Evaluation in green building design for conversion projects: case studies and comparative approaches

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Abstract. By 2020, the manufacturing and construction industries sector is responsible for 16.3 percent of Europe's greenhouse gas emissions, third after the energy industries sector (31.4%) and transportation sector (29.0%). The built heritage is one of the first targets for mitigation and improvement of current environmental conditions. Carl Elefante's now famous statement "*The Greenest Building Is... One That Is Already Built*" wide the aspiration of the green concept to building design not only to new construction but also to the existing building stock. The purpose of the hypothetical intervention would aim at improving the three dimensions of sustainability - environmental, economic, and social - as applied to the building artifact. The dimensions of sustainability related with the concept of green building, that aims to implement user health through the design of healthy indoor environments. As a result of providing the definitions of Green Building design mainly found in the literature, the first approach of the paper is a critical reading of three case studies in the field of sustainable building, the criteria used in ex-ante evaluation, comparing their results, and providing a general procedural a logical framework to understand the initial part of the design process approaching to sustainability.

1 Introduction

The construction sector is responsible for more than 40 percent of global energy use and one-third of emissions in terms of greenhouse gas [1,2]. The effects of these dynamics, especially when correlated with the effects on climate, compel reflections that concern not only environmental, but also social and economic sustainability by aspiring to consider a holistic approach to sustainable design [3]. "*The Greenest Building Is... One That Is Already Built*" [4], this is Carl Elefante's assertion that accompanies the author's question of whether sustainability can be achieved by extending the concept of green only to new construction and not by expanding the challenge to the existing building stock. In this regard, in 2016, it is estimated that 70% of the existing building stock will have a life of 50 years after its construction [5], bringing to the center of the issue in terms of built heritage the concept of life extension of buildings [6].

The paper considers building conversion framed as a process aimed at making the heritage more suitable for the pre-existing function or for a new function [7], through interventions that include a change in function or use, affecting the structural appearance of a building, extending the concept of refurbishment to interventions on the interior layout [8]. Similar definitions can be encountered in the literature under the nomenclature of adaptive reuse or adaptation [9]. Likewise and considering existing heritage, the goal of green design is to reduce environmental impacts due to the building itself while simultaneously providing a healthy environment for the users within it [10]; the concept of green building is juxtaposed with the concept of sustainable building, it is an essential component for the related concepts of sustainable design, sustainable development, and sustainability in holistic terms, simultaneously considering the dimensions of sustainability: environmental, social, and economic [11]. In the second paragraph is framed the general framework in terms of green building and assessment approaches; in the third paragraph case studied and criteria are explained; the fourth and the final part sets an evaluation framework according to the case studies previously exposed.

The paper lays out initial reasoning regarding doctoral research undertaken at the Department of Architecture at Roma Tre University (Italy) and carried out for a period abroad at the Marcel Breuer Doctoral School of Architecture, University of Pécs (Hungary).

2 Green Building: definition, assessment approaches and terminological aspects

The following paragraph aims to identify the general framework of the research, to define general definition for green building design approaches and to set the terminological assessment framework.

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2.1 General framework

In the literature, terminology related to green building design is widely used as an answer to concern about sustainability in the construction industry [12]. This concern is supported by Mariasiu [13] whereby human activities do not occur without the formation of consequences for the environment, including the construction industry. In this sense, green buildings and related design are the answer in environmental, economic and social terms to the consequences of activity in the construction industry.

Table 1. Protocols for green building certification.

