Publishing Series in PROJECT | Essays and Researches

Resilience between Mitigation and Adaptation
vol. 03 | 2020 | paper 14 | pp. 248-259

ISSN (print): 2704-6087
ISSN (online): 2704-615X
ISBN (print): 978-88-5509-094-0
ISBN (online): 978-88-5509-096-4

RESILIENT RESTORATION AND REUSE
Methods, instruments and tools

Marco Morandotti, Daniela Besana

section
ARCHITECTURE

typology
RESEARCH & EXPERIMENTATION

DOI
10.19229/978-88-5509-096-4/3142020

ABSTRACT

The paper presents a preliminary impact assessment method in the case of interventions for functional recovery and existing buildings regeneration, based on the concepts of resilience and sustainability. The research illustrates the theoretical, methodological and design aspects connected to the concept of resilience, understood as a transformation of an existing building, with particular attention to the definition of methods for the knowledge and evaluation of critical points and vulnerability of the architectural heritage. It's considered as indispensable premise to understand the impact of possible design actions and to monitor the transformability thresholds of the building itself, in order to set up a sustainable reuse. The aim is to define and to describe a pre-planning analysis and assessment tool capable of supporting the decision-making processes. This synthetically stated methodology is the result of an ongoing research at the STEP Laboratory of the University of Pavia with the goal of proposing a tool capable of supporting decisions in the preliminary stages of processes oriented to adaptive reuse, in order to evaluate the compatibility of different transformative hypotheses coherently with the conservation needs of an existing building. The possible developments of this methodology could concern its application as decision support tools for building and urban regeneration interventions where the preliminary assessment of re-used sustainable scenarios and the impact evaluation on the existing buildings is necessary, starting from the preliminary phases of the design process.

KEYWORDS

cultural heritage, resilience, reuse, sustainability, knowledge

Marco Morandotti, Engineer and PhD, is a Full Professor of Technical Architecture at the DICAr Department of the University of Pavia (Italy). He carries out research on the conservation and sustainable enhancement of Cultural Heritage, with reference to typological and technological design solutions. Mob. +39 348/29.00.458 | E-mail: marco.morandotti@unipv.it

Daniela Besana, Engineer/Architect and PhD, is an Associate Professor of Technical Architecture at the DICAr Department of the University of Pavia (Italy). She carries out research on the restoration and sustainable reuse of Cultural Heritage, with reference to construction technologies and design strategies for the intervention on the existing buildings. Tel. +39 (0)382/98.54.04 | E-mail: daniela.besana@unipv.it

The Re^3 (Resilient, Restoration and Reuse) method, here following described, deals with the main topic of cultural heritage preservation and valorisation. It focuses on the perspective of sustainable reuse and takes into account resilience assessment and evaluation of the built environment as a way to guarantee less intrusive, more responsible and more sustainable reuse projects. In this field, a theoretical methodology has been developed within the STEP laboratory (Laboratorio di Scienza e Tecnica per l'Edilizia e la Progettazione) at the Department of Civil Engineering and Architecture (DICAr) of University of Pavia. This is based on some synthetic indicators able to describe the leftover performances of a generic existing building, to evaluate the most efficient strategy of intervention, and finally to determine the impacts of these transformative actions on its constituent systems.

Resilience even more frequently is recognised as one of the key topics within social, ecological and urban sustainable development (Hassler and Kohler, 2014). The attitude of a territory, a city, or a complex organized system to adapt and to respond positively to the changes and demands of the context, or the capacity to incorporate changes for a continuous experience (Berkes, Colding and Folke, 2003), is recognized as one of the primary values in a sustainable evolutionary perspective. Resilience is generally defined as the capacity of a complex system to change in response to the action of a disturbing force (Holling, 1973), reaching a new state of equilibrium albeit. In the ecological and ecosystemic field in particular, resilience is defined as the «capacity of systems to reorganize themselves (and evolve) as a consequence of stress phenomena» (Colucci, 2012, p. 11). In the context of urban studies, resilience cities are able to understand the systemic changes currently taking place to identify possible adaptation strategies.

