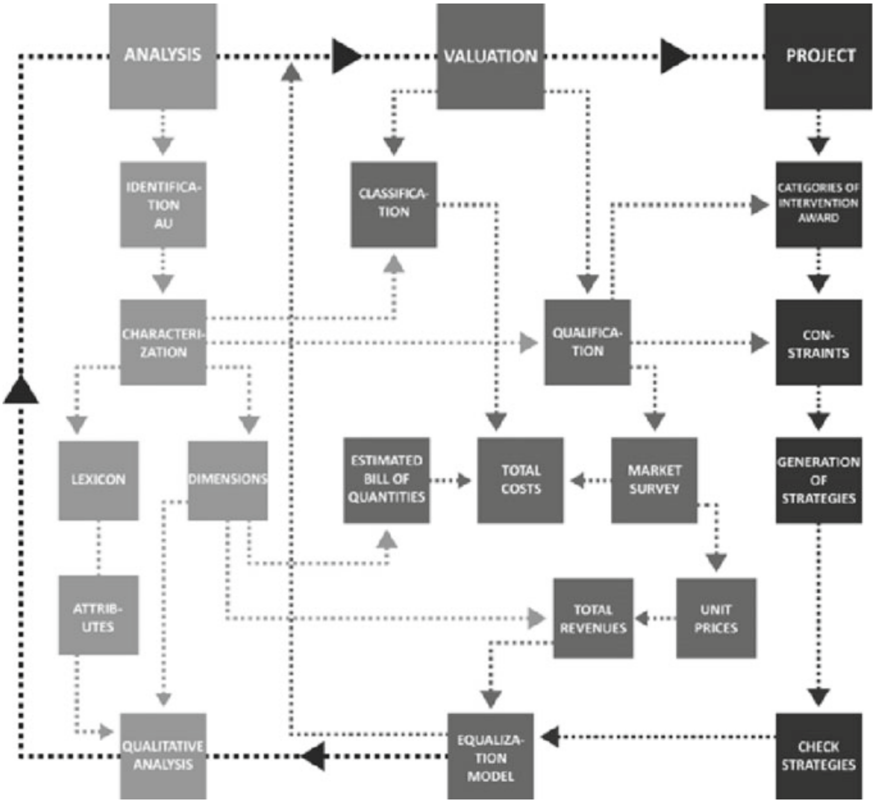

Fig. 2 Conceptual map of the circular strategic planning pattern

Project enables the syntactic linkages between AUs progressively (by designing several more or less conservative strategies) envisaging the adjustment of the urban-landscape context as a whole.

The model sorts each AU to a specific CI_{hk}—where $h = (1, 2, \ldots, 5)$ is the number of groups of *IC* (1. Ordinary Maintenance, 2. Extraordinary Maintenance, 3. Renovation, 4. Demolition and Reconstruction with or without extension, 5. Restoration), $h = (1, \ldots, 3)$ is the AU's level of maintenance (supposing a soft, medium or consistent intervention)—basing on a set of constraints v representing a set of values.

To sort the AU to the specific CI a set of constraints is used: for each CI some qualification constraints $\vec{v}_g, g = (1, 2, \ldots, m)$ and an access constraint $\bar{v}$ are defined:

– $\vec{v}_g$ are the conditions of conformity of the AU to the set of values expressed by the specific CI so that it can be part of it:
– $\bar{v}$ is the access threshold, that is the minimum number of $\vec{v}_g$ the AU exceeds.

$$CI \leftrightarrow \exists i_1, \ldots, i_k (k \leq t, t \leq 1) \mid b_{i_j} \geq \bar{v}_{i_j} \quad \forall j = 1, \ldots, k \tag{11}$$

where $\bar{v}_{i_j}$ represents the threshold of the j th criterion, k is the number of the criteria by means of which $\bar{v}_{i_j} \geq t_{i_j}$ is verified, and t_{i_j} is the minimum threshold.

A strategy, that can be more conservative or transformative, is defined by setting the constraints, which, starting from the most conservative can be progressively relaxed then admitting more and more AUs to the transformative CI.

A MAVT model allows us to compare the designed strategies (Wang et al. 2009; Zhou et al. 2006) according to the impact on:

- *Identity matrix*, calculated by taking into account the presence of typical facade elements, and of the size of the building cubage which an overall conservative CI is associated to;
- *Landscape matrix*, calculated by taking into account the overall cubage increase due to the potential prevailing of the transformative CIs, whose qualitative index depends on the overall quality score, k^*, and quantitative index is an inverse function of β (Sect. 3.2, Eq. (6));
- *Economic matrix*, calculated by taking into account the overall profitability of the renovation program, based on the difference between the expected real estate market value and the sum of total cost and current real estate market value; two converging indexes are r' (Sect. 3.2, Eq. (3)), from the entrepreneurial perspective, and f^* from the house owners perspective;
- *Functional matrix*, calculated by taking into account: the size of the AUs (depending on the cubage increase), the amount of AUs to which is associated a transformative CI, and the technology level (k_t score) of the buildings.

Thus, the trade-off between efficiency and fairness (Napoli et al. 2019) is outlined.

In order to calculate the costs of the works to be associated to each AU according to each CI, a parametric cost analysis was carried out taking into account the building type (22 types have been outlined) and the works classes (masonries, roofs, finishes, plants, window frames, insulations etc.).

In order to calculate the revenues coming from the transformations, a real estate market survey has been carried out over the segment of the old town (Gabrielli et al. 2017), describing a 75 cases sample according to 30 attributes grouped in four main characteristics (location, k_e, prospect, k_i, technology, k_t, architectural, k_a), and performing a multivariate analysis providing the multiple linear regression equation basing on which the current and final real estate market value were appraised:

$$V_m = a_1 k_e + a_2 k_i + a_3 k_t + a_4 k_a + b \tag{12}$$

4 Applications and Results

The application proposed is the follow-up of the previous experiment aimed at designing the strategy (CI arrangement) that maximizes the multiple equalization objective function enabling the prospect of the Detailed Plan. As above said, a strategy is designed by releasing the constraints v_g and $\bar{v}$. The model provides in real time the CI arrangement and the related attributes corresponding to a specific constraint profile, that can be more conservative (restrictive) or transformative (expansive). Here we compare the previous results to the ones related to the implementation of the cost and revenues coming from the energy retrofit.

As first, the calculation of the energy features has been performed over the sample, as displayed in Figs. 3 and 4, showing respectively the distribution and the map of the basic characteristics of the buildings and the result of the energy performance over the sample.

The second stage concerns the calculation of the unit costs of the 15 CI corresponding to the 22 building types, that have been compared to the unit costs without energy retrofit, as displayed in Fig. 5, showing the percentage increase.

Once implemented the new unit costs in the strategic planning model, the new total costs for each strategy have been calculated. Some comparisons between the distributions with/without retrofit costs are displayed in Fig. 6 comparing the results of four exemplary strategies (1, 5, 8, 11).

Figure 7 displays the progressive modification of the CI as far the constraints are released (strategies 1, 5, 7, 13).

Such a wide range of conservative/transformative strategies outlines the involvement of a broad spectrum of the values involved and at the same time enabled, each of which needs to be appraised as for monetary measurements and for qualitative assessments.

Furthermore, due to the heterogeneity of the historical urban fabric, shared and effective valuation rules need to be defined especially when the CI assigned to an AU significantly modifies its axiological (i.e. individual or private) profile, as well

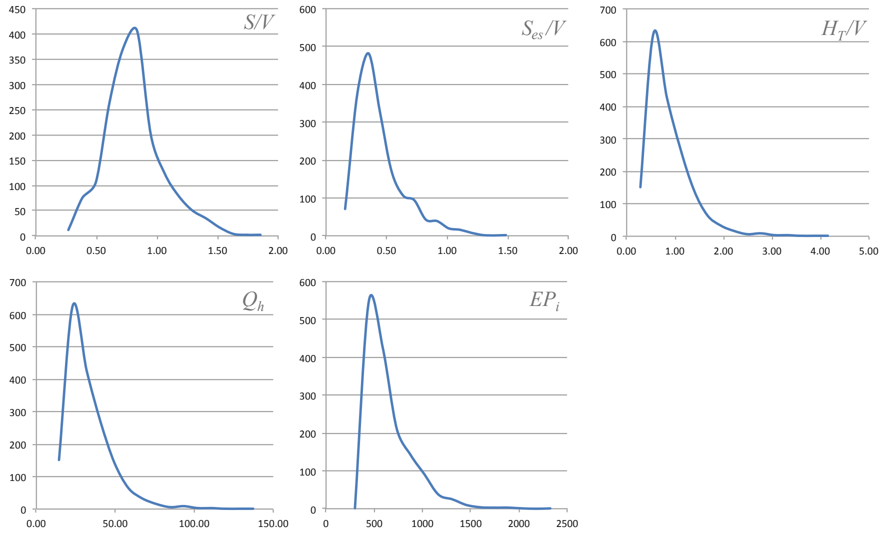

Fig. 3 Distribution of the energy characteristics and performance over the sample

as the economic potential, and ethical (i.e. public) values, mostly qualitative as for the relevance of the AU within the urban-landscape context.

Based on the characteristics of the AUs of the sample, a set of logical functions modify the current attributes of each AU according to the CI assigned, also concerning the cubage increase in case of CI supposing such works.

Figures 8 and 9 sample this range displaying the variation of aggregated value score k^*, prospect value score k_i, technology value score k_t, architectural value score k_a from strategy 3 to strategy 13.

Figures 10 and 11 display the variation of cubage, real estate market value, the ratio real estate market value/cost, and the ratio (real estate market value-cost)/cost from strategy 3 to strategy 13.

The last elaboration provides a synoptic view of the decisional model based on the MAVT approach, simplified by keeping the weights constant, and used only to assess each strategy, once outlined the value functions for each axiological matrix. Each strategy is now represented in terms of the four scores attributed to the strategies according to the four matrices. Thus, each strategy can be compared to each other and the trade off or convergence relations (Sect. 3.4) between such matrices can be outlined (Figs. 12 and 13).

Each strategy is represented in an overall framework comprising four diagrams. Each diagram represents in its axes a couple of matrices related to each other in order to display trade-off or convergence relation between each couple of matrices. Each strategy is displayed in each diagram by means of the score it gets from the point of view of each matrix.