Evaluation system	First use	Country	Ranking
BREEAM *www.breeam.org*	1989	United Kindom	Outstanding Excellent Very Good Good Pass Unclassified
LEED	1998	United States of America	Platinum Gold Silver Certified
CASBEE	2001	Japan	S Excellent A Very Good B+ Good B- Rather poor C Poor
Green Star	2003	Australia, New Zeland, South Africa	6 Stars 5 Stars 4 stars
DGNB/BNB	2006	Germany	Gold Silver Bronze
GBEL	2007	China	3 stars 2 stars 1 star
Green Globes	2005	United States of America	4 GGlobes 3 GGlobes 2 GGlobes 1 GGlobes
Living Building Challenge	2005	United States of America Canada	-

The U.S. Environmental Protection Agency [14] defines green buildings as the set of practices and interventions aimed at establishing environmentally responsible and resource-efficient designs and processes throughout a building's life cycle with regard to site selection, in the case of new construction, design, construction, operation, maintenance, rehabilitation, and deconstruction. The issue of defining the goals of green design has been accompanied by the challenges posed by national and international agencies in terms of building assessment and rating systems (Table 1). The comparative picture among the different protocols shows how they have developed over a time span of the past 30 years from the most diverse geographic and cultural contexts. The most well-established rating mechanism consists of the predetermination of a set of classes (rankings), established on the basis of specific desired composite performance responses; measurement of the relative performance of the building or project will serve to assign the corresponding class or ranking to the element being evaluated.

2.2 Terminological foreword to the assessment

The paper considers the *ex-ante* evaluation of projects with the aim of improving them [15], particularly multi-criteria evaluation processes that pose the ambition of evaluating different aspects of the scope in question with the aim of outlining a preferable profile among the solutions available the decision problem [16]. Therefore, the *criteria* are defined as aspects of evaluation, which can be part of macro-criteria and are defined by indicators, measurement scale (quantitative or qualitative) and objective function (positive or negative); *alternatives* are defined as solutions to the decision problem, comparable to each other through performance against each criterion. Systematization is done by defining criteria (in column) and alternatives (in row), composes an operational tool that will be referred to as an *evaluation matrix*. The conduct of such an evaluation matrix can be made explicit through a set of procedures that will be *technical*, to obtain a *ranking* of alternatives that consists of a ranking drawn up based on the scores obtained by each alternative. In the end, the assessment needs an objective and the decision *point of view* (identified as an economic operator, community group, technician, etc.) and can, if necessary, be declined into different *scenarios* [16].

The robustness of the results obtained can be tested by *sensitivity analyses*, which consist of testing for consistent changes in the evaluation outcome brought about by small changes in the input data.

3 Case studies

The following paragraph aims to lay out three case studies selected in literature in order to describe ex-ante evaluation project in the sustainability field according to the use of multi-criteria evaluation methods and functional building conversion. The case studies were selected according to the author's literature review, considering the following characteristics: a) designing concerning existing constructions; b) using of multi-criteria evaluations; c) ex-ante evaluation phase; d) sustainability criteria field; e) recent application; f) application can be retraces.

3.1 Sapieha Palace in Vilnius (Lithuania)

Sapieha Palace, built between 1691 and 1697, named after the family that owned it, is a building of the period and late Baroque style located in Vilnius, Lithuania (Figure 1). It is the only surviving building complex of high historical value designed by Giovanni Pietro Perti and decorated with frescoes by Michelangelo Palloni.

Fig. 1. Sapieha Palace in Vilnius, north side. (Source: Wikimedia Commons, (License CC BY-SA 4.0).

It became the property of the Russian government in the early 1800s used as a military hospital and was destroyed in its interior components only to be renovated in the early 1900s and then abandoned after the War. The palace is nestled in a 17th-century park with paths, avenues and pools of water, remnants of which remain today.