Within the field of civil engineering, the increased resilience in cultural heritage is mainly developed in relation to anthropogenic and natural risk management procedures (Jigyasu et alii, 2013), pertaining to calamitous events. A specific declination is then that of the application of the concept of resilience (in its true mechanical meaning) to the issue of reducing the seismic vulnerability of existing structures, with particular reference to historical ones. In the specific case of historic cultural heritage, resilience will be defined as the tolerable transformation that a generic existing building system can undergo without the impact that it has on its constituent systems generates undesirable transformative effects. This would otherwise irreparably compromise its consistency and semantic coherence, if not its physical existence.

On the opposite, if resilience will be assessed since the beginning of the decision process as a key factor, the design choices will hopefully be more conscious of the transformation impacts on the existing building, and therefore more adequate to accommodate changes arising from new uses, or from performance and regulatory updates to previous uses. In this perspective, the concept of resilience is intrinsically linked to the theoretical and methodological approach of the sustainable reuse of historic building heritage and, more generally, with that of the valorisation of cultural heritage.

Adaptability and transformability are essential topics within the general framework of resilient thinking (Folke et alii, 2010). That's why an approach to sustainable conservation of the built environment should consider the opportunities deriving from the adaption to new functions while making use of specific analysis tools able to estimate the level of compatibility between existing structures and new conceivable uses. According to Italian Codice dei Beni Culturali e del Paesaggio (D.lgs. 42/2004, art. 6 c.2), the enhancement of cultural heritage should never overwhelm its conservation issues. Claiming that «Valorisation is implemented in forms that are compatible with protection and that do not jeopardize its requirements», Italian regulation perimeters any intervention, subjecting valorisation strategies to conservation requirements. By defining a compatible level of transformation, it can be recognized a possible connection between the paradigms of sustainable valorisation and the residual resilience of heritage assets.

The research combines performance approach with the principles of resilient thinking applied to the built heritage, defining a repeatable and standardized process for supporting decision-making in adaptive reuse projects. The methodology is developed through analysis, diagnosis and evaluation and includes two assessment indices able to estimate the leftover performances of existing building with regard to multiple intended uses and the impact of the transformative actions in relation with the estimated resilience thresholds. Within the previously described theoretical framework, a quantitative approach based on the resilience thresholds for the preliminary assessment of impacts of new functions in existing buildings was developed with the aim of supporting the stakeholders for effective decision-making processes on adaptive reuse.

A consistent number of the most influential decisions for the building process are made in its first phases (Petersen and Svendsen, 2010), when there are few certain data. In this framework, it is crucial to dispose of decision-making support tools that are not required to perform detailed analysis or to reach final results, but rather to highlight the overall impact of the planned actions and the relationships between the design hypothesis (Schlueter and Thesseling, 2009). These tools can be more reliable when used in a comparative way more than in an absolute one, with the aim of evaluating a set of proposed strategies with a multi-criteria approach.

When the object of study is related to an existing building, the preliminary assessment of the expected impact of each transformation is strategical and, along with the increase of value of the building, it's become of primary importance. The related analysis should be strictly connected with the actual state of the building, by giving huge space to the considerations on its historical development and heritage value. It is, in fact, thought mainly to measure the residual capacities of an existing system to answer to potential contemporary needs intended as a multi-disciplinary set of specification. Moreover, the possible reuse alternatives are taken into account in their broader aspects with the aim of getting an idea on the transformative vocation of the building. The methodology has already been tested with the application to some case studies belonging to the built heritage of the University of Pavia, and as a consequence of this test, some modifications to the method have been recently defined, and are here presented for the first time. Further developments of the research will evaluate the possible exploitation of methodological results achieved for the definition of a repeatable process endorsed by an IT (Information Technology) tool in order to support decision-making in adaptive reuse projects.

Evaluation method proposed | The research here presented combines meta-design/performance approach with the principles of resilient thinking, applied to historical cultural heritage in a life cycle-oriented perspective. It addresses the issue of functional compatibility and the reduction of impact between new functions and existing building, also in relation to the urban environment for its sustainable regeneration. It is therefore necessary to identify thresholds of transformation that are compatible with the thresholds of resilience of the existing building. The aim of this methodology is to evaluate at a very early stage of the design process the impact of new functions on the existing buildings in order to avoid erroneous previsions and transformation strategies. Failing this, a design solution albeit congruent with new requirements and current regulatory constraints, may generate unacceptable consumption of material, typological, and technological integrity.