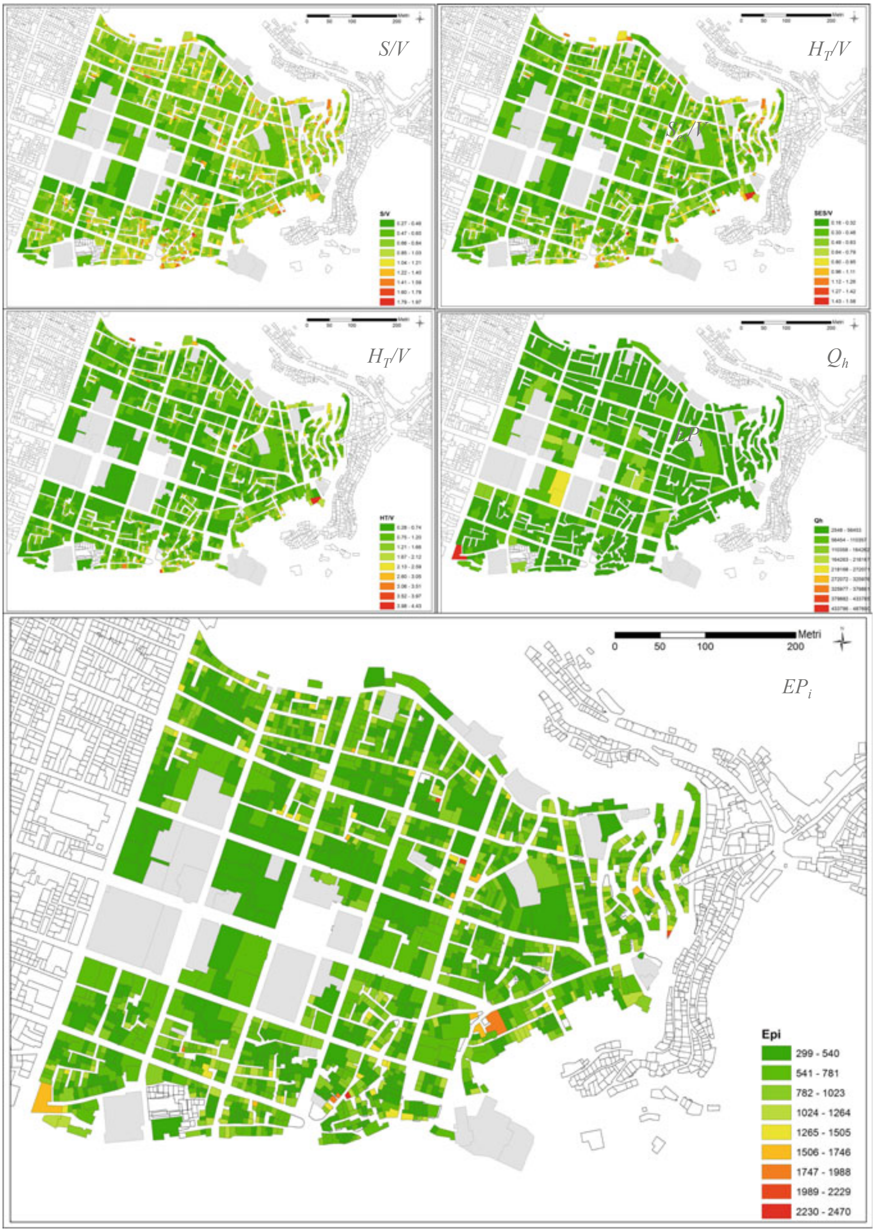

Fig. 4 Maps of the energy characteristics and performance

CME	MO1	MO2	MO3	MS1	MS2	MS3	RI1	RI2	RI3	Res1	Res2	Res3	DR1	DR2	DR3
a CME	83%	54%	29%	14%	11%	12%	7%	6%	4%	23%	10%	7%	9%	9%	19%
b CME	101%	42%	22%	11%	7%	8%	5%	3%	1%	17%	7%	5%	9%	9%	19%
c CME	95%	73%	37%	18%	13%	14%	7%	6%	3%	26%	10%	8%	9%	9%	19%
d CME	115%	62%	31%	15%	10%	9%	5%	3%	1%	20%	7%	5%	9%	9%	19%
e CME	50%	58%	28%	14%	10%	12%	6%	5%	3%	23%	9%	7%	9%	9%	19%
f CME	60%	40%	21%	10%	7%	8%	4%	3%	1%	16%	6%	5%	9%	9%	19%
g CME	42%	41%	21%	10%	7%	8%	4%	3%	1%	16%	6%	5%	9%	9%	19%
h CME	36%	54%	28%	13%	10%	12%	6%	5%	2%	22%	9%	7%	9%	9%	19%
i CME	49%	62%	32%	15%	11%	13%	7%	5%	3%	24%	9%	7%	9%	9%	19%
l CME	60%	48%	24%	11%	8%	8%	4%	3%	1%	17%	6%	5%	9%	9%	19%
m CME	32%	42%	21%	10%	7%	8%	4%	3%	1%	16%	6%	5%	9%	9%	19%
n CME	27%	55%	28%	13%	10%	12%	6%	5%	2%	22%	9%	7%	9%	9%	19%
o CME	116%	62%	31%	15%	10%	9%	5%	3%	1%	20%	7%	5%	9%	9%	19%
p CME	102%	69%	35%	17%	12%	12%	6%	5%	2%	24%	9%	7%	9%	9%	19%
q CME	43%	38%	20%	9%	7%	7%	4%	3%	0%	15%	6%	4%	9%	9%	19%
r CME	26%	45%	23%	10%	8%	9%	4%	3%	1%	18%	7%	5%	9%	9%	19%
s CME	80%	64%	32%	15%	11%	11%	6%	4%	2%	22%	8%	6%	9%	9%	19%
t CME	64%	52%	27%	13%	9%	10%	5%	4%	1%	21%	8%	6%	9%	9%	19%
u CME	47%	58%	31%	16%	12%	14%	8%	7%	4%	24%	11%	9%	12%	12%	21%
v CME	53%	38%	20%	9%	6%	7%	3%	2%	0%	15%	5%	4%	9%	9%	19%
w CME	73%	44%	23%	11%	7%	7%	4%	2%	0%	13%	6%	4%	9%	9%	19%
z CME	50%	51%	26%	11%	8%	9%	4%	3%	0%	15%	6%	5%	9%	9%	19%

Fig. 5 Percentage increase of the energy retrofit unit costs for each CI and for each building type

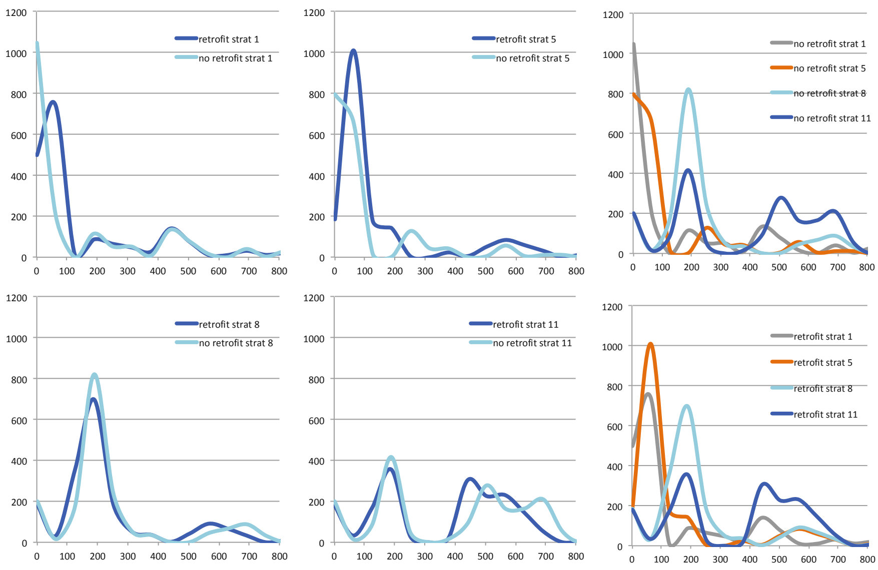

Fig. 6 Comparison between the distributions of the costs with and without energy retrofit, in four exemplary strategies

Fig. 7 Category of intervention in four different strategies progressively more transformative (1, 5, 7, 13)

If a strategy corresponds to a quadruple of dots, representing the strategies all together the corresponding four sequences of dots outline the trade-off or convergence relations between matrices (Figs. 12 and 13, empty dots). Thus, the trade-off or convergence relations can be defined in order to compare the 15 strategies without (empty grey) and with (full red) energy retrofit. At last, the pattern highlights the best strategy (the one with the largest square connecting the four dots) according to the two prospects: without retrofit strategy 8 is the best (Fig. 12), with retrofit strategy 1 is the best (Fig. 13).

Fig. 8 Qualitative arrangement of strategy 3

5 Discussions

The results of the proposed experimentation can be summarized and commented with reference to the five methodological and operational areas that we have tried to integrate.

The first concerns the analysis of the state of affairs, which although based on the database supporting the Detailed Plan, has been filtered according to the aims of the general model, aimed at forming a plurality of strategies with different and progressive degree of protection or transformation of the fabric building-urban.

In particular, the large and detailed data was traced back to a synthetic representation of the urban fabric, consistently: with the measurements necessary for both the energy calculation and the interscalar evaluations; with the qualitative assessments

Fig. 9 Qualitative arrangement of strategy 13

necessary for the formation of the intervention strategies; with monetary valuations, in particular the cost accounting and the real estate market appraisal, necessary for the equalization calculations; finally all these evaluations provided the material for the logical relations through which the constraint systems were formed, and releasing which the different strategies were outlined.

The calculation of the energy characteristics of the buildings and of the primary energy needs has provided results that are consistent with the climatic zone in which Ragusa is included. The prevalence of old and masonry buildings (Fig. 1) and the consequent low energy needs (Figs. 3 and 4) do not encourage radical and economically demanding retrofits, despite the fact that fiscal incentives are confirmed every year.

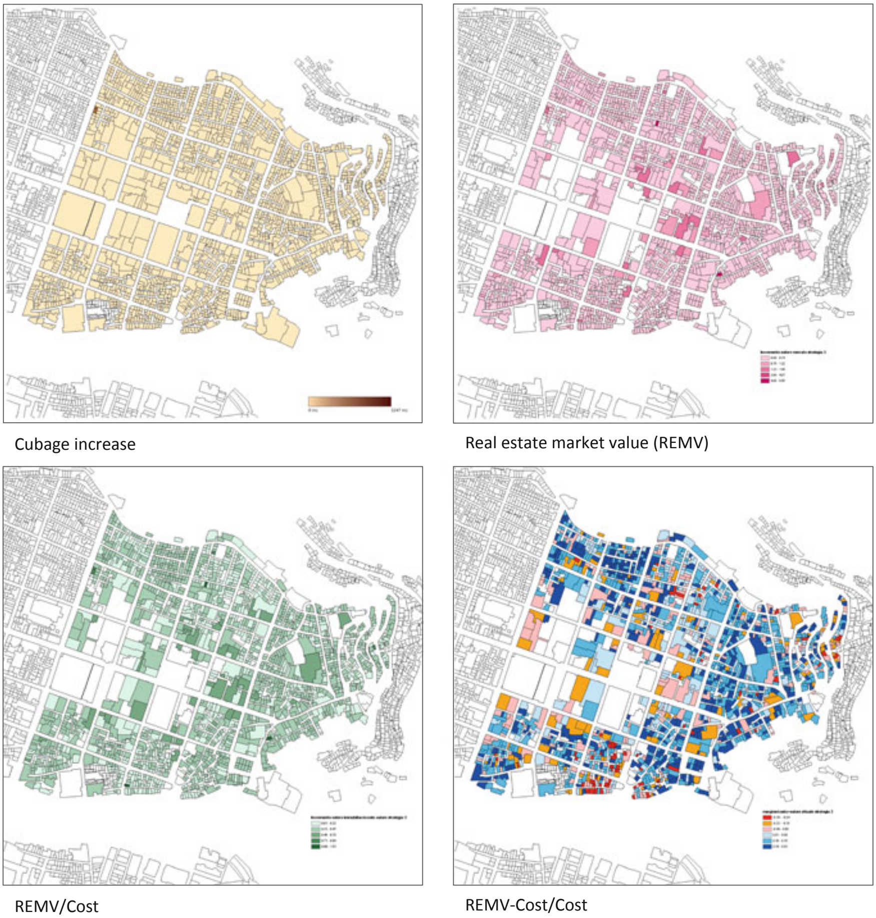

Fig. 10 Quantitative (cubage) and economic (profitability) arrangement of strategy 3

Nonetheless, the energy calculation was included among the references for the estimate of the parametric costs of urban renewal works, and the resulting total costs, referring to the 15 strategies, were calculated and compared (Figs. 5–7). As the energy retrofit works are present in all the Category of Intervention, the percentage increase of the unit cost for Ordinary Maintenance is relevant (Fig. 5).

Accordingly, comparing with/without energy retrofit by means of the distribution analysis, the exemplary strategies 1, 5, 8, 11 (Fig. 6) show that the probability density functions, in case of energy retrofit, slide towards right mostly in the conservative strategies.

The most conservative strategies do not fit the contexts in which, like Ragusa Superiore, architectural values are mostly spread and the context value prevail on the individual architectural values, as opposed to Ragusa Ibla, the older and original part

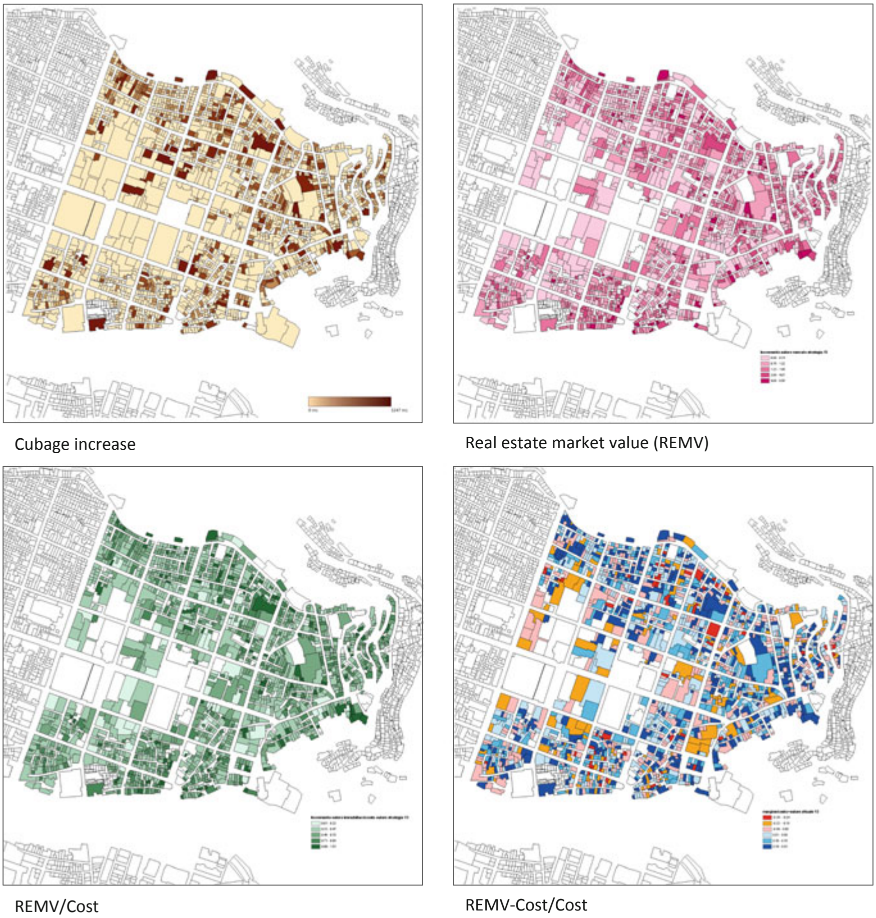

Fig. 11 Quantitative (cubage) and economic (profitability) arrangement of strategy 13

of the old town of Ragusa, where the recent increase of the real estate market values supports preservation. As a consequence, the development perspective of Ragusa Superiore is sometime suggested as effect of transformative interventions supposing a relevant quota of AU (the less significant) to be included in cubage increase CI (Fig. 7).

The comparison of the "value arrangements" of two opposing strategies, conservative *vs* transformative (Figs. 8 and 9), shows the importance of the model aimed at optimizing the strategy in the light of the true valuation of authentic values (Giuffrida 2017).

In the ground of equalization, economic as first, and in the light of the real estate market survey results, the same comparison (strategies 3 and 13) revealed that a modest impact on the overall profitability of the intervention program needs a rele-

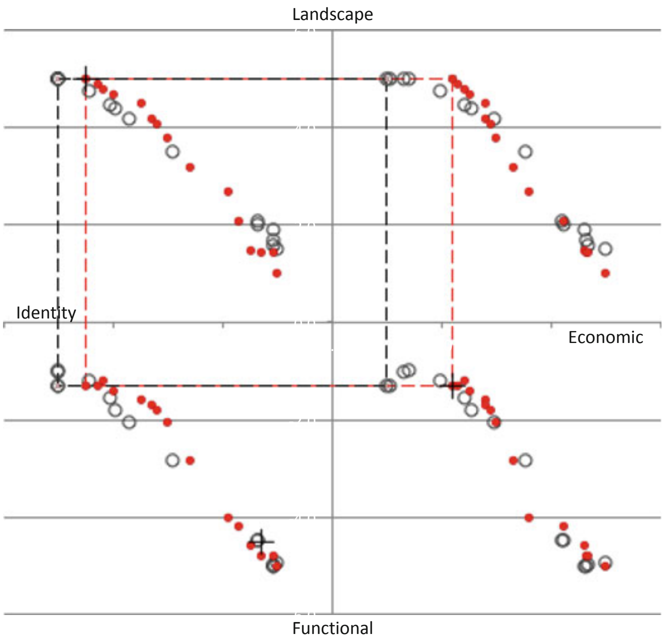

Fig. 12 Comparison between strategy 1 with/without retrofit: the first one wins

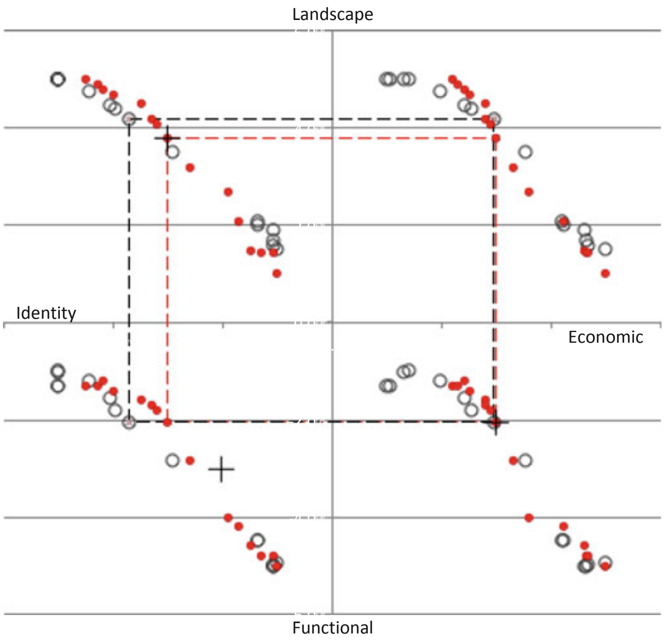

Fig. 13 Comparison between strategy 8 with/without retrofit: the second one wins

vant cubage increase, with prejudice to the identity and urban-landscape axiological matrices of the old town.