The goal of the research [17] is the formulation of a ranking among alternatives for the conversion of Sapieha Palace. Given the complexity, the decision-making process for identifying the preferred functional alternative for conversion is supported by multi-criteria evaluation, systems widely used for interventions on the built heritage [18]. This assessment is done by identifying criteria and determining the priority vector (i.e., the expression of preferences among the criteria) through the administration of questionnaires to experts; the entire process is based on the accuracy of the BIM model built by the authors. The technique used is Weighted Aggregated Sum Product Assessment (WASPAS) [19], and supports the methodology in ten stages: stage one consists of describing the problem by defining criteria and alternatives; stage two involves the selection of experts to evaluate alternatives based on the given criteria; stage three is the administration of the questionnaires to the experts; stage four sees the experts' individual matrices converted into a group matrix; the next stage involves the normalization of the group matrix; stage six consists of assigning weights to the criteria within the normalized matrix; stage seven, eight and nine consist of mathematical procedures in order to define a ranking among the alternatives (stage ten). The research suggests five macro-criteria aimed at promoting the principles of sustainable development (economic, natural and social impact) and the principles of cultural preservation of historical heritage (Table 2). The alternatives suggested by the research consist of: a1) conversion to cultural center with tourist information center and permanent museum; a2) conversion to research institute; a3) conversion to accommodation service and conference center. The authors selected 10 experts in the field of building heritage, professionals and employees in the research field and with professional experience of 5-20 years. The evaluation process showed that conversion of the building into a cultural center with tourist information center and permanent museum is the preferred choice, confirmed by the sensitivity analysis.

Table 2. Research evaluation criteria [17].

Criteria	Indicator	Min /Max
Economic impact	Investment to investigation and research	-
	Investment in design	-
	Investment in reconstruction works	-
	Generating income for the municipality / city	+
Impact on the natural environment	Job creation for municipal city residents	+
	Benefits for city / country society	+
	Benefits for private business	+
	Benefits for heritage preservation	+
Social impact	Preserving the surrounding landscape	+
	Possibilities of park use for public needs and recreation	+
	Pollution during reconstruction works	-
	Pollution during operation of the facility	-
Cultural-historical preservation	Preserving the building's authenticity	+
	Activities that help propagate history and culture	+
	Public access to heritage and history	+
	Technical-economic value of an object	+
	Architectural-compositional value of an object	+
Technical-architectural	Volume of reconstruction works	-
	Suitability of the internal layout for the conversion purpose	+
	Infrastructure adaptation possibilities	+
	Lifetime of the building after reconstruction	+

3.2 Tanaro Valley in Piedmont Region (Italy)

Territory divided between two Italian regions (Liguria and Piedmont) overlooked by the Ligurian Alps and characterized by the fusion of a protected flora, mixed between alpine plants and other species of Mediterranean origin. The valley (Figure 2) has wooded and hilly landscapes, alternating with rugged rocky peaks. An area rich in an important historical, architectural and archaeological heritage made up of the remains of medieval castles and watchtowers of Saracen origin, relics of the pre-Roman trade route, Roman bridges and small historic centers with buildings dating back to the 10th century.The goal of the research [20] is related to the reuse of industrial and cultural heritage in the Valley.

This heritage presents nine eligible buildings in terms of redevelopment: i-ii-iii) silk factories; iv) spinning mill; v) cotton mill; vi) chemical factory; vii) lime kiln; viii-ix) brick kiln; constitute, therefore, the nine alternatives of the decision problem. The evaluation process is structured in the following phases.

Fig. 2. Landscape from Tanaro Valley (Garessio). (Source Wikicommons, Author Giorgno Stangni, License CC BY-SA 3.0).

The first phase consists of the construction of the evaluation matrix (9x15); the second phase is concerned with the identification of the preference function for each criterion; the third phase includes the construction of seven functional scenarios for redevelopment: a1) residential building, a2) retirement home , b) luxury hotel, c) farm and educational farm d) office building; e) socio-cultural center; f) ecomuseum; phase four is concerned with the assignment of weights to the criteria and phase five is concerned with the formulation of the ranking.

Table 3. Research evaluation criteria [20].