The proposed workflow is articulated into four main steps, synthetically described as follows: 1) evaluation of residual performances of the existing building with regard to different intended uses, by means of a specific index defined as Performance Adequacy and Vulnerability (PAV) index; 2) evaluation of most efficient reuse strategies for a specific intended function; 3) preliminary – early stage design; 4) evaluation of expected performances of the building, simulating the design transformations calculating the value of the Performance Adequacy and Vulnerability index after the transformation (PAV1); 5) evaluation of the impact of the transformative actions in terms of estimated resilience thresholds, by means of a specific index defined as Resilience Threshold Value (RTV).

Main goal is to guide the actors involved in the process to achieve a preliminary reliable knowledge framework on the existing building to be used to understand the attitude of transformation and the resilience thresholds, and to provide a set of tools able to compare different design hypothesis on the basis of a standardized assessment grid. In order to be effective and expendable within the building process, the methodology is closely linked to a specific national regulatory framework. That's why the calculation of many parameters refers to Italian laws or technical standards.

Therefore, in the case of application to different national contexts, it would be necessary to correct the ranges of the benchmark values in order to fit different standards, without modifying the methodology as a whole. This simplified approach is supposed to be successful in the framework of a preliminary investigation on the building because it is simpler and faster than an evaluation based on the effective dimension of each technical element of the building system, although still reliable (Fig. 1).

Performance Adequacy and Vulnerability index (PAV) | PAV index is thought to follow the preliminary investigation phase on the building and to help the professional in summarizing its most influential aspects with reference to some design hypothesis related to possible alternative uses (Morandotti et alii, 2019). It is composed by six specific indicators: usability; well-being; safety; accessibility; conservation; flexibility. Each is calculated as the average of different parameters and is measured on a scale from 0 (missing) to 3 (good) with reference to its level of adequacy compared to specific ranges of values determined in accordance with the Italian regulatory framework and technical standards.

The methodology here described has been integrated in a BIM-based workflow in order to ensure control and transparency on the whole process. Although sufficiency requirements are limited to a preliminary model, which is coherent with the level of knowledge on the building and can be queried to perform different kind of analysis on the building.

Definition of reuse strategies | Once the state of consistency of the existing building on which it is intended to work is known, the proposed method, although in a pre-project phase, becomes as an instrument able to address different paths of approaching the project. The possible design strategies for reuse have therefore been evaluated and, in view of their simplification, they have been classified into 11 possible case studies related to the relationships that can be generated between the existing structure and new additions: the addition of a volume (addition), on the cover (superposition), on the façade (hanging), at the base or through the creation of an underground space (excavation) or by adding a connection volume between two separate buildings (connection). Other design strategies can also be realised or by a volume inside or outside the existing building (intrusion/wrapping), by simple internal re-functionalization or by merely improving energy performance or changing architectural language (bioclimatic and chameleon). For a first simplification, it is possible to have them aggregated into three macro-categories: Insertion, Addition and Recladding.

The aim of the research was therefore to understand how the three groups of strategies can influence the performance characteristics of the existing structure and how they can integrate the gaps calculated through the PAV indicator, with the aim of reveal which of them is potentially more adequate to respond to the transformative demands of the building, without any deterministic constraint, but naturally leaving the designer the freedom to decline the single strategy in a specific project proposal. In this regard, for the purpose of use established by the project hypothesis, the aim is to obtain and evaluate the performance increase on the factory in relation to the possible intervention strategies. Therefore, a first evaluation takes place considering and therefore excluding those strategies not applicable to the specific case, due to intrinsic characteristics of the building (for example construction technology, historical architectural value or state of preservation), due to regulatory constraints (impossibility of be-