Further and final considerations concern the overall valuation of the 15 strategies that can be designed by releasing the constraints, as above explained (Sect. 3.4, Eq. (11)). The comparison pattern, based on a MAVT model, highlights both the complementary and the conflicting relations between the four axiological matrices assumed as overarching value dimensions of the praxeological coordination, toward which the whole analytic and evaluation path converge.

The diagrams of Figs. 12 and 13, show the trade-off and complementary relations between the four matrices—without energy retrofit (empty bubbles) and with energy retrofit (full bubbles).

Strategy 1 is the best in case of energy retrofit: the red rectangle is greater; strategy 8 is the best in case of no energy retrofit: the black rectangle is greater.

This experimentation shows that a conservative strategy can become the best with energy retrofit; otherwise, without energy retrofit a more transformative strategy needs to be implemented.

6 Conclusions

This experimentation concerns the evaluation of the impact of the widespread energy retrofit in the strategic planning for redeveloping historical urban fabrics.

The analysis, evaluation and planning path we propose follows a conceptual framework arranging technological, axiological and praxeological co-ordinations, which overarch respectively: the formation of wealth; the distinction between wealth and value; the selection of the forms of wealth with a higher value content.

With reference to a wide sample of the historical urban fabric of Ragusa Superiore, (Italy), a generative strategic planning model (Kyrkou and Karthaus 2011) was designed. It's able to sort the AUs through the different CIs by releasing the constraints preserving the more valuable AUs from inappropriate transformation.

The prospect of sustainable local development (Hemphill et al. 2004) focused on urban-architectural quality for inhabitants, fits the directives of the urban-architectural quality preservation especially in the low density value urban areas.

In this sense, equalization doesn't refer only to valuation, but also to the design of options, like in this case, where, on the one hand, the poor architectural-urban quality is compensated with a real estate economic benefit (a transformative CI), on the other hand the surplus coming from the unbalance revenue-cost can be used to incentive the conservative CI for the valuable buildings.

References

Berardi U (2013) Sustainability assessment of urban communities through rating systems. Environ Dev Sustain 15(5):1573–1591

Carter A, Robert P (2017) Strategy and partnership in urban regeneration. In: Roberts P, Sykes H, Grager R (eds) Urban regeneration. 2nd ed. Sage, London, pp 44–69

Caruso M, Perra E (1994) Ragusa—La città e il suo disegno. Genesi di un organismo urbano tra '600 e '700. Tarquinia, Gangemi

Conte E, Monno V (2012) Beyond the buildingcentric approach: a vision for an integrated evaluation of sustainable buildings. Environ Impact Assess Rev 34:31–40

Della Spina L, Scrivo R, Ventura C, Viglianisi A (2015) Urban renewal: negotiation procedures and evaluation models. In: Gervasi O et al (eds) Computational science and its applications—ICCSA 2015. ICCSA 2015. Lecture Notes in Computer Science, vol 9157. Springer, Cham. ISBN: 978-3-319-21469-6 (Print), 978-3-319-21470-2 (Online). https://doi.org/10.1007/978-3-319-21470-2_7

Della Spina L, Lorè I, Scrivo R, Viglianisi A (2017) An integrated assessment approach as a decision support system for urban planning and urban regeneration policies. Buildings 7:85. https://doi.org/10.3390/buildings7040085, http://www.mdpi.com/2075-5309/7/4/85

Elgert L (2018) Rating the sustainable city: 'Measurementality', transparency, and unexpected outcomes at the knowledge-policy interface. Environ Sci Policy 79:16–24

Gabrielli L, Giuffrida S, Trovato MR (2017) Gaps and overlaps of urban housing sub-market: hard clustering and fuzzy clustering approaches. In: Appraisal: from theory to practice, pp 203–219. https://doi.org/10.1007/978-3-319-49676-4_15. ISBN:978-3-319-49675-7

Gagliano A, Nocera F, Patania F, Capizzi G (2013) A case study of energy efficiency retrofit in social housing units. Energy Procedia 42:289–298

Gagliano A, Giuffrida S, Nocera F, Detommaso M (2017) Energy efficient measure to upgrade a multistory residential in a nZEB. AIMS Energy 5(4):pp 601–624

Giuffrida S (2017) The true value. On understanding something. In: Stanghellini S, Morano P, Bottero M, Oppio A (eds) Appraisal: from theory to practice. Green Energy and Technology. Springer, Cham, pp 1–14. https://doi.org/10.1007/978-3-319-49676-4_1

Giuffrida S, Trovato MR (2017) From the Object to land. Architectural design and economic valuation in the multiple dimensions of the industrial estates. In: Gervasi O. et al. (eds) Computational science and its applications—ICCSA 2017. Lecture Notes in Computer Science, vol 10406. Springer, Cham, pp 591–606. https://doi.org/10.1007/978-3-319-62398-6_42

Giuffrida S, Gagliano F, Nocera F, Trovato MR (2018) Landscape assessment and economic accounting in wind farm programming: two cases in Sicily, Land, vol 7, no 4. https://doi.org/10.3390/land7040120

Healey P (1997) A strategic approach to sustainable urban regeneration. J Property Dev 1:105–112

Hemphill L, Berry J, McGreal S (2004) An indicator-based approach to measuring sustainable urban regeneration performance: part 1, conceptual foundations and methodological framework. Urban Stud 41(4):725–755

ISO—International Organization for Standardization (2007) Building components and building elements: thermal resistance and thermal transmittance, calculation method, Standard ISO EN 6946

ISO—International Organization for Standardization, Energy performance of buildings—calculation of energy use for space heating and cooling, Standard ISO EN 13790, 2008

Kyrkou D, Karthaus R (2011) Urban sustainability standards: predetermined checklists or adaptable frameworks? Procedia Engineering 21:204–211

Menassa CC (2011) Evaluating sustainable retrofits in existing buildings under uncertainty. Energy Build 43:3576–3583. https://doi.org/10.1016/j.enbuild.2011.09.030

Municipality of Ragusa (2010) General variant of the master plan, and detailed plan of the Historic Center of Ragusa

Napoli G, Giuffrida S, Trovato MR (2019) Efficiency versus fairness in the management of public housing assets in Palermo (Italy). Sustainability 11(4):1199. https://doi.org/10.3390/su11041199
Olsen Erik L, Chen QY (2003) Energy consumption and comfort analysis for different low-energy cooling systems in a mild climate. Energy Build 35(6):560–571
Sullivan LJ, Rydin Y, Buchanan C (2014) Neighbourhood sustainability frameworks-a literature review. Centre for Urban Sustainability and Resilience 2014, University College London, Working Paper
Valente L (2001) Ragusa Ibla: memoria, calamità e piano. Consiglio Scientifico Internazionale Sviluppo Sostenibile, Milano
Wang J-J, Jing Y-Y, Zhang C-F, Zhao J-H (2009) Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renew Sustain Energy Rev 13:2263–2278. https://doi.org/10.1016/j.rser.2009.06.021
Zhou P, Ang BW, Poh KL (2006) Decision analysis in energy and environmental modeling: an update. Energy 31:2604–2622. https://doi.org/10.1016/j.energy.2005.10.023

Off-Site Construction. The Economic Analyses for the Energy Requalification of the Existing Buildings

Antonio Nesticò, Gianluigi De Mare and Irene Aurigemma

Abstract The issue of energy efficiency in buildings is now of prime importance, both in terms of financial and environmental impacts. In this sense, the broad literature is expressed in agreement. The theme, which is certainly important for the entire construction sector, is analyzed here taking as a reference the off-site construction, sometimes little investigated in sector studies, both with regard to new buildings and with regard to existing prefabricated buildings. In the first case, in fact, new buildings must comply with the increasingly stringent energy standards that national and international regulations prescribe; in the second case, prefabricated constructions with low energy performance are widespread in many countries, for which efficiency measures are required. In both circumstances, however, the market is increasingly tempted to the problem, for reasons not only of housing comfort but also purely monetary, also attributable to the greater appreciation that a high energy performance has on the market. In this perspective, the paper first articulates the phases of an investigation protocol to be re-purposed in the definition of the interventions to be implemented for the energy efficiency of buildings. Subsequently, with specific reference to existing prefabricated buildings, it aims to select alternative processes capable of increasing the energy efficiency of vertical opaque structures. The preliminary technical selection of possible actions is followed by the necessary financial analysis. This, by comparing the investment and operating costs with the revenues generated by the savings on consumption, makes it possible to establish the best intervention option.

The contribution to this paper is the result of the joint work of the three authors, to which the paper has to be attributed in equal parts.

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Keywords Building envelope energy retrofit · Off-site construction · Economic evaluation

1 Introduction. Off-Site Construction and Technological Innovation in Architectural Design

Industry has three strategic priorities: smart construction and digital design, sustainable construction and improved trade performance. Off-site construction represents a potential catalyst for these technological challenges. Synthesis between industrial manufacturing and construction, it allows you to move the construction of building works largely in the factory (off-site), and then complete the works on site with optimization of costs and execution times (Miorin 2017; Barbosa et al. 2017).

The process of industrialization of construction began in the twentieth century in different ways and at different times in various European countries. In France, Germany, Great Britain and Holland, after the Second World War, there was a radical spread of the system of industrial prefabrication to cope with reconstruction programs for residences and school buildings. In Italy, in the same period, the technological gap in various production sectors is also reflected in the construction sector. Prefabricated construction is reduced to the import of construction technologies and innovative materials that are not part of traditional techniques. It was only in the 1960s that the high demand for building goods led planners and builders to build prefabricated structures. On the French model, Italian companies specialize in "heavy" reinforced concrete panel prefabrication, especially for residential buildings, leaving little room for "light" type technology, i.e. thin steel or prestressed reinforced concrete structures and thin panels (Poretti 2013). In about thirty years, however, the new way of building sees a sharp decline. The causes are both economic, due to the high operating and planting costs that lead to the crisis of small and medium enterprises, and cultural, due to the lack of evolution of building prototypes as a result of changing housing needs, which also lead to a drastic decline in architectural quality.

Today's construction industry operators recognize the need to increase the productivity levels of the construction industry through Modern Methods of Construction (MMCs), advanced off-site prefabrication systems. This is done together with the Building Information Modelling (BIM), which allows the digitization of the entire building process from design conception to management, up to cost control extended to the entire life cycle of the product (Miorin 2018).

In recent years, new generation buildings have become more widespread on a global scale, due to the need to reduce operating costs in the face of an increase in performance, with particular regard to energy performance. The aim is to ensure the pursuit of increasingly stringent objectives in terms of energy efficiency and the use of renewable sources, as imposed by the European agreements for 2030 for both new and existing buildings. Also in this perspective, off-site construction is particularly important. This is obviously a realization process that must be based on a multidisciplinary approach, able to integrate together the phases of planning, design, processing in the factory of different materials, assembly on site of the construction elements (Smith 2014a). The application of these new design and construction models requires a deep specialization of all operators in the sector. Designers must use the new IT tools to digitise the construction process. Builders and construction workers, often unskilled and rather old, must integrate the manual skills and tradition of building with new industrial technologies, thus determining an increase in productivity.

The literature shows that off-site construction, increasingly widespread in the international building scene, is concretely capable of generating multiple economic benefits. Alongside monetary savings (Smith 2014b), the important environmental effects in terms of reducing energy consumption and hence carbon dioxide emissions should not be overlooked (Southern 2016).

2 Aim of the Paper

Nowadays the construction market is increasingly focused on the maintenance and upgrading of existing buildings. These are complex activities, which require careful technical and economic evaluations and which may concern products made either with traditional techniques, in masonry or reinforced concrete, or with the technique of heavy prefabrication. Prefabricated structures, more or less widespread in individual countries, were built in Italy between the first post-war period and the early Nineties, often with marked limits in terms of thermal insulation capacity. These limits, generally to be attributed to the different components of the building, sometimes depend heavily on the building envelope, whose concrete panels rarely provide the necessary energy efficiency requirements.

The energy requalification of the prefabricated building envelope can be achieved through different possible interventions. The aim of the work is to demonstrate that the optimal technical solution choice is based on a rigorous economic analysis to be developed by comparing previously identified project alternatives. The pursuit of this object is achieved by structuring this paper into four sections. Section 3 contains the study methodology, which consists of a protocol for the economic evaluation of energy efficiency measures. Section 4 shows a possible selection of the interventions to be made on the envelope that makes up the prefabricated building structure. Section 5 implements the investigation protocol to a case study. Section 6 discusses the results and reports the conclusions.

3 Materials and Methods. A Protocol for the Economic Evaluation of Energy Efficiency Measures

The methodological approach for the definition of energy improvement interventions of the building envelope provides for a multi-stage procedure with studies on the energy characterization of the prefabricated building, the technical-architectural design of the building works, the economic evaluation of the initiative. The different steps are in Fig. 1.

