

PAPER • OPEN ACCESS

A decision-making process for resilience assessment in adaptive reuse

To cite this article: M Morandotti *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **296** 012031

View the [article online](#) for updates and enhancements.

A decision-making process for resilience assessment in adaptive reuse

M Morandotti¹, D Besana¹, C Cecchini^{1*}, A Chiesa¹

¹ Department of Civil Engineering and Architecture (DICA), University of Pavia, Via Ferrata 1, 27100, Pavia, Italy

*cristina.cecchini01@universitadipavia.it

Abstract. In the field of public heritage valorisation through renovation, resilience assessment is crucial to foresee the impact of each project action, monitor the transformability thresholds and achieve more sustainable restoration projects. Within this framework, methodologies to achieve early evaluation of different project alternatives since the very preliminary design phases are supposed to be a key factor for the success of the building process, as it is highlighted by the Italian public procurement code (D.Lgs 50/2016). Therefore, the role of the contracting authority is crucial, as it is called both to activate the process through the definition of the project requirements and to accomplish the evaluation of the proposed solutions by respecting the principles of public interests, legality, transparency and responsibility.

In order to achieve these goals, the research proposes a standard methodology composed of a list of synthetic indicators and the criteria for their combination, aiming to assess the residual performances of the building and evaluate the compliance with new intended uses through the match with a set of conceivable design strategies. In this direction, two assessment tools are defined: the PAV (Performance Adequacy and Vulnerability), which is calculated on the actual state of the building for the evaluation of its residual efficiency with reference to some transformative hypothesis and then integrated in a grid of design strategies, and the RTE (Resilience Threshold Evaluation) though to measure the expected transformative impacts on the building and their positive or negative implications within its resilience thresholds.

The methodology is implemented in a BIM-based process with the definition of a simplified informative model that makes it possible to retrieve all the information and to define the calculation rules in order to activate the defined methodology with the advantage of ensuring time-saving, data-safety and transparency in the process.

1. Introduction

Recent debate on sustainable development increasingly includes resilience among its main topics, implying a more dynamic view of the future, where changing and not stability is the norm [1]. Originally coming from ecology where it is defined as the capacity of a system to react to the changes of its context [2], in engineering, resilience is mainly cited with relation to risk management, stressing that the preservation of variety within our natural and built environments is a key factor for development. While change is essential for evolution, adaptability and transformability are keywords of resilient thinking [3] and therefore heritage valorization through adaptive reuse [4] can be regarded as a successful strategy.

Descending to the building scale, resilience will be here meant as the acceptable transformative load that a generic building system is able to bear without compromising its physical, typological or historical identity. In this term resilience limits will be intended as the thresholds above which undesirable effects



would spoil the good, by altering irreparably its consistency and semantic coherence, if not its physical existence. Within