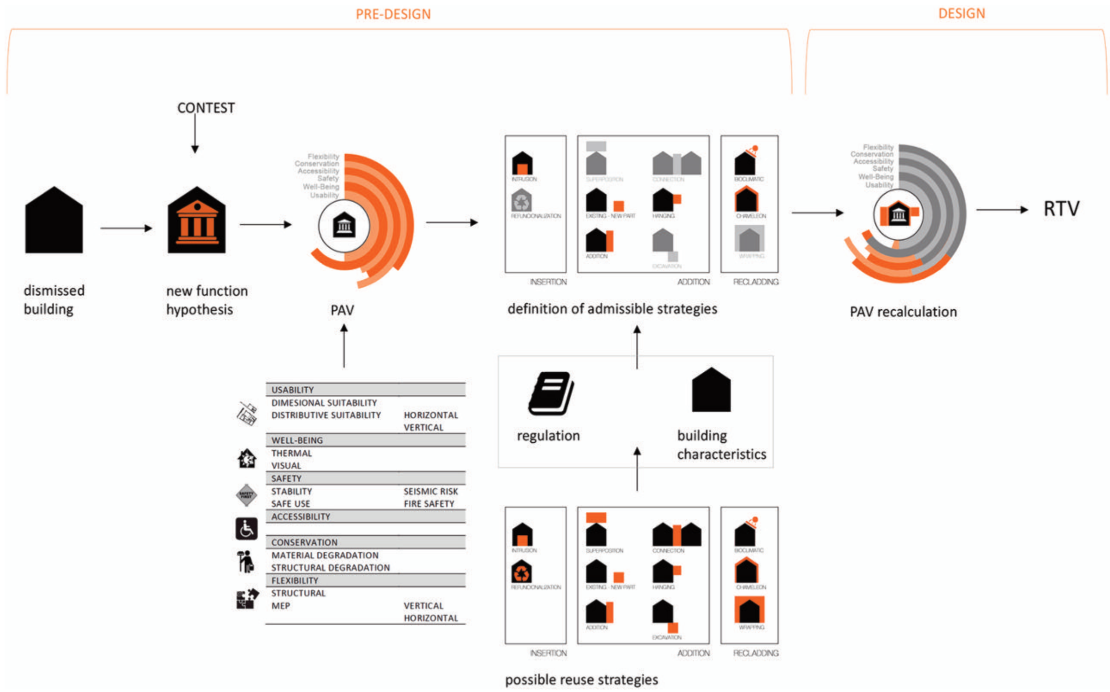


Fig. 1 | General structure of the research.

ing able to increase the maximum building height, distances from boundaries, etc.) and finally for constraints dictated by the context in which it is inserted.

Once excluded the unworkable strategies it is therefore possible to proceed, through a pair comparison matrix, to evaluate the PAV indicators and, secondly, to evaluate the strategy itself through a pair comparison matrix made on the admissible strategies on the specific case. Once this process has been reiterated to all the allowable strategies it will therefore be possible to synthetically assess which of the strategies is the one that most significantly improves the PAV indicators. It is clear that this arises and must act as a tool, able to control a priori the impacts of the strategy choice on the existing while leaving the designer the possibility of choosing, combining several strategies to optimize at best the indicators lacking in the PAV and finally to propose its own project design solution.

This procedure, as will be described more precisely later, is also coherent with the methods of comparison and evaluation proposed with the new Procurement Code. Furthermore, it seems to open a real application of its own by a hypothetical contracting station which is called to evaluate, also with simplified modalities referable, for example to the Design Preliminary Document phase, as many intervention hypotheses compatible with the intervention strategies applicable to the project.

		PAV			IMPACTS							
		existing building	design hypothesis	increase	material removal	structural alteration	spatial alteration	surface alteration	morphologic alteration	identity weakening	TOTAL (0 –18)	TOTAL (scaled 0 –3)
1	USABILITY	2	2,25	0,25	2	2	2	1	3	2	12	2
2	COMFORT	0,5	1	0,5	2	0	0	2	1	0	5	0,83
3	SAFETY	1,5	2	0,5	1	2	2	0	1	1	7	1,17
4	ACCESSIBILITY	2	3	1	3	1	2	1	2	1	10	1,67
5	CONSERVATION	1,5	2,5	1	2	1	0	2	0	0	5	0,83
6	FLEXIBILITY	1,25	1,5	0,25	1	1	2	1	1	2	8	1,33

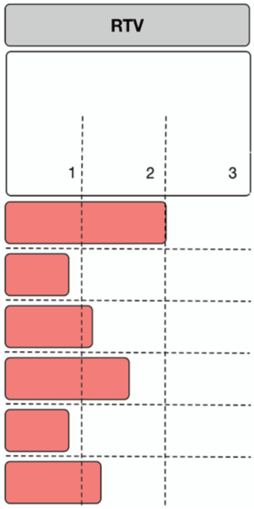


Fig. 2 | Synoptic evaluation table of PAV and RTV indexes.