The first phase of the protocol concerns the collection and processing of all general, technical and architectural information of the building, as well as the analysis of climatic and environmental data, geometric and dimensional of the construction, thermophysical of the components of the building envelope, the performance characteristics of the installed systems (Stage 1). These operations are fundamental for the evaluation of the energy performance and the specific consumption of the building in its actual state, as a result of the implementation of the data previously collected within thermodynamic simulation software (Stage 2–3). Inspections of the building allow to detect possible critical situations due to high energy requirements. The tools of investigation can be many, starting from the visual examination of the construction, where the components of the building-plant system have clearly poor thermal qualities, to the use of innovative non-destructive techniques, such as infrared thermography, useful to highlight thermal bridges, moisture phenomena and heat dispersion (Stage 4). The possible strategies of energy efficiency are determined starting from a careful analysis of the current conditions and the thermophysical parameters of the building (Stage 5). The optimal energy retrofit solution for the building envelope is the result of the economic evaluation of the alternatives, which must take into account the effect of any European and/or national funding (Stage 6). Indicators of financial convenience (NPV, IRR, Pay Back Period, B/C ratio) and environmental, social or cultural impact (CO2 emissions, reduction in pollution levels and number of diseases, etc.) return the results of the research (Stage 7) (Fiore et al. 2016; Nesticò et al. 2015, 2018).

4 Overview of Retrofit Actions for the Building Envelope of Prefabricated Structures

In general, good design practices for existing buildings recognize several intents aimed at improving the energy performance of building components:

a. the addition and/or subtraction of volumes and surfaces;
b. the integration of deficient sub-system elements;
c. the replacement of parts of the structure.

The volumetric addition actions concern the insertion of both technical compartments for the housing of systems and connection systems (stairs or elevators),

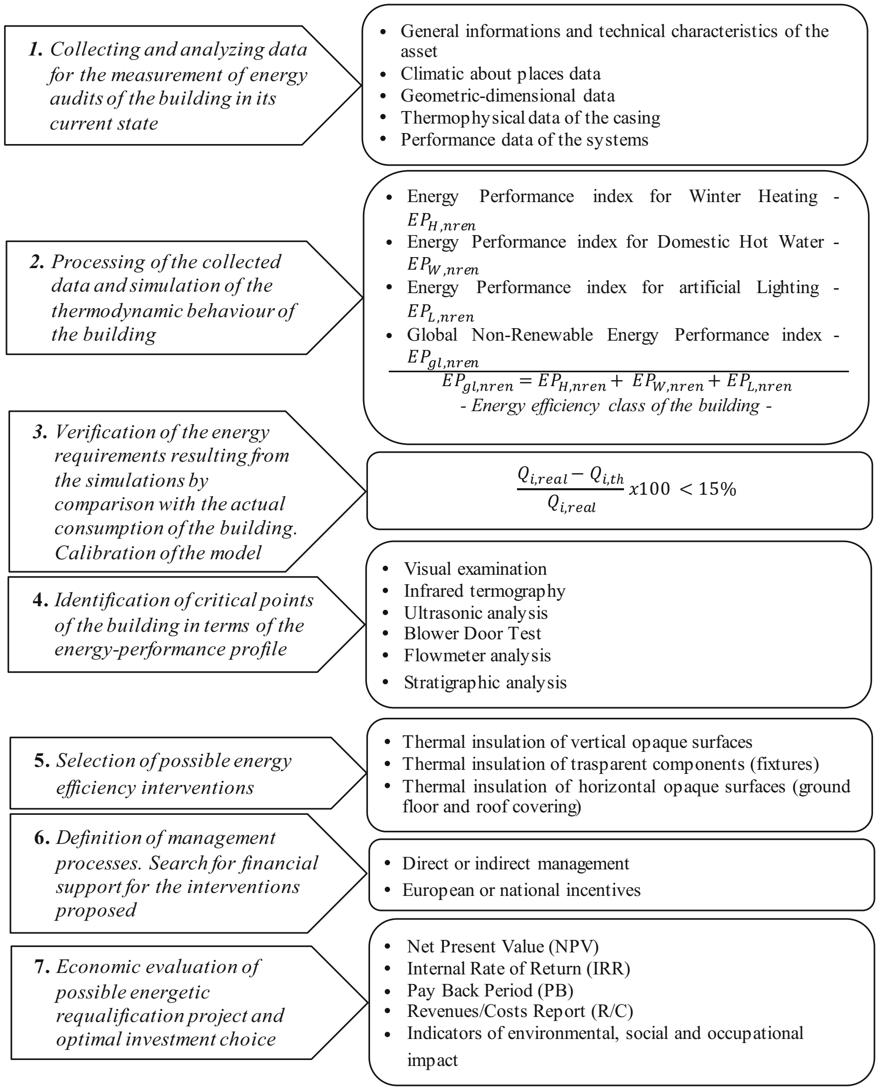

Fig. 1 Stages of the study protocol

and new cubes for the extension of the building. Such actions, able to guarantee an improvement of the functions and of the relationship of the built environment with its surroundings, are often associated with the subtraction of surfaces or volumes, in order to create new open or semi-open spaces useful for the passive air-conditioning of the building. Frequently used in design practice are also the thermal buffers. These are volumes added to the facade to form climatic greenhouses, ventilation and solar fireplaces, double-skin facades. These guarantee the bioclimatic adaptation of the building, because they are able to optimize the levels of comfort of the internal environments.

The integration activities of a deficient sub-system elements concern walls and horizons, for which it is essential to improve the thermal insulation capacity (Landolfo et al. 2012). The techniques for the thermal insulation of the perimeter walls are manifold. It can be operated:

- from the outside of the wall surface, using external "cladding systems", creating ventilated facades and thermal insulating plasters;
- from the inside, with the application of composite thermal insulation panels;
- in the cavity, using the technique of blowing insulating material, granular or liquid type, depending on the thickness of the interspace itself.

Retrofitting of roof structures is necessary to maintain thermo-hygrometric comfort conditions in both winter and summer. It is possible to intervene: on the extrados of the floor, with ventilated systems; on the intrados, with the integration of thermal insulation panels, using different techniques in according to the type of structure (flat or sloping roof, practicable or not practicable attic). Innovative systems are the Green Roofs and the Cool Roofs, the latter composed of materials with a high capacity to reflect incident solar irradiance. They are effective systems to cope with the summer overheating of buildings and large urban areas.

The replacement of components or parts of a manufactured product mainly concerns the transparent elements of the casing, i.e. the fixtures. The simplest and fastest interventions involve the replacement of only the glazed element, where the existing profiles have satisfactory thermal requirements. However, it is common to replace the entire window with different technologies and high-performance materials, such as profiles in thermal break aluminium, PVC or low-density wood.

In the majority of cases, the shell of the prefabricated building plays a predominant role in the energy performance of the entire system built, as it does not guarantee the minimum standards of thermal insulation and transmittance. In this way, insufficient conditions are created for the winter and summer comfort of the interior. These problems are mainly impute to a lack of or reduced insulation of the concrete wall panels, the presence of single and athermic glass and the absence of shielding devices (Rossetti 2013). Another frequent cause of energy loss is the shape of thermal bridges at the junctions between the structural elements.

The energy efficiency of the building envelope is an objective to be pursued with strategies that are always respectful of the context in which they operate. This means using specific construction techniques depending on the architectural, technological and thermophysical characteristics of the building and in relation to the state of degradation of the existing building.

With regard to prefabricated buildings, thermal performance and energy efficiency are mainly influenced by three factors:

- the way in which the building's constituent elements are constructed (partial or total hardening);
- the materials used (systems entirely made of concrete, integrated with insulating materials and cement);

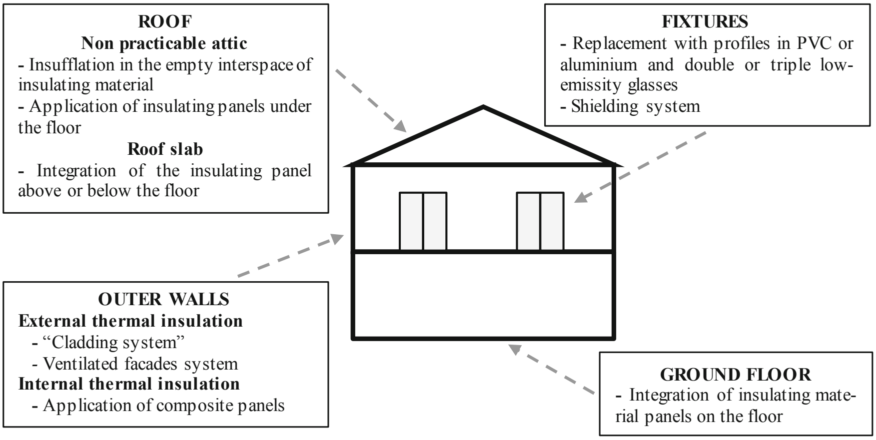

Fig. 2 Main energy retrofitting measures for the shell of prefabricated building's

– the geometry of the building components (one-dimensional, two-dimensional or three-dimensional systems).

The vertical opaque surfaces of prefabricated structures are more suitable for external integration of layers, most of which are dry-assembled. These are insulation systems with overcoat and ventilated facades. The thermal insulation materials to be applied must guarantee an increase in the thermal inertia of the stratification in order to achieve a better level of internal environmental comfort and control of thermal loads in the summer (Di Giuseppe et al. 2012; Di Perna et al. 2008).

For glass surfaces, the most technically effective intervention is the replacement of the entire in-frame with multi-chamber structures in PVC or aluminium with thermal break with double or triple low-emission glass. Usually it is necessary to significantly reduce solar radiation and increase the thermal resistance of windows and doors by means of horizontal (for facades facing south) or vertical (for surfaces facing east or west) shielding systems, applied outside the building.

Figure 2 shows the main energy retrofitting interventions for the shell of prefabricated buildings.

5 Case Study. Selection of Interventions for the Energy Efficiency of the Shell of a Prefabricated School Building

The study protocol described in Sect. 3 is now applied in order to establish the building interventions useful for the thermal insulation of the vertical opaque surfaces of a prefabricated school building. The aim is to achieve the optimum solution in terms of energy efficiency and economic convenience.

Step 1. *Collecting and analyzing data for the measurement of energy audits of the building in its current state*

The school building under study is located in Avellino (Italy) and is characterized by the heavy prefabrication construction system, widely used in Campania during the post-earthquake reconstruction programs of 1980. In particular, the building is realized through an open system in modular prefabrication, called Easy Building System (EBS). The plan area is 1,147 m^2, it is distributed on a single level and is of the court type. The six pedagogical units (classrooms), the atrium, the kitchen and the dining room are distributed around an inner central courtyard.

The load-bearing structure of the building consists of a network of beams and pillars in hot-rolled steel sections, while the outer walls are made by pre-formed panels in concrete with a continuous central insulating core in polystyrene. The transparent surfaces highlight two types of frame: profiles in cold anodized aluminium alloy and in thermal break aluminium. In both cases, the glass is athermic double glazing with an air-tight cavity. The attic floor is composed of a trapezoidal steel sheet with a layer of insulation in expanded polystyrene.

The heating system consists of a traditional natural gas boiler with a thermal output of 167.3 kW. The domestic hot water production system is an autonomous-mode system and consists of a wall mounted storage electric water heater, installed in each toilet, with a nominal power of 1.2 kW.

Step 2. *Processing of the collected data and simulation of the thermodynamic behaviour of the building*

The energy balance is obtained by implementing the architectural, technological, environmental, thermal and plant data with the software TerMus (Acca), in accordance with UNI TS 11300. The results place the building in class D and give a non-renewable energy performance index of 362.95 kWh/m^2 year. Table 1 shows the energy data of the building system.

Step 3. *Verification of the energy requirements resulting from the simulations by comparison with the actual consumption of the building. Calibration of the model parameters*

Table 1 Energy data of the building-plant system

Energy efficiency classification	D	
Global non-renewable energy performance index—$EP_{gl,nren}$	362.95	(kWh/m^2year)
Energy performance index for winter heating—$EP_{H,nren}$	184.31	(kWh/m^2year)
Energy performance index for domestic hot water—$EP_{W,nren}$	160.00	(kWh/m^2year)
Energy performance index for artificial lighting—$EP_{L,nren}$	18.64	(kWh/m^2year)
Primary energy requirement for Heating—QP_H	194,944	(kWh)
Primary energy requirement for domestic hot water—QP_W	209,905	(kWh)
Primary energy requirement for artificial lighting—QP_L	24,457	(kWh)

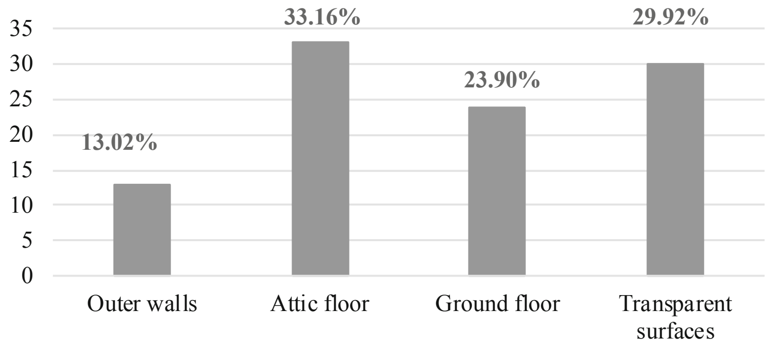

Fig. 3 Themal losses of the building envelope

The energy simulation model correctly reproduces the thermodynamic behaviour of the building, as the difference between the theoretical and actual energy requirements is less than 15%.

Step 4. *Identification of the critical points of the building in terms of the energy-performance profile*

Surveys of the building show the good state of conservation of the external walls. These are not affected by water infiltration and/or mold formation. Measurements with infrared camera detect the presence of shaped thermal bridges at the connection between the closing elements. This causes a change in the heat flow. In particular, the greatest heat losses are recorded near the attic floor (33.61%) and the transparent closures (29.31%), as shown in Fig. 3.

Step 5. *Selection of possible energy efficiency interventions*

The proposed retrofit measures aim to improve the thermal performance of the building envelope. Through a passive approach, we work on the vertical opaque surfaces, on the windows, on the attic and ground floor. For vertical opaque surfaces, two design alternatives are compared, which envisage different construction techniques and thermal insulation materials:

- I.M.1_EPS. *"Cladding" system*, with insulating material in sintered expanded polystyrene (thickness 100 mm);
- I.M.1_RW. *Ventilated facade*, composed of sandwich panels in a high-density rock wool, with metal support in pre-painted galvanized steel and finished on the outer surface with a porcelain stoneware slab (total thickness 83 mm).