Criteria	Indicator	Min/ Max
Private driveway accessibility	Distance to Highway 28	-
Pedestrian accessibility or by public transportation	Distance to Ceva station	-
Available building area	-	+
Property area available	Vegetated area	+
Flexibility of interior spaces	Potential internal distribution	+
Architectural quality	Historical and artistic value	+
Maintenance status	-	+
Property value	Cadastral value of the property	-
Appurtenant area of the property	Empty portion of land behind and adjacent to the building	+
Landscape and natural quality	-	+
Presence of surrounding buildings of interest	Historic, artistic, architectural and tourist buildings within 1km radius	+
Acoustic quality	Distance from sources of noise	+
Presence of commercial activities	Stores, supermarkets within 500m radius	+
Presence of nearby public services	Banks, clinics, etc within 500 meters	+
Accommodation and hospitality services	Bars, restaurants, hotels	+

The ranking among alternatives is obtained through the support of the PROMETHEE [21] technique, the criteria were selected inspired based on cases in the literature in terms of real estate economics, sustainable urban development and reuse of abandoned properties (Table 3). The final ranking, shows that alternative 5, the cotton mill, is the building that would be most suitable in terms of reuse in different scenarios.

3.3 Fahmy Palace in Alexandria (Egypt)

Positioned on a hill that places it in a privileged position with respect to the sea front, the building was a summer house, square in plan, set on three floors and built in the neoclassical style by an Italian architect between the 1920s and 1930s, in the style typical of the representative buildings of wealthy families in Cairo at that time (Figure 3). Many wealthy families, in fact, who became rich through the cotton trade, used to build similar villas near the sea, but many, however, were destroyed or disappeared. The side not facing the sea featured a monumental garden. In the 1990s, due to a dispute between the heirs, the building suffered considerable damage that almost led to its collapse.

Fig. 3. Fahmy Palace (Alexandria). (Source Wikicommons, Author Aya Mahmoud Naguib Ibrahim, License CC BY-SA 4.0).

The goal of the research [22] consists of establishing the best conversion in terms of functional alternatives for the Aziza Fahmy Palace, a residential building built in the 1920s and 1930s in the Zizna district of Alexandria, Egypt. The evaluation consists of 5 phases: the composition d a hierarchical evaluation model, in which the reuse of the building is set as the goal, at the upper nodes the evaluation criteria and at the lower nodes the alternatives to the decision problem; the second phase includes pairwise comparison of the evaluation criteria carried out by experts within the decision domain; the third phase consists of the normalization of the matrix which as a result provides the order of preference of the criteria themselves; the fourth phase consists of evaluating each alternative taking into account the pre-posed withdrawals; and the final phase consists of the formulation of the ranking of alternatives.

Table 4. Research evaluation criteria [22].

Criteria	Indicator
Heritage value	Protect Protection and enhancement heritage significant
Architectural value	Compatibility (new functional appropriateness to original layout)
	Recognizability of heritage and new function
	Building's physical stability
	The respectabilityy of building's sytem
Economic value	Economic benefits
	Adaptation costs
Social value	Effect on society
Environmental value	Congruity with Land uses
	Accessibility

The technique supporting this process is the Analytic Hierarchy Process (AHP) [23] and considers five macro criteria that can be applied in evaluation areas involving heritage buildings (Table 4). The first alternative to the decision-making process proposed by the property owner involves conversion to a hotel; the second functional alternative involves an office building; the third alternative consists of a museum; and the fourth alternative, which will be the preferred choice at the end of the evaluation, describes a building for diverse uses including hotels, restaurants, and shopping centers.

4 Conclusion: an evaluation framework

The research previously set [17,20,22] represent an overview of the progress of doctoral research in the field of multi-criteria evaluations in terms of the conversion of existing buildings by approaching the topic of sustainability. The scope of applications (Table 5) differs by geographic area, number of alternatives, and scenarios. Specifically, the Lombardy case study [20], which as alternatives presents the building to be convert, performs a sensitivity analysis through the generation of seven functional scenarios (in terms of function) in order to confirm that the preferred alternative (number 5) remains so in most scenarios.

The technicality and inclusiveness (Table 6) of the three case studies are characterized by the type of criteria and its priority and the different ranking methods.

Table 5. Scope of application of the three case studies outlined in the previous paragraph.