Resilience Threshold Value index (RTV) | The Resilience Threshold Value index (RTV) represents the result of a synthetic evaluation process aimed at the assessment of the impacts of possible design alternatives, related to the performance improvement assessed through PAV methodology formerly described. This section of the general approach has been recently upgraded since former stages of the method and is here described for the first time. Operationally, the proposed method foresees that after the definition of the reuse strategies, a coherent design solution is developed at a preliminary stage.

A new PAV assessment may be developed, taking into account these design hypotheses. In the following we will refer as PAV0 to the performance evaluation of the building before the transformation, and as PAV1 to the performance evaluation of the same building after the transformation itself. Therefore, for each of the six PAV indicator may be calculated a positive value shift (Δ PAVn) defined as the result of the difference between PAV1n and PAV0n.

The variation of each PAV indicator is related to six potential negative impacts on the building, assumed as control variables of the system, defined as following: a) Material removal, b) Structural alteration, c) Spatial alteration, d) Surface alteration, e) Morphologic alteration, f) Identity weakening. Case by case it will be assessed if the design solution under evaluation, alongside an increase of a specific PAV value (or transformation driver), will affect (and eventually how much) one or several of the control variables, according to the following evaluation scale:

A) Material removal – missing (0); limited (1); relevant (2); valuable (3), affecting valuable elements;

B) Structural alteration – missing (0); limited (1); relevant but reversible (2); relevant and not reversible (3);
C) Spatial alteration – missing (0); limited (1); relevant (2); valuable (3);
D) Surface alteration – missing (0); limited (1); relevant (2); valuable (3), affecting valuable elements;
E) Morphologic alteration – missing (0); limited (1); moderate (2); relevant (3);
F) Identity weakening – missing (0); limited (1); moderate (2); relevant (3).

A synthetic evaluation chart is defined and filled up assigning a specific value to each of the control variables in relation to each of PAV indicators, as exemplified in the Figure 2. Through this process, the Resilience Threshold Value (RTV) is obtained, where each of the six control variables is quantified. The variables' values show the amount of the expected impact on the existing building generated by a specific improvement of the performance level as assessed by the corresponding PAV indicator. A secondary result of the method is the possibility to identify at a glance if some control variables score the maximum value which may suggest further analysis on specific design solutions, due to local strong impact; i.e. a usability gain of 0,25 implies an impact of 2, also showing a specific critical value related to "morphologic alteration" of the building.

The opportunity to simultaneously check both performance improvement and impact may suggest to the stakeholder (i.e. the designer, the owner, the facility manager, etc.) if the design solution under evaluation generates (or not) a sustainable transformative pressure in terms of negative impact versus positive transformations. For each PAV indicator is therefore possible to synthetize not only a positive variation related to the specific performance increase, but also a negative impact affected on the building itself (Figg. 3-5). A comprehensive graphic representation of the whole assessment process may be synthetized in a six-axis graph, in which each axis represents a specific driver of transformation, scaled in a range of 0-3 values, calculated in the PAV assessment, both at the existing phase (PAV0) and after the preliminary design stage (PAV1), where the radius of each circle represents the normalized impact value generated by the specific driver.

Conclusion and future developments | The research here presented allowed to define an approach towards a preliminary performance assessment for existing buildings with a view to the resilient development of the built environment. The methodology has a double value, intended both as investigation and assessment tool, useful for defying an effective knowledge base on the building, while the implementation within a BIM workflow ensures time-saving, data-safety and transparency.