For each possible solution, dynamic thermal parameters are calculated, verifying that the thermal transmittance (U), periodic thermal transmittance (Y_{IE}) and surface mass (M_S) values in Table 2 comply with the minimum requirements imposed by the Ministerial Decree of 06/26/2015. Both alternatives guarantee excellent insulation of the perimeter panels. The analysis of the thermophysical characteristics also shows

Table 2 Improvements to vertical opaque surfaces. Thermophysical characteristics

Design solutions	U (W/m^2K)	Y_{IE} (W/m^2K)	Phase displacement (h)	M_s (kg/m^2)
Current conditions	0.65	0.34	6.81	184
I.M.1_EPS	0.22	0.02	10.57	186
I.M.1_RW	0.27	0.02	11.18	219

that the two solutions are absolutely equivalent, resulting a mean reduction of the thermal transmittance value of about 62%.

For fixtures and for opaque horizontal surfaces, a single hypothesis of intervention is selected. In fact, preliminary evaluations of various retrofit actions that involve the use of different thermal insulating materials, give the same results in terms of thermo-physiological characteristics of building components. Therefore, solutions are chosen:

- I.M.2. Replacement of the windows with multi-chamber profiles in thermal break aluminium alloy and low emission double glazing, with chamber containing 90% argon gas;
- I.M.3. Insulation of the first floor slab by means of thermal insulating panels in expanded polystyrene with graphite additive and subsequent laying of lightweight concrete screed. Thermal insulation of the attic floor by blowing in a layer of expanded clay in granules.

Compared to existing windows, the thermal transmittance value of the entire glass-frame component is significantly reduced by about 68%, reaching a value of 1.27 W/m^2K. For both horizontal components of the envelope, is estimated an medium reduction of thermal transmittance of about 60%.

The achievement of appreciable results in terms of reduction of energy requirements and monetary savings on primary energy consumption, can be guaranteed by considering together the solutions prepared for each architectural component. Two design combinations are then economically evaluated, in which only the possible insulation of vertical opaque surfaces (I.M.1_EPS and I.M.1_RW) varies, while the pre-measurement for the floors (I.M.3) and for the transparent closures (I.M.2) is pre-established:

- **C.I.M.1** = I.M.1_EPS + I.M.2 + I.M.3 ("cladding" system);
- **C.I.M.2** = I.M.1_RW + I.M.2 + I.M.3 (ventilated façade).

The results of the thermodynamic simulations show that the two design proposals produce the same effects in terms of reduction of heat loss and energy saving, equal to about 37–38% (Table 3). With the retrofit strategies identified, the building is in energy class B.

Step 6. *Definition of management processes. Search for financial support for the interventions proposed*

Table 3 Energy characteristics of project proposals

	Current condition	C.I.M.1	C.I.M.2
Energy efficiency classification	D	B	B
$EP_{gl,nren}$ (kWh/m^{2}year)	362.95	257.24	258.20
Electricity consumption (kWh/year)	97,064	96,971	96,972
Methane consumption (kWh/year)	185,153	78,898	79,860
Total energy requirement (kWh/year)	282,217	175,869	176,832
Total energy saving (kWh/year)		106,348	105,385
Total energy saving (%)		38%	37%

Table 4 Investment cost for the project proposal C.I.M.1

C.I.M.1	Intervention	Cost (€)
I.M.1_EPS	"Cladding" system with insulating material in sintered expanded polystyrene	38,782
I.M.2	Fixtures in thermal break aluminium alloy + low emission double glazing	50,774
I.M.3	First floor slab insulation with thermal insulating panels in EPS with graphite additive + thermal insulation of the attic floor with a layer of expanded clay in granules	105,883
	Total investment	195,438

The financial evaluation is developed with reference to two hypotheses:

1. investment costs incurred 100% by the Public Administration;
2. 60% of the investment cost is covered by resources deriving from the Regional Operational Programme (European Regional Development Fund) 2014–2020.

Step 7. *Economic evaluation of possible energetic requalification project and optimal investment choice*

The Cost-Benefit Analysis (CBA) is developed, which requires the estimation of costs, both investment and management, and the estimation of revenues, the latter consisting of savings for lower energy consumption and reduced maintenance costs. The analysis period is assumed to be 25 years and consists of the construction phase, equal to 1 year during which the works are carried out, and the operating phase, in which the project generates positive cash flows.

From the bill of quantities, the investment costs for the two retrofit hypotheses, the external cladding system with EPS panels (C.I.M.1) and the ventilated façade with stone wool sandwich panels (C.I.M.2), are respectively equal to 195,438 € and 199,440 € (Tables 4 and 5). These costs are net of Value Added Tax (VAT) and concern materials, transport to the worksite and labour.

Operating costs are estimated on the basis of ordinary and extra-ordinary maintenance costs, which include inspection, cleaning, adjustment, repair and consumables

Table 5 Investment cost for the project proposal C.I.M.2

C.I.M.2	Intervention	Cost (€)
I.M.1_RW	Ventilated facade with sandwich panels in a high-density rock wool	42,784
I.M.2	Fixtures in thermal break aluminium alloy + low emission double glazing	50,774
I.M.3	First floor slab insulation with thermal insulating panels in EPS with graphite additive + thermal insulation of the attic floor with a layer of expanded clay in granules	105,883
	Total investment	199,440

Table 6 Energy savings

	Current condition	C.I.M.1	C.I.M.2
Electricity consumption (kWh/year)	97,064	96,971	96,972
Cost of electricity (€/year)	27,178	27,152	27,152
Methane consumption (kWh/year)	185,153	78,898	79,860
Methane cost (€/year)	16,664	7,100	7,187
Total energy requirement (kWh/year)	282,217	175,869	176,832
Total energy cost (€/year)	43,842	34,253	34,340
Total energy saving (kWh/year)		106,348	105,385
Total energy saving (€/year)		9,589	9,502

costs. In the case of the C.I.M.1 combination, the operating costs, difference between the costs of *post*-operative and *ante*-operative maintenance, are due to the extra cost (3,378 €) for the remake of the siloxane finish layer of the thermal insulation.

In terms of revenues, the retrofit actions lead to a reduction in energy consumption, which falls from 282,217 to 175,869 kWh/year for the C.I.M.1 solution and to 176,832 kWh/year for the C.I.M.2 solution, with annual monetary savings amounting to 9,589 € and 9,502 € respectively (Table 6). For the C.I.M.1 solution, further savings derive from the lack of ordinary maintenance costs for the surface layer of the walls (25,033 €).

Since the periodic maintenance of the components of the energy-efficient building envelope is charged, another revenue item is the residual value of the investment at the 25th year of the analysis period. This residual value amounts to 109,554 € for the C.I.M.1 solution and 77,358 € for the C.I.M.2 solution.

The data collected allow the construction of the financial plans, for each project solution and for both financing hypotheses. By way of example, Table 7 shows the financial plan for the C.I.M.2 project solution in the event that the POR-ERDF 2014–2020 funds can be used.

The results of the Cost-Benefit Analysis are expressed using the summary indicators: Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Back Period (PB) (De Mare et al. 2012). In the absence of financial contributions from outside,

Table 7 C.I.M.1 solution in case of use POR-ERDF funds 2014–2020. Financial plan

Year	1	2	3	4	5	6	7
Investment cost (€)	−79,776	0	0	0	0	0	0
Energy requirement (€)	0	9,502	9,502	9,502	9,502	9,502	9,502
Cost of *ante*-operative maint. (€)	0	−2,629	−2,629	−2,629	−2,629	−2,629	−2,629
Cost of *post*-operative maint. (€)	0	−2,200	−2,200	−2,200	−2,200	−2,200	−2,200
Difference in maint. costs (€)	0	429	429	429	429	429	429
Benefits (€)	0	9,931	9,931	9,931	9,931	9,931	9,931
Costs (€)	−79,776	0	0	0	0	0	0
Cash flows (€)	−79,776	9,931	9,931	9,931	9,931	9,931	9,931
Discounted cash flows (€)	−76,708	9,181	8,828	8,489	8,162	7,848	7,546
Cumulated cash flows (€)	−76,708	−67,526	−58,698	−50,209	−42,047	−34,199	−26,652
Year	8	9	10	11	…	24	25
Investment cost (€)	0	0	0	0	…	0	0
Energy requirement (€)	9,502	9,502	9,502	9,502	…	9,502	9,502
Cost of *ante*-operative maint. (€)	−2,629	−2,629	−2,629	−2,629	…	−2,629	−2,629
Cost of *post*-operative maint. (€)	−2,200	−2,200	−2,200	−2,200	…	−2,200	−2,200
Difference in maint. costs (€)	429	429	429	429	…	429	429
Benefits (€)	9,931	9,931	9,931	9,931	…	9,931	87,289
Costs (€)	0	0	0	0	…	0	0
Cash flows (€)	9,931	9,931	9,931	9,931	…	9,931	87,289
Discounted cash flows (€)	7,256	6,977	6,709	6,451	…	3,874	32,743
Cumulated cash flows (€)	−19,396	−12,419	−5,710	741	…	78,521	111,265

Table 8 Financial convenience indicators

Indicators	C.I.M.1		C.I.M.2	
	P.A. capital	POR-ERDF 2014–2020	P.A. capital	POR-ERDF 2014–2020
NPV	−1,766 €	110,987 €	−3,797 €	111,265 €
IRR	–	13.01%	–	13.11%
PB	–	10.54 years	–	10.88 years

the Net Present Values are slightly negative, amounting to –1,766 € for the C.I.M.1 solution and –3,797 € for the C.I.M.2 intervention. This explains the long period of time, just over 25 years, needed to return on the investment if they do not help with external fees. This is obviously without considering environmental, social and comfort effects, not counted in the study but which would certainly have a favorable impact on the results of the evaluations (Table 8).

In reverse, the interventions generate largely positive financial results if the investment cost is covered at 60% by POR-ERDF 2014–2020 funds. In this case, the IRR is around 13%. It emerges that the two design solutions, C.I.M.1 and C.I.M.2, are substantially equivalent, since the similar technical performances translate into financial effects very close to each other. In fact, the NPVs are 110,987 € and 111,265 € respectively, as shown in Table 8.

6 Conclusions

Nowadays, architecture is increasingly interested in the industrialization of buildings, driven by objectives to raise profitability levels but also by the need for decarbonization and environmental sustainability. In this perspective, off-site construction offers undoubted advantages, because it allows: to employ skilled labour, working in a closed and controlled environment that is not affected by the climate; to design precisely, reducing errors and the production of waste materials; to speed up the construction process and to optimize profit margins (Bernstein 2011; De Mare et al. 2013; Nesticò and Moffa 2018).

But requirements also arise with respect to existing prefabricated buildings, which generally do not meet current energy performance requirements. This makes it necessary to intervene with rehabilitation works. To this end, the present work aims first of all to detect the determining wheel that often assumes the building envelope. The study then proposes to outline a protocol of investigation based on the principles of the Cost-Benefits Analysis (CBA) and aimed at selecting the design option that, among those considered technically useful for energy efficiency, is the most convenient from the economic point of view.

It has been demonstrated that among the many possible technical solutions for increasing the thermal well-being of the building, the implementation of the ACR can solve critical issues in the decisional process where it is necessary to choose the optimal intervention of energy retrofit of the building envelope.

The application of the model to a case-study, that of a school building with heavy prefabricated structures, shows that the retrofitting actions on the building envelope can include the insulation system with expanded polystyrene and the insulated façade with sandwich panels in rock wool. The results open up interesting perspectives of research if one considers the possibility of taking into account in the analysis the positive externalities of an environmental and social nature, to be evaluated by implementing multi-criteria techniques (Bottero et al. 2014; Nesticò and Pipolo 2015; Napoli et al. 2017; Del Giudice et al. 2018; Della Spina et al. 2018; Nesticò et al. 2019).

References

Barbosa F, Woetzel J, Mischke J, Ribeirinho MJ, Sridhar M, Parsons M, Bertram N, Brown S (2017) Reinventing construction: a route to higher productivity. McKinsey Global Institute, New York

Bernstein HM (2011) Prefabrication and modularization: increasing productivity in the construction industry. McGraw-Hill Construction

Bottero M, Ferretti V, Mondini G (2014) Constructing multi-attribute value functions for sustainability assessment of urban projects. In: Lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics), 8581 LNCS, pp 51–64. https://doi.org/10.1007/978-3-319-09150-1_5. Springer-Verlag, Berlin Heidelberg (D)

De Mare G, Nesticò A, Caprino RM (2012) (a cura di) La valutazione finanziaria di progetti per il rilancio del territorio. Applicazioni a casi reali, ISBN: 978-88-204-0446-8. FrancoAngeli, Milano

De Mare G, Manganelli B, Nesticò A (2013) Dynamic analysis of the property market in the city of Avellino (Italy). The Wheaton-Di Pasquale model applied to the residential segment. In Murgante B, Misra S, Carlini M, Torre C, Nguyen HQ, Taniar D, Apduhan BO, Gervasi O (eds) ICCSA 2013, LNCS, Part III, vol 7973, pp 509–523. https://doi.org/10.10007/978-3-642-39646-5_37. Springer-Verlag, Berlin Heidelberg (D)

Del Giudice V, De Paola P, Forte F (2018) Valuation of historical, cultural and environmental resources, between traditional approaches and future perspectives. In: Green energy and technology, pp. 177–186. https://doi.org/10.1007/978-3-319-78271-3_14. Springer, Cham

Della Spina L, Calabro' F (2018) Decision support model for conservation, reuse and valorization of the historic cultural heritage. In: Gervasi O et al (eds) Computational science and its applications—ICCSA 2018. Lecture Notes in Computer Science, vol 10962, pp. 3–17. https://doi.org/10.1007/978-3-319-95168-3_1. Springer-Verlag, Berlin Heidelberg (D)

Di Giuseppe E, Fantini L, D'Orazio M, Di Perna C (2012) Un indice di comfort abitativo nel certificato energetico. Costruire in Laterizio 147:56–60

Di Perna C, Stazi F, Ursini Casalena A, Stazi A (2008) Massa e comfort: necessità di una adeguata capacità termica areica interna periodica. L'industria dei laterizi 110:88–101