Case study	Geographic area	Alternatives	Point of view	Scenarios
Sapieha Palace	Vilnius (Lithuania)	Functional option: 1) cultural center, museum; 2) research institute; 3) hotel, conference hall.	Application field experts	Scenario with no change in the evaluation matrix
Tanaro Valley	Lombardy (Italy)	Building option: 1-2-3) silk factories; 4) spinning mill; 5) cotton mill; 6) chemical factory; 7) lime kiln; 8-9) brick kiln.	Investor	Functional option: 1) housing; 2) retirement home; 3) luxury hotel; 4) farm and didactic farm 5) office building; 6) socio-cultural center; 7) ecomuseum.
Aziza Famiy Palace	Alexandria (Egypt)	Functional option: 1) hotel; 2) office building; 3) museum; 4) misted use.	Application experts	Scenario with no change in the evaluation matrix

From the overview of the three case studies presented in the paper, it can be seen that the point of view of the evaluation procedure, and the related choice to be made, is that represented by expert knowledge leading to a top-down procedural form. Also, the application carried out in the Tanaro Valley geographic area can be considered a representation of an expert viewpoint, since the investor has specific knowledge and his own known indicators to assess his individual category benefit. Although multi-criteria evaluations lend themselves well to procedural configurations capable of incorporating the instances of local interest groups, citizens, and stakeholders with participatory practices [24,25].

These cases seem to be oriented only to the interpretation of the decision maker's point of view, which in turn is expressed to protect the general interest. It is then appropriate to highlight how the reported case studies refer to the same design phase, i.e., a level of initial design feasibility.

The concept of green design is very often associated with the mainly environmental and energetic aspects of the building (systems, envelope, energy balance, etc.) and is more related to new construction.

However, the applications discussed highlight that a green-oriented process raises questions and choices in this regard from the earliest stages of selection, and therefore

requires the use of decision support tools from the pre-design stages.

Already the simple search among the alternative functions to be accommodated by the existing building to be redeveloped (case study 1 and 3) implies effects and impacts that affect all areas of holistic sustainability, and thus also the green aspect.

Even in the opposite case, where the choice is to be made on which available building a set of functional scenarios can be included (application 2), the choice follows aspects of sustainability and green. Therefore, these are preliminary choices that, as evidenced by the criteria considered, have an impact in a sustainable key that affects feasibility. Although these are assessments aimed at sustainability in holistic terms of design alternatives, the set of indicators grouped into categories of criteria also refers to architectural and historical-cultural features as competing elements of social and economic values.

This is given precisely by the purpose of the assessment: the redevelopment of the existing building stock, which irrespective of the starting conditions of the building confronts the designer and the assessor with such considerations. The criteria, moreover, can be represented in different ways: a) they are expressed in terms of impact, and thus in terms of possible positive or negative change over the medium and long term, as in the first application; b) in terms of measuring effects, and thus as direct measurability of actions acting in the short term, as in the second application; c) in terms of change in value, as in the third application.

Table 6. Technicality and inclusiveness of the three case studies exposed in the previous paragraph.

Case study	Criteria	Technique	Criteria priority	Ranking methods
Sapieha Palace	1) economic impact; 2) social impact; 3) impact on the natural environment; 4) cultural-historical preservation; 5) technical-architectural.	WASPAS	Hierarchization by qualitative assessments encapsulated in a collective matrix composed by single vector priority	Performance evaluation using qualitative-quantitative normalized matrices
Tanaro Valley	1) private driveway accessibility; 2) building area disposability; 3) available property area; 4) flexibility of interior spaces; 5) architectural quality; 6) state of maintenance; 7) property value; 8) appurtenant area of the property; 9) scenic and natural quality; 10) presence of surrounding buildings of interest; 11) acoustic quality 12) presence of commercial activities 13) presence of public services 14) presence of accommodation and hospitality services	PROMETHEE	Hierarchization by qualitative assessments by the typical decision maker (investor)	Performance evaluation of alternatives taking into account the criteria and sensitivity analysis taking into account the scenarios.
Aziza Famiy Palace	1) Heritage value; 2) Architectural value; 3) economic value; 4) social value; 5) environmental value.	AHP	Pairwise comparison of criteria by expert panel	Ranking of alternatives by qualitative evaluation and pairwise comparison

Multi-criteria evaluations applied to the building sector represent a virtuous and flexible procedure for understanding complexity: while in the first and last applications the alternative solutions to the decision problem are the functions to be settled, in the second application the function represents the reference scenario for electing the building to be redeveloped.