The whole study aims to define an evaluation tool for existing buildings based on measurable performance requirements where all the parameters are simply retrievable with direct surveys, consistently with the preliminary stages of investigation on the building. The methodology may play an interesting role when integrated within the

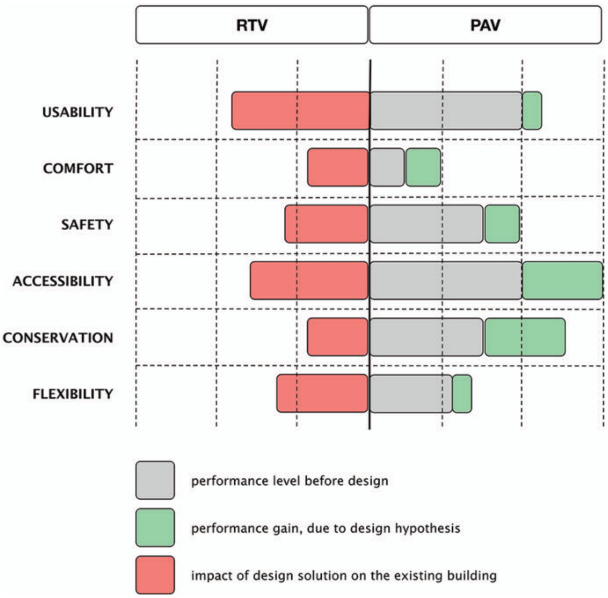
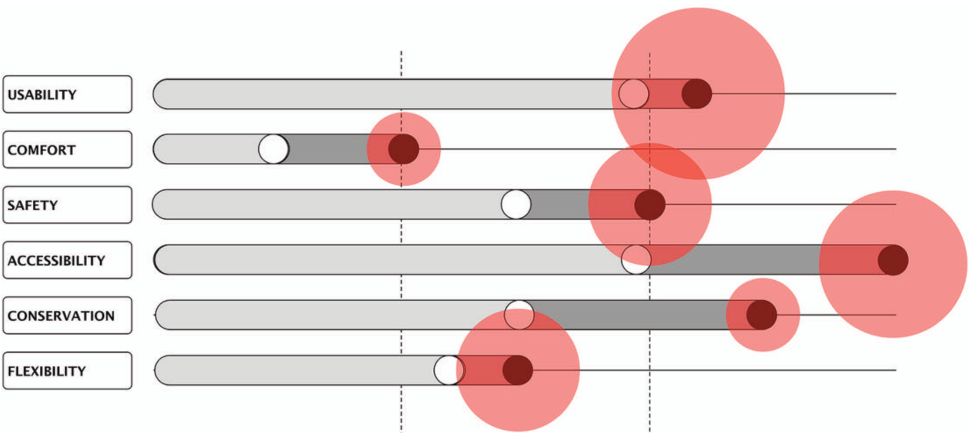


Fig. 3 | RTV and PAV comparison.

Fig. 4 | RTV index showing normalized values of indicators.

Fig. 5 | PAV and RTV graphic, showing both performance improvements (horizontal bars) and impacts (circles).



Italian Procurement Code (D.lgs. 50/2016), especially with reference to the evaluation of different design proposals when adaptive reuse projects are developed. The aim is to provide the contracting authorities and the competitors involved in the design competition a shared and transparent workflow in order to strengthen the evaluation of different design alternatives.

In the case of an adaptive reuse project, before the design competition, during the meta-design and pre-analysis phase, it's necessary for the public administration to identify, among several possibilities with regard to intended uses, the one that appears to be the most suitable in relation to the constraints imposed by the existing building and more respectful of its level of transformability. The pre-evaluation of the impacts that new uses will determine on the existing buildings is crucial to balance the conservation needs and the transformation requirements expressed by needs' framework. Once established this first step the new requirements and the building assessments are taken into account along with the financial limits and possible design strategies. The identification of selected strategies may be intended as a further recommendation for participants (art. 3, section 4).

The set of tender documents defines the domain of the project actions, addressing it towards the achievements of specific objectives by the administration. During the design contest, the competitors involved are asked to develop and analyse multiple design solutions and to expose the assessment of each in qualitative terms, under technical, economic and environmental profiles. Then, they will propose to the contracting authority the design alternative that gains the best ratio between costs and benefits, by considering the needs of users, the performance deficits of the existing building and the budget thresholds expressed in the tender documents. In this phase, the participants shall recalculate the PAV in relation to different design alternatives. Therefore, RTV index is evaluated in order to understand the impacts of the project actions with reference to the transformability thresholds of the building.