Fiore P, Nesticò A, Macchiaroli M (2016) The energy improvement of monumental buildings. An investigation protocol and case studies [La riqualificazione energetica degli edifici monumentali. Un protocollo di intervento e caso studio]. Valori e Valutazioni, 16:45–55, ISSN: 2036-2404. DEI Tipografia del Genio Civile, Roma

Landolfo R, Losasso M, Pinto MR (2012) (a cura di) Innovazione e sostenibilità negli interventi di riqualificazione edilizia. Alinea editrice, Firenze

Miorin T (2017) Rebuild 2017. Edilizia off-site, Outlook ReLab, Trento

Miorin T (2018) Ricostruire un'Italia a prova di futuro. In: Rebuild 2018. Decarbonizzare l'edilizia. Outlook ReLab, 03, Trento

Napoli G, Gabrielli L, Barbaro S (2017) The efficiency of the incentives for the public buildings energy retrofit. The case of the Italian regions of the "objective convergence". Valori e Valutazioni, vol. 18, pp. 25–39, ISSN: 2036-2404. DEI Tipografia del Genio Civile, Roma

Nesticò A, Moffa R (2018) Economic analysis and operational research tools for estimating productivity levels in off-site construction [Analisi economiche e strumenti di Ricerca Operativa per la stima dei livelli di produttività nell'edilizia off-site]. Valori e Valutazioni 20:107–126. ISSN: 2036-2404. DEI Tipografia del Genio Civile, Roma

Nesticò A, Pipolo O (2015) A protocol for sustainable building interventions: financial analysis and environmental effects. Int J Bus Intell Data Min 10(3):199–212. https://doi.org/10.1504/IJBIDM.2015.071325 (InderscienceEnterprisesLtd., Genève, Switzerland)

Nesticò A, Macchiaroli M, Pipolo O (2015) Costs and benefits in the recovery of historic buildings: The application of an economic model. Sustainability 7(11):14661–14676. https://doi.org/10.3390/su71114661.MDPIAG,Basel,Switzerland

Nesticò A, Morano P, Sica F (2018) A model to support the public administration decisions for the investments selection on historic buildings. J Cult Herit 33:201–207. https://doi.org/10.1016/j.culher.2018.03.008 (Elsevier)

Nesticò A, Guarini MR, Morano P, Sica F (2019) An economic analysis algorithm for urban forestry projects. Sustainability 11(2):314. https://doi.org/10.3390/su11020314 (MDPI AG, Basel, Switzerland)

Poretti S (2013) Un'industrializzazione sfasata. L'industrializzazione nei quartieri di ediliza residenziale pubblica. Aracne editrice, Roma, pp 11–13

Rossetti M (2013) Proposta per una riqualificazione dell'edilizia sociale realizzata con tecniche di prefabbricazione pesante e industrializzazione dei getti. In: Città e Paesaggio. Paesaggi periferici. Strategie di rigenerazione Urbana, pp. 270–277

Smith RE (2014a) Off-Site construction implementation resource: off-site and modular construction explained. In: Off-Site Construction Council, National Institute of Building Sciences

Smith RE (2014b) Report of the results of the 2014 off-site construction industry survey. In: Off-Site Construction Council, National Institute of Building Sciences

Southern J (2016) Smart construction. How offsite manufacturing can transform our industry. In: KPMG

Multi-criteria Decision Analysis of a Building Element Integrating Energy Use, Environmental, Economic and Aesthetic Parameters in Its Life Cycle

Giulia Sonetti and Patrizia Lombardi

Abstract With the increasing concern of the building environmental impacts, governmental regulation and people own consciousness have shown rising interest in buildings protocols and methods for sustainability certification. Life cycle assessment (LCA) represents a useful tool for designers, companies and building owners in every phase of the construction process, but its daily use encounters several applicability problems. It is indeed hard to take into account crucial parameters regarding the economic, aesthetic and energetic performances of each alternative in a whole sight. The aim of this paper is to exploit LCA techniques to evaluate the environmental impacts of three different types of roof analysed within the building component scale. A green, reverse, and simply waterproofed roofs have been drawn and split into each component's environmental impacts, whereas a multi-criteria decision analysis (MCDA) tool integrating economic, social and aesthetic parameters. LCA results showed that the reversed roof solution gives out the minimum environmental damage ($-69, 46\%$ compared to the common waterproofed roof). The results from this LCA analysis are included in a more holist MCDA approach which is able to consider different objectives (thermal performance, construction cost, aesthetic performance, social utility, environmental impact). This integrated evaluation is conducted according to different scenarios and points of view (eco-social and business-as-usual) and gave scenarios with a synoptic assessment of each maximized performance. Conclusive remarks show that an MCDA qualitative analysis coupled with the quantitative result from LCA appeared to be very helpful in comparing options in the design phase of a building, and a useful communication tool among all the stakeholder of the construction process. This new approach based on the LCA-AHP analysis can help decision makers to find sustainable alternatives among available options and promises a more sustainable product or process.

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Keywords Environmental performance · Building assessment · LCA · MCDA · Decision making

1 Introduction

With the increasing concern of the building environmental impacts amongst public and private companies, governmental regulation and people own consciousness have shown rising aspiration towards sustainable urban development. The building sector is one of the most contributors to global energy consumption and environmental impacts—it is often called "the 40% sector" (CAN Europe 2005; Cabeza et al. 2014; Nejat et al. 2015) because it is responsible for up to 40% of total energy use worldwide (UNEP 2007; WBCSD 2007; De T'Serclaes 2007). What is currently hard to achieve, is not the evaluation of a specific characteristic of a single material, or of the overall building performance, but rather the synoptic assessment of an assembly of elements among the same construction process. The lack of such vision discourages architects and designers to innovate or propose a new agreed solution. Life cycle assessment (LCA) provides a holistic approach to define materials and products environmental impacts along with their use-phase and disposal scenario (Alshamrani et al. 2014; De Felice et al. 2013; Vilches et al. 2017). Several single building materials and products have already been assessed with LCA (De Felice et al. 2013; Guardigli et al. 2011; Jeswani et al. 2010): wood, concrete (Björklund and Tillman 1997), roofs (Berto et al. 2018), insulating stone wool (Schmidt et al. 2004), hard floor coverings (Günther and Langowski 1997), and so on. However, there is still a little number of analyses on medium scale elements (Chau et al. 2015; Vilches et al. 2017).

As highlighted in many different reviews on LCA in the built environment (Anand and Amor 2017; Buyle et al. 2013; Jeswani et al. 2010), there are no solid guidelines on which stream of methods should be applied under specific circumstances. Although they can be applied for comparing different building designs with respect to their environmental impacts, there are still some drawbacks in boundary scoping, methodology framework, data inventory and practices, which impairs their usefulness as a decision making support tool. Conceivably, the usefulness of LCA can be further enhanced in building construction by standardizing the requirements for individual studies on the boundary scoping, methodology choices and data inventories so as to establish benchmarks for different types of buildings. Also, it is important to extend the current scope of LCA to include effects of indoor environmental qualities, building location as well as social considerations. The fundamental LCA concept is useful to formulate the building environmental assessment schemes embracing all these aspects. Of equal importance, is to search for effective policy governance measures to encourage building designers and developers to apply life cycle study in early design stage even though it may slightly prolong the tight building design schedule. The aim of this paper is to exploit LCA methodologies (Sect. 2.1) to evaluate the environmental impacts of three different types of roof analysed within the building component scale (explained in Sect. 2.2). A green, reverse, and simply waterproofed roofs have been drawn and split into each component's environmental impacts, whereas a multi-criteria decision analysis (MCDA) tool integrating economic, social and aesthetic parameters (Sect. 2.3). The results (Sect. 3) from this LCA analysis are included in a more holist MCDA approach which is able to consider different objectives (thermal performance, construction cost, aesthetic performance, social utility, environmental impact). This integrated evaluation is conducted according to different scenarios and points of view (eco-social and business-as-usual) and gave scenarios with a synoptic assessment of each maximized performance.

Conclusive remarks in Sect. 4 show that an MCDA qualitative analysis coupled with the quantitative result from LCA appeared to be very helpful in comparing options in the design phase of a building, and a useful communication tool among all the stakeholder of the construction process.

2 Methods

2.1 LCA Scoping

The aim of the first part of this study is the comparison between the environmental impacts of three different types of roof, in order to identify the solution with the minimum amount of damage points. The functional unit is constituted by one square meter of roof. The system boundaries go from the raw material extraction to the disposal scenario, considering the machines and the energy needed in the production phases, for the transportation from the firm to the site and for the end-life treatment of those materials. Unlike the single material analysis, here the energy consumptions for summer/winter cooling/heating is included.

The method follows the SimaPro function scheme, where data collection for the product and its components are collected, the single framed are for contents of each database and the double framed for the calculation and the evaluation phases. The assumption at the base of the evaluation is the one embedded in the Eco-indicator 99 method, modified with the updated database dedicated to the Italian products and processes presented by Neri (2007). Eco-indicator 99 takes into account three damage categories (Human Health, Ecosystem Quality, Resources) and the following impact categories: Human Health Carcinogenic, Respiratory organics, Respiratory inorganics, Climate change, Radiation and Ozone layer measured in DALY (Disability Adjusted Life Years); Ecosystem Quality Ecotoxicity, Acidification, Eutrophication, and Landuse measured in PDF * m^2y (Potentially Disappeared Fraction of Plants species), Resources, Minerals and Fossil fuels measured in MJ surplus. All the transportations input was considered from the nearest production plant to the building site that has been set in Salerno, Italy. The geographical setting is also crucial for the climatic boundary condition when calculating the thermal load within 1 ms of the practical unit. The amount of Thermal Power (Pti) needed to maintain an internal room temperature of 20 °C in wintertime is given by the (1):

$$Pti= (l/s) * S * DT Þ Pti= ki * Si * Dti \quad (1)$$

where:

l is the thermal conductivity (W/mK), s is the thickness (m), S is the surface area (m^2) (supposed to be orthogonal to the thermal incoming flux. i.e. that the roof is horizontal and *D*T is maximum), and *D*T is the difference between external and internal temperature, and $k = 1/(1/a_i + 1/a_e + \Sigma s_i/l_i)$. The Primary Energy Q_{ti} is obtained by multiplying P_{ti} to hours/day, to days/months, to the months/year and to the supposed life years of the building, only for the supposed operational time frame of heat plant. In order to take into account also another important parameter like diffusivity, increased during summer, for the calculation of the cooling thermal power some adjustment factors by means of experimental data and diurnal variation of temperature and the thermal lag. Obviously, it is assumed that each proposed roof package must respect every law prerequisite in terms of security, safe, maximum U value, sound reduction and humidity control (dlg n° 192, following the 2002/91/CE).

2.2 LCI—Life Cycle Inventory

The roof assembly tagged R1 is a waterproofed concrete roof. It is made up as illustrated in Fig. 1 to calculate its thermal performances. The results (U value = 1.772 W/m^2K, total thickness = 0.32 m, superficial mass = 370 kg/m^2) were input in Simapro for the energy consumption during winter and summer. The process flow was compiled as in Table 1.

With the same structure as the R1, R2 is a typical reversed roof. It has the R1's layers plus an insulation layer of polystyrene (7 cm), a waterproof layer and a gravel bed on the top (8 cm) are illustrated in Fig. 2.

The R3 roof is a typical green roof composed as the R1 plus an insulation layer of expanded polystyrene (8 cm), an air gap between the structure that collect the ground and the above understructure (2 cm), waterproof layer and a ground bed on the top (10 cm) with a certain percentage of humidity to let the plants grow on it. The thermal properties are calculated with the Termus software.

2.3 Multi-criteria Decision Analysis

Multi-criteria decision analysis (MCDA) provides a systematic process for trading off effects of various alternatives, taking into account all the aspects and values involved in the decision and synthesized individual contributions. Originally developed in the field of Operative Research, discrete MCDA is able to determine lists of priorities from a finite series of choice options (alternatives) which are assessed and compared in relation to identified characteristics of the problem (criteria) when it is appropriately broken down into its fundamental elements. In particular, MCDA

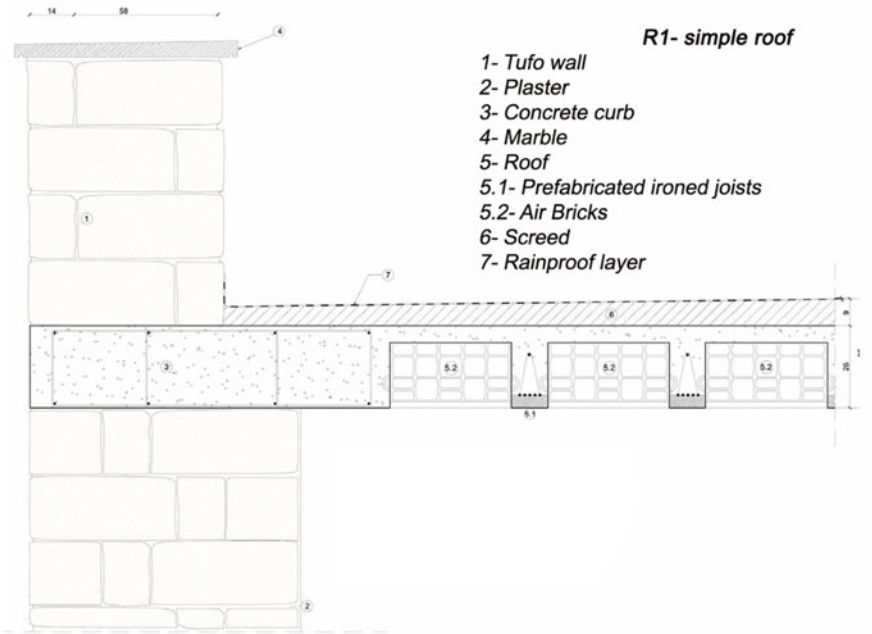

Fig. 1 The roof assembly tagged R1 (waterproofed concrete roof)

provides the following benefits: a clear definition of the criteria used in the selection of an option between alternative solutions; a weighting of the criteria to be used in the evaluation, in accordance with different point of views; a combination of multiple aspects which have a different nature; a comparison between objectives, strategies of the various subjects involved, and available resources; a transparent and explicit evaluation approach.

Literature presents a wide range of MCDA methods which can be grouped in families, as quantitative, qualitative and mixed (Figueira et al. 2005). These differ from each other in the nature of the information they are able to manage, i.e. cardinal (hard), ordinal (soft) or mixed data.