Finally, although the contribution deals with a selection of only three case studies, it attempts to highlight how multi-criteria applications represent a procedurally versatile tool that can be applied in different ways; green building assessment can be considered already in the early stages of building design; multi-criteria assessments aspire to define the preferable choice by taking into account and bringing together individual operators with the ability to outline a choice that guarantees the general interest.

References

1. A.N. Nielsen, R. L. Jensen, T. S. Larsen, S.B. Nissen, Build Environ. **103**, 165 (2016)
2. European Commission. *EU Energy in Figures. Statistical Pocketbook (2022*)
3. A. F.L. Baratta, F. Finucci, A. Magarò*TECHNE*. **21**, 304 (2021)
4. C. Elefante, Forum J. **21**, 26 (2007)

5. D. F. Gewirtzman, J. of Architect. Engin. Technol. **5,** 3 (2017)
6. L. Wong, *Adaptive Reuse: Extending the Lives of Buildings*. Walter de Gruyter GmbH; (2017)
7. J. Douglas, *Building Adaptation*. (Elsevier Ltd 2006)
8. G. Giebeler, H. Krause, R. Fisch, F. Musso, B. Lenz, A. Rudolphi. *Refurbishment Manual*. DETAIL - Institut für internationale Architektur-Dokumentation GmbH & Co. KG (2009)
9. ICOMOS*, New Zealand Charter for the Conservation of Places of Cultural Heritage Value* (2010)
10. F. D. K. Ching, I. M. Shapiro, *Green Building Illustrated*. John Wiley & Sons (2014)
11. R. N. Lacroix, E. Stamatiou, Green Architecture and Sustainable Development: Applications & Perspectives. In: *Proc. of the 3rd IASME/WSEAS Int. Conf. on Energy, Environment, Ecosystems and Sustainable Development,* Agios Nikolaos, Greece, July 24-26, 603 (2007)
12. S. Attaran, Internat. Rev. of Manag. and Marketing **3**,122 (2013)
13. F. Mariasiu, Internat. Rev. of Manag. and Marketing **3**, 1 (2013)
14. U.S. Environmental Protection Agency. *Basic Information: Green Building* (2012)
15. P. Rostirolla, *La Fattibilità Economico-Finanziaria. Metodi e Applicazioni* (1998)
16. S. Miccoli, F. Finucci, R. Murro, Adv. Mat. Res. **1030-1032**, 2519 (2014)
17. M. Pavlovskis, D. Migilinskas, J. Antucheviciene, V. Kutut, Symmetry (Basel) **11**, 1 (2019)
18. Z. Morkūnaitė, D. Kalibatas, D. Kalibatienė, J. of Civil Engin. and Manag. **25**, 76 (2019)
19. E. K. Zavadskas, Z. Turskis, J. Antucheviciene, Electronics and Electrical Engin. **122,** 6 (2012)
20. M. Bottero, C. D'Alpaos, A. Oppio,. Sustainability **11**, 1 (2019)
21. J.P. Brans, M. Bertrand, *Prométhée-Gaia: Une Méthodologie d'aide à La Décision En Présence de Critères Multiples.* Éditions de l'Université de Bruxelles (2002).
22. H. Haroun, A.F. Bakr, A. Hasan, Alexandria Engin. J. **58**, 467 (2019)
23. T. L. Saaty. *The Analytic Hierarchy Process : Planning, Priority Setting, Resource Allocation*. McGraw-Hill International Book Co (1980)
24. G. Munda, Eur. J. Oper. Res. **158**, 662 (2004)
25. S. Miccoli, F. Finucci, R. Murro, Pollack Periodica **10**,143 (2015)