In the future, it will be very interesting to apply this methodology to case studies that do not strictly refer only to the Italian context. In fact, while the proposed methodology remains the same, it will be necessary to prepare an update of the values used for the definition of the indicators in order to respond to a varied regulatory reference framework. This experimentation may therefore become an opportunity for a possible evolution and expansion of knowledge related to the assessment of the impact of reuse actions on cultural heritage.

Future developments aim to the exploitation of theoretical and applicative research activities for the definition of a repeatable process endorsed by an IT (Information Technology) tool for supporting decision-making in adaptive reuse projects. In this way, it will be possible to transfer the research group know-how to the market thanks to the development of the IT tool and to the consultancy and mentorship in the use of the methodology, in both public and private sector. A possible final goal is to set up a commercial product in the form of either a stand-alone app, or a plug-in interacting

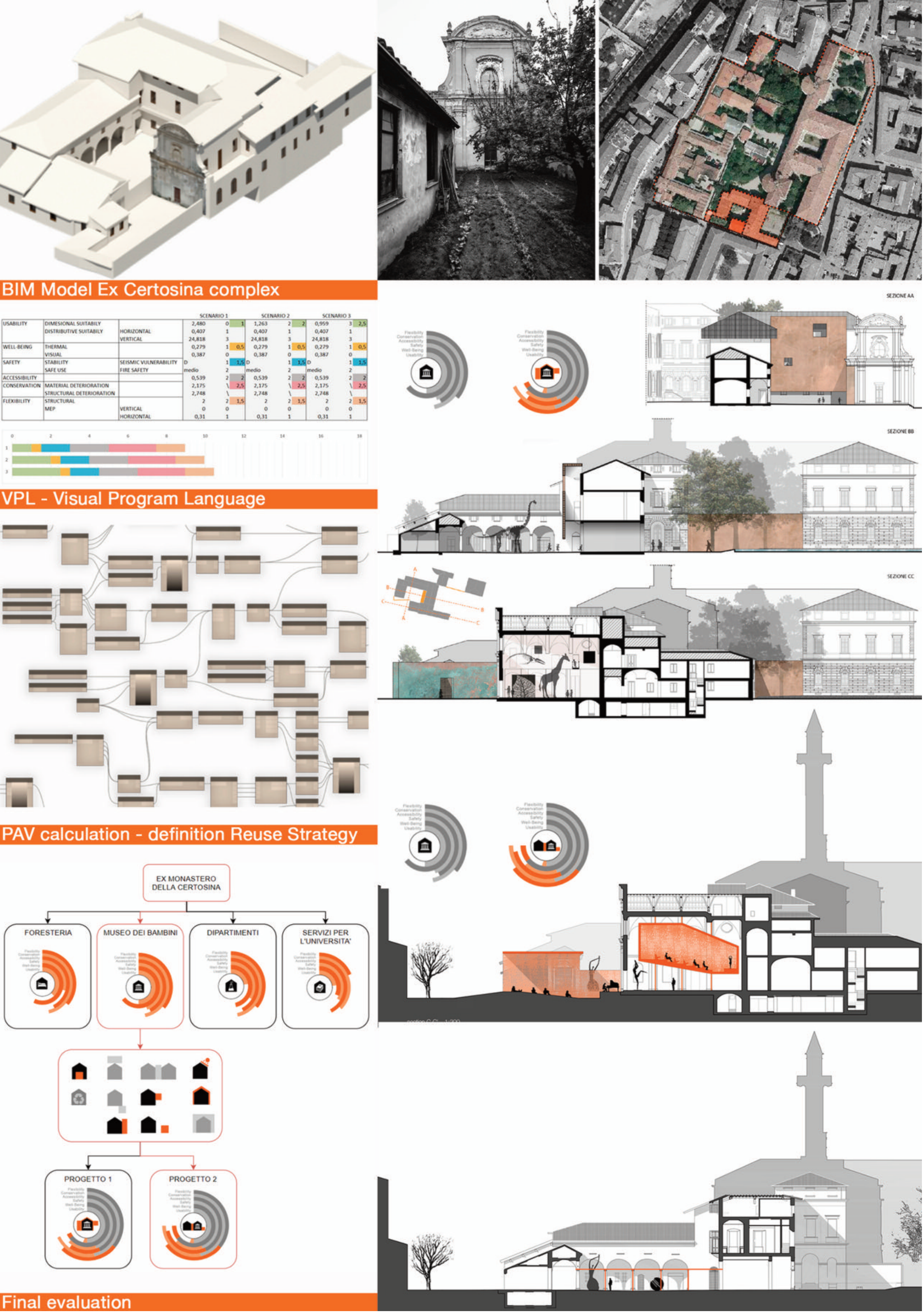


Fig. 6 | Application of Re^3 method to the Ex Certosina complex case study, Pavia.

with main existing building software already on the market such as BIM (Building Information Modeling) software and FM (Facility Management) platforms.

References

Berkes, F. Colding, J. and Folke, C. (2003), *Navigating social-ecological systems – Building resilience for complexity and change*, Cambridge University Press, Cambridge (UK).

Colucci, A. (2012), *Le città resilienti – Approcci e strategie*, Jean Monnet Centre of Pavia, Pavia. [Online] Available at: www.jeanmonnet-pv.it/Jean_Monnet_Centre_of_Excellence/publications_files/full_txt_colucci_jm.pdf [Accessed 24 November 2019].

Decreto Legislativo 18 aprile 2016 n. 50, *Codice dei contratti pubblici*. [Online] Available at: www.bosettiegatti.eu/info/norme/statali/2016_0050.htm [Accessed 25November 2019].