There are two major schools of thought in MCDA that govern the methods proposed in this field: the French school, represented by the ELimination and (Et) Choice Translating REality (ELECTRE) family of outranking methods; and the American school represented by the Analytical Hierarchy Process (AHP), proposed by Saaty in the 80's (Saaty 1990, 1996b). These schools regard both the evaluation of a finite set of alternatives, based on a finite set of conflicting criteria, by a decision making body. However, the French school channels subjective human judgments through partial systems of binary outranking relations between the alternatives and via a total system of outranking relations, while the American school allows to design partial value functions on the set of alternatives (being able to assess a global value function, too). That is why, for the scope of this work, that is encompassing many

Table 1 Example of process flow in the Simapro Software (R1—simple roof)

1 mq rainproof layer in PVC (SARNAFIL G 476-20) (sp = 0.002), 1p; weight = 2.8 kg	Transport, lorry 28t/CH S, 2214.8 kg km From Sarnafil firm plant in Milano to the building site in Salerno = 791 km * 2.8 = 2214.8 kg km
1 mq lightened concrete (10 cm = 0.1 m) 1p; weight: 45 kg	Transport, lorry 28t/CH S, 2240 kg km slab from the firm to the site, supposing a cave near Salerno which can provide all the components: 112 kg * 20 km = 2240 kg km
1 mq airbrick floor with ironed joints (0.22 m) 1p; weight: 117.744 + 114.92 + 88 = 321 kg	ExtTemp, max = 31.2 °C, intT = 26 °C. DifExtTmax-intT = 5.2. DTeqmax = (15.2 − 8.5)/200) * (700370) + 10.5 = 21.555 (h23) Adjusting factor: −0.3/DTeq = 21.255 Pte = 1.772 * 1 * (21.255) = 38 W
1 mq plaster (0.01 m) 0.75 p/0.02 * 0.015 = 0.75p; 28 * 0.75 = 21 kg	Eti = 37.664 W * 4 h/d * 2 * 26d/y * 100y = 783408.288 W = 783.408 kWh (heat)
Heat, natural gas, at boiler condensing modulating <100 kW/RER S 3648.902	Transport, lorry 28t/CH S, 5448.8 kg km air bricks: 272.44 kg * 20 km = 5448.8 kg km
kWh energy consumption during winter: P_{ti} = 1.772 * 1 * (20 − 2) = 31.896 W Eti = 31.896 W * 8 h/g * 26 g/m * 5.5 m/a * 100a = 3648902.4 W = 3648.902 kWh	Transport, lorry 28t/CH S 280 kg km plaster: 14 kg * 20 km = 280 kg km
kWh Heat: energy consumption during summer: superficial mass: 370 kg/m^2	RP_Recycle PVC from the site (with coproduct) Sarnafil membrane: 2.8 kg
ExtTemp, max = 31.2 °C, intT = 26 °C. DifExtTmax-intT = 5.2. DTeqmax = (15.2 − 8.5)/200) * (700370) + 10.5 = 21.555 (h23) Adjusting factor: −0.3/DTeq = 21.255 Pte = 1.772 * 1 * (21.255) = 37.664 W	RP_Recycle concrete screed no steeled (with coproduct): 45 kg
Eti = 37.664 W * 4 h/d * 2 * 26d/y * 100y = 783408.288 W = 783.408 kWh (heat)	RP_Recycle concrete floor (with coproduct): 272.44 kg − 2.112 (steel) * 2 − 1.12 = 267 kg
RP_Recycle steel (with coproduct): kg 2.112 * 2 + 1.12 = 5.3 kg	RP_Recycle plaster (with coproduct): 14 kg

alternatives at the time (making useless the comparison couples to couples of different options), we chose to adopt the Analytic Hierarchy Process (AHP), developed by Saaty (1980, 1992, 1993, 1994, 1995, 1996a) which translates expert judgments in a 9 points-scale, providing cardinal indices for operationalizing. The mathematician Thomas L. Saaty developed the AHP as an aid to managers in making decisions. Subjective assessments and objective facts are incorporated into a logical hierarchical AHP framework to provide decision-makers with an intuitive and common sense approach in quantifying the importance of each decision element through a comparison process. This process enables decision-makers to reduce a complex problem to a hierarchical form with several levels (Saaty and Forman 1993).

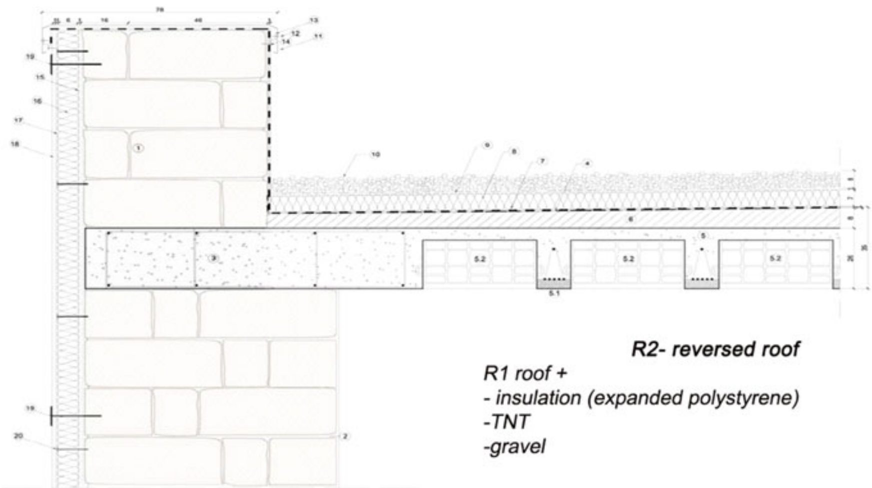

Fig. 2 The roof assembly tagged R2 (reversed roof)

In setting up the decision hierarchy, the number of levels depends on the complexity of the problem and on the degree of detail the analyst requires to solve the problem. Generally, the hierarchy has at least three levels: goal, criteria and alternatives (Saaty 1995). Since each level entails pairwise comparison of its elements, Saaty suggests the number of elements at each level is limited at a maximum of nine (Saaty and Vargas 1991).

The process starts by determining the relative importance of particular alternatives with respect to the criteria and the sub-criteria (Saaty and Kearns 1991). Then the criteria are compared with respect to the goal. Finally, the results of these two analyses are synthesised by calculating the relative importance of the alternatives with respect to achieving the goal.

The process of comparison is represented by forming a comparative matrix. If the analyst has at his disposal n alternatives, or criteria that form the comparative matrix, then he must make $n(n - 1)/2$ evaluations. Pairwise comparison data are collected for only half of the matrix elements: diagonal elements always equal one and the lower triangle elements of the matrix are the reciprocal of the upper ones.

Pairwise comparisons give to the user a basis to reveal his/her preference by comparing two elements. Furthermore, the user has the option of expressing preferences between the two as equally preferred, weakly preferred, strongly preferred, or absolutely preferred, which would be translated into pairwise weights of 1, 3, 5, 7 and 9, respectively. The numbers 2, 4, 6 and 8 are used as intermediate values when there is not an agreement between preferences. The reciprocal numbers 1/2, 1/3, …, 1/8, 1/9 complete the matrices. The technique of the AHP takes as input the above comparisons and produces the relative weights of elements at each level as output using the "eigenvalue" method. The eigenvector of each comparative matrix is the priority list, while the eigenvalue gives the measure of consistency in making the assessment or comparison. The synthesised eigenvector is the global sequence of the alternatives with respect to achieving the goal.

The last step of the procedure aggregates relative weights of various levels obtained from the previous step in order to produce a vector of composite weights which serves as ratings of decision alternatives in achieving the most general objective of the problem. The use of AHP is facilitated by the availability of a user-friendly supporting software Expert Choice that we used for the calculation.

3 Results

3.1 Results from LCA

From the analysis of the result of the LCA applied to the three types of roofs (Table 2), it can be inferred that the R2 solution, i.e. the reversed roof, provides the minimum damage (32.621 Pt), with a reduction in comparison to the simple roof (R1) by 69.46% (see Fig. 3). The green roof (R3) produces 33.146 damages points. In *Human Health* the reversed roof produces the minimum damage (9.2596 Pt) with a reduction in comparison to the simple roof by 37.99%, above all for the *Carbon Dioxide, Fossil* contained in the fossil fuels category and most founded in the process for the cooling and heating loads. In *Ecosystem Quality* the green roof produces the minimum damage (0.62078 Pt) with a reduction in comparison to the simple roof by the 47.36% above all due to two components, 1095.5 kg of *Nitrogen oxides* and *Transformation to dump site, benthos*, funded in the process for cooling and heating. The reversed roof damage is 0.67491 Pt. In Resources the reversed roof produces the minimum damage with 22.686 Pt, decreasing the impacts by the 74.96% above all thanks to the minor consumption of *Gas, Natural, in Ground* used for the cooling and heating of the building. The other most affected damage categories are the "respiratory inorganic", due to the particulate matter emission in transportation and excavation of the material from the cave. The one that is strongly reduced is the "Climate Change" category, thanks to the dramatically reduced energy consumption during the using phase when the roof is in a way or in another well insulated. The disposal scenario of a particular plastic layer in the reversed roof makes the percentage of carcinogens increase in the histogram bars, so a polyolefin or special paper substitute can be suggested in order to avoid that negative impact.

3.2 Results from AHP

The first step in applying the AHP model is dividing the problem into one or more criteria which will be used to weight the alternatives options (Fig. 4). This means

Table 2 Comparison between the three roof total damage points according to eco-indicator 99 assessment method

Comparing 1 p 'green roof' (R3), 1 p 'reversed roof' (R2) and 1 p 'simple roof' (R1)	R3	R2	R1
Total	33.145976	32.620652	106.831487
Carcinogens Pt	0.9084119628	0.9841191168	1.004148323
Respiratory organics Pt	0.00763135484	0.007414438007	0.01503910413
Respiratory inorganics Pt	7.212694771	6.803770798	8.5384135
Climate change Pt	1.324238064	1.457387747	5.459976974
Radiation Pt	0.005789951968	0.006007926603	0.0155119458
Ozone layer Pt	0.0008189146497	0.0008740981077	0.003561682825
Ecotoxicity Pt	0.05274776477	0.1731405503	0.2618430628
Acidification/Eutrophication Pt	0.3194349386	0.2557380259	0.4943969149
Land use Pt	0.2485956065	0.2460343585	0.4233034532
Minerals Pt	0.3015665528	0.2722716805	0.6319686174
Fossil fuels Pt	22.76404612	22.41392649	89.98332425

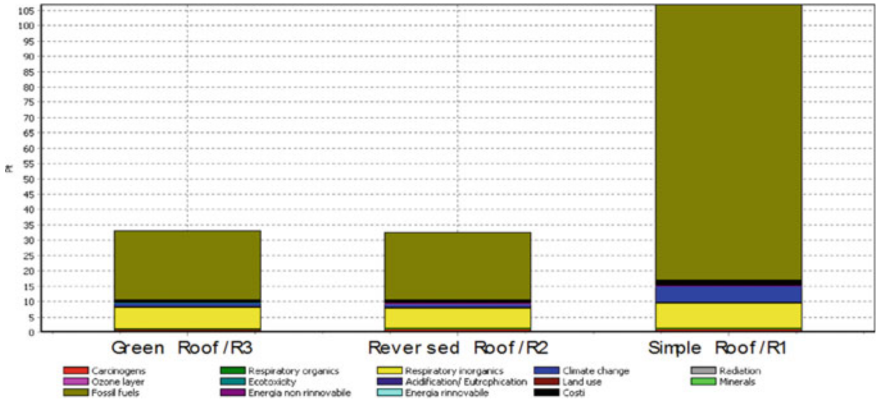

Fig. 3 Comparison between the three roof total damage points according to the eco-indicator assessment method

that it is necessary to define the hierarchical levels: goal, criteria, sub-criteria and alternatives.

In our case, the goal is to assess the different type of roofs according to their performances on the aesthetic, economic, and social point of views. The final set criteria are as follows:

1. Thermal resistance
2. Construction costs
3. Aesthetics

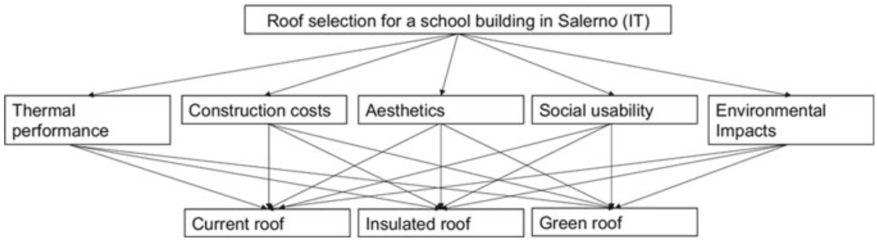

Fig. 4 The decision hierarchy. At the top level is the main goal of the decision making. The second level consists of the criteria that contributes to the overall goal. The third level is comprised of the different alternatives

4. Social usability
5. Environmental impacts.

Both the first and last criteria are derived from the previous LCA application. Additional quantitative data are related to the costs of each option. These are obtained summing up materials and site assembly as found in the regional built environment costs of unit list: the gravel roof (R2) turned out to cost 176.26 €/ms, the green one (R3) 195 €/ms, while the simply waterproof roof (R1) costs 125.69 €/ms.

The performance evaluation of the aesthetical and social issues has been conducted by the authors in consultation with designers, by adopting the pair comparison approach suggested by Saaty (2005).

The results from the overall performance evaluation of the three roofs are illustrated in Fig. 5, which reflects the neutral scenario (all criteria weights are equal to 1). As one can notice, the overall performances of the green roof are higher than the others. Specifically, this roof shows very high performance for the aesthetics (see photo) and social issues (gardening, etc.). On the contrary, the insulated roof is performing better in the thermal and environmental aspects while the current one (R1) only in relation to the construction cost criterion.

Two additional extreme evaluation scenarios have been considered in this application in order to reflect the major viewpoints of the built environment stakeholders involved, and specifically:

- an 'eco-social' scenario, where the aesthetic, social and context criteria are the only weighted criteria (Fig. 6);
- an opposite 'efficient' technical viewpoint ('business as usual') scenario where only the thermal performances and building costs are considered (Fig. 7).

In the first case, it is again the green roof to achieve higher performances, followed by the insulated and the current one. On the contrary, in the second case, it is the insulated roof to be ranked first.

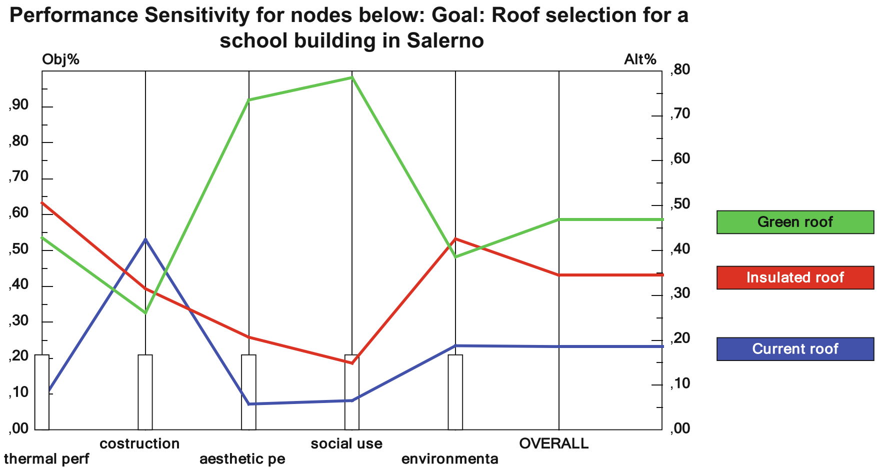

Fig. 5 The overall performance evaluation of the three roofs with the AHP method

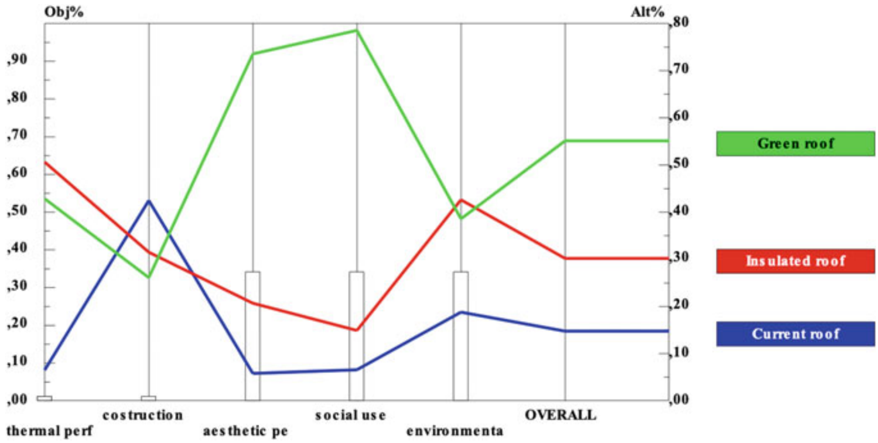

Fig. 6 The performance evaluation of the three roofs with the AHP method second an ‘eco-social’ scenario, the only weighted criteria are the aesthetic, social and context ones

4 Discussions and Conclusions

Regarding the first LCA comparison discussed in this paper, it is plain that the major source of environmental damage comes from the energy consumption in the use phase. This means that, in order to reduce this and consequently the overall impact, not only is necessary count on renewable energy sources to avoid fossil fuels and gas consumption, but it will be also crucial to beat on the energy performance of

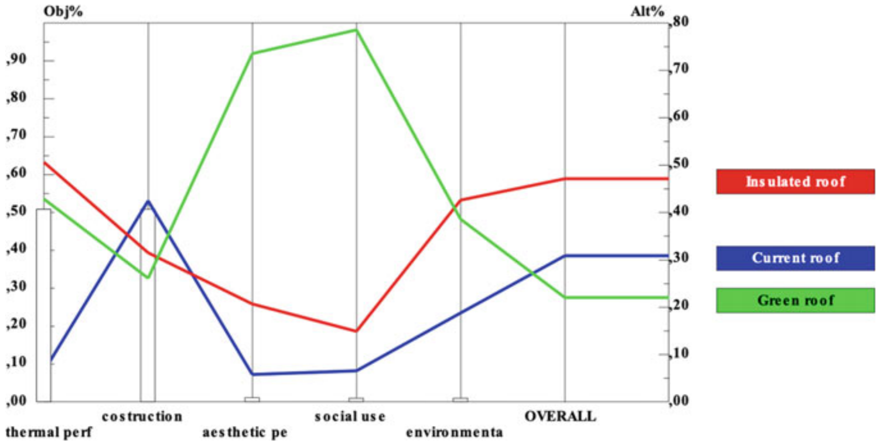

Fig. 7 The performance evaluation of the three roofs with the AHP method second an "efficientist" scenario where only the thermal performances and building costs are considered

the single component. If a layer of insulation, at first step analysis, would present a major embodied energy or higher pollutants index in the production phase, those effects could be overcome by less energy required for cooling and heating. In other words, apparently more polluting insulation would be more desirable than a natural, non-treated layer. The latest could be less impacting in the production or disposal phase but making the cooling and heating loads rise up for a longer period of time. For the peculiarity of the building sector, long-term performance is essential to do a correct evaluation. Regarding the methodology used to compare the alternatives, a strong accent must be put on the essential availability of a local database and different assessment methods that involve local material, transportation, resources and pollutant potentially dangerous, and any other local special boundary. It could have been useful to have compared, starting from the same database set, the result with other assessment methods to compare also different weight factor for the three ranking perspectives (Hierarchist, Individualist, Egalitarian). In the end, the work showed that the relationship between design, energy consumption and disposal scenario is very, very complex (Sonetti 2011), yet the implementation toward integrated ICT for regenerative sustainability design can be further developed (Sonetti et al. 2018, 2019). Experimental use of MCDA and LCA by individuals as an architectural design tool and integrated with existing decision-making software for energy planning can also be further envisaged as a useful step toward practical implication of this study (Abastante et al. 2017; Tavella and Lami 2018; Todella et al. 2018).

Although with its limitation, the LCA methodology seems to be the only one that can provide scientific data to make:

- the designer aware of the sustainability of the building since the earlier sketches
- the producer pushed to avoid pollutants emission during the production process of the material and to forecast a sustainable disposal scenario (the more the renewable energies will be part of the energy sources, the more a material environmental impact will fall not in the use phase but in its manufacturing and disposal phases)
- the public administration promoter of good practice and awarded green behaviour by buildings, constructors and designers
- the user aware of the added value of the building and conscious of the footprint left on the Earth.

To let in that virtuous circle a big effort is required from every single actor of the building process, but, as researchers, huge preliminary works will be needed to provide a social standard to which compare the results at the small, medium and large scale. Above all in Italy, on side of the energy performance declaration now mandatory for all the new construction, it could be useful one contemporary, mandatory Ecolabel criteria for the building material, package or whole construction, in order to force the research and the market in this direction. However, MCDA brought new perspective into traditional LCA. Conceptually, the use of qualitative, participative and prospective elements of MCDA procedural framework are complementing LCA. MCDA can provide information on site-specific aspects that cope well with the local constraint about social and economic issues, even when acquired by expert panels in a qualitative way, but risks are around the corner: LCA reliability can be stretched out beyond comparability if different scales and level of deepness are included all together on the results. This might lead to a trade-off between broadening and deepening the approach, with the result of making LCA even more complex and time-consuming for everyday use (if economic and social aspect are quantified as the environmental impact) or too analytical know-how and resources while trying to involve many stakeholders and criteria. One of the major advantages of our methodology is that it: breaks down a problem into elementary aspects; collects basic input data for all criteria of LCA Analysis and AHP Model; classifies the various environmental impacts; aggregate weights and scores to establish the final ranking in order to define the optimum solution. We believe that our new approach based on the LCA-AHP analysis helps decision makers to find sustainable alternatives among available options and promises a more sustainable product or process.

References

Abastante F, Lami IM, Lombardi P (2017) An integrated participative spatial decision support system for smart energy urban scenarios: a financial and economic approach. Buildings 7:103

Alshamrani OS, Galal K, Alkass S (2014) Integrated LCA-LEED sustainability assessment model for structure and envelope systems of school buildings. Build Environ 80:61–70. https://doi.org/10.1016/j.buildenv.2014.05.021

Anand CK, Amor B (2017) Recent developments, future challenges and new research directions in LCA of buildings: a critical review. Renew Sustain Energy Rev 67:408–416. https://doi.org/10.1016/j.rser.2016.09.058

Berto R, Stival CA, Rosato P (2018) Enhancing the environmental performance of industrial settlements: an economic evaluation of extensive green roof competitiveness. Build Environ 127:58–68

Björklund T, Tillman A-M (1997). LCA of building frame structures environmental impact over the life cycle of wooden and concrete Frames. Technical Environmental Planning Report 1997:2 Chalmers University of Technology, Uppsala

Buyle M, Braet J, Audenaert A (2013) Life cycle assessment in the construction sector: a review. Renew Sustain Energy Rev 26:379–388. https://doi.org/10.1016/j.rser.2013.05.001

Cabeza LF, Rincón L, Vilariño V, Pérez G, Castell A (2014) Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: a review. Renew Sustain Energy Rev 29:394–416. https://doi.org/10.1016/j.rser.2013.08.037

CAN Europe (2005) Input from environmental NGOs at the start of next round of the European Climate Change Program (ECCP). Climate Action Network Brussels, 24th October 2005

Chau CK, Leung TM, Ng WY (2015) A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. Appl Energy 143:395–413. https://doi.org/10.1016/j.apenergy.2015.01.023

De Felice F, Campagiorni F, Petrillo A (2013) Economic and environmental evaluation via an integrated method based on LCA and MCDA. Procedia—Soc Behav Sci 99:1–10. https://doi.org/10.1016/j.sbspro.2013.10.465

De T'Serclaes P (2007) Financing energy efficient homes, existing policy responses to financial barriers: IEA information paper. International Energy Agency (IEA), OECD/IEA, Paris, France, p 2007

Figueira J, Greco S, Ehrgott M (eds) (2005) Multiple criteria decision analysis: state of the art surveys, vol 78. Springer Science & Business Media

Guardigli L, Monari F, Bragadin MA (2011) Assessing environmental impact of green buildings through LCA methods: a comparison between reinforced concrete and wood structures in the European context. Procedia Eng. 21:1199–1206. https://doi.org/10.1016/j.proeng.2011.11.2131

Günther A, Langowski H-C (1997) Life cycle assessment study on resilient floor coverings. Int J LCA 2(2):73–80

Jeswani HK, Azapagic A, Schepelmann P, Ritthoff M (2010) Options for broadening and deepening the LCA approaches. J Clean Prod 18:120–127. https://doi.org/10.1016/j.jclepro.2009.09.023

L.D. 152 (2006). Decreto Legislativo 3 aprile 2006, n. 152, Norme in materia ambientale. Italian law 152 of the 3rd April 2006 on the environmental field edited in Gazzetta Ufficiale n. 88 of 14 April 2006—Supplemento Ordinario n. 96

Nejat P, Jomehzadeh F, Taheri MM, Gohari M, Majid MZA (2015) A global review of energy consumption, CO_2 emissions and policy in the residential sector (with an overview of the top ten CO_2 emitting countries). Renew Sustain Energy Rev 43:843–862

Neri P (2007) Verso la Valutazione Ambientale degli Edifici—life cycle assessment a supporto della progettazione eco-sostenibile. Edited by Alinea Editrice, ISBN 9878860551740. http://www.alinea.it

Saaty TL (1980) The analytic hierarchy process. McGraw Hill, New York

Saaty TA (1990) Decision-making for Leaders, RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA

Saaty TL (1992) Multicriteria decision making—the analytic hierarchy process, vol I. RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA 15213, AHP Series

Saaty TL (1993) What is a relative measurement? The Ratio scale phantom. Mathemat Comput Modell 17(4-5):1–12

Saaty TL (1994) Fundamentals of decision making and priority theory with the analytic hierarchy process, vol. VI. RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA 15213, AHP Series

Saaty TL (1995) Decision making for leaders, vol. II. RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA 15213, AHP Series

Saaty TL (1996a) Decision-making with dependence and feed-back—the analytic hierarchy process. RWS Publications, Pittsburg

Saaty TL (1996b) The analytic network process. RWS publications, Pittsburgh, USA (completed revision 2001)

Saaty TL (2005) Theory and applications of the analytic network process: decision making with benefits, opportunities, costs, and risks. RWS Publications, Pittsburgh

Saaty TL, Forman E (1993) The hierarchon, vol. V. RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA, 15213. AHP Series

Saaty TL, Kearns K (1991) Analytical planning, vol IV. RWS Publications, 4922 Ellsworth Ave., Pittsburgh, PA 15213. AHP Series

Saaty TL, Vargas LG (1991) Prediction, projection and forecasting. Kluwer Accademic, Boston

Schmidt AC, Jensen AA, Clausen AU, Kamstrup O, Postlethwaite D (2004) A comparative life cycle assessment of building insulation products made of stones wool, paper wool and flax. Int J Life Cycle Assess 9:53–56, 122–129

Sonetti G (2011) Environmental convenience of a building retrofit. In Proceedings of conference: people and buildings held at the offices of Arup UK. Network for Comfort and Energy Use in Buildings, London

Sonetti G, Naboni E, Brown M (2018) Exploring the potentials of ICT tools for human-centric regenerative design. Sustainability 10(4):1217

Sonetti G, Brown M, Naboni E (2019) About the triggering of UN sustainable development goals and regenerative sustainability in higher education. Sustainability 11(1):254

Tavella E, Lami I (2018) Negotiating perspectives and values through soft OR in the context of urban renewal. J Oper Res Soc 70:1–26

Todella E, Lami IM, Armando A (2018) Experimental use of strategic choice approach (SCA) by individuals as an architectural design tool. Gr Decis Negot 8:1–16

UNEP (2007) Buildings and climate change: status. Challenges and Opportunities, UNEP, p 2007

Vilches A, Garcia-Martinez A, Sanchez-Montañes B (2017) Life cycle assessment (LCA) of building refurbishment: a literature review. Energy Build 135:286–301. https://doi.org/10.1016/j.enbuild.2016.11.042

World Business Council for Sustainable Development (2007) Energy efficiency in buildings: business realities and opportunities. WBCSD