Decreto Legislativo 22 gennaio 2004 n. 42, *Codice dei beni culturali e del paesaggio*. [Online] Available at: www.bosettiegatti.eu/info/norme/statali/2004_0042.htm [Accessed 25 November 2019].

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T. and Rockström, J. (2010), "Resilience thinking: integrating resilience adaptability and transformability", in *Ecology and Society*, vol. 15, n. 4, art. 20. [Online] Available at: www.ecologyandsociety.org/vol15/iss4/art20/ [Accessed 24 November 2019].

Hassler, U. and Kohler, N. (2014), "Resilience in the built environment", in *Building Research & Information*, vol. 42, issue 2, pp. 119-129. [Online] Available at: doi.org/10.1080/09613218.2014.873593 [Accessed 24 November 2019].

Holling, C. S. (1973), "Resilience and Stability of Ecological Systems", in *Annual Review of Ecology and Systematics*, vol. 4, issue 1, pp. 1-23. [Online] Available at: www.jstor.org/stable/2096802 [Accessed 24 November 2019].

Jigyasu, R. et alii (2013), *Heritage and Resilience – Issues and Opportunities for Reducing Disaster Risks*, Global Platform for Disaster Risk Reduction, Geneva. [Online] Available at: nrl.northumbria.ac.uk/17231/1/Heritage_and_Resilience_Report_for_UNISDR_2013.pdf [Accessed 24 November 2019].

Morandotti, M., Besana, D., Cecchini, C. and Chiesa, A. (2019), "Challenges of sustainable reuse – A resilience-based approach", in Biscontin, G. and Driussi, G. (eds), *Il patrimonio culturale in mutamento. Le sfide dell'uso – Scienza e Beni Culturali, XXXV Convegno Internazionale 2019*, Edizioni Arcadia Ricerche, Venezia, pp. 331-342.

Petersen, S. and Svendsen, S. (2010), "Method and simulation program informed decisions in the early stages of building design", in *Energy and Buildings*, vol. 42, issue 7, pp. 1113-1119. [Online] Available at: doi.org/10.1016/j.enbuild.2010.02.002 [Accessed 24 November 2019].

Schlueter, A. and Thesseling, F. (2009), "Building Information model based energy/exergy performance assessment in early design stages", in *Automation in Construction*, vol. 18, issue 2, pp. 153-163. [Online] Available at: doi.org/10.1016/j.autcon.2008.07.003 [Accessed 24 November 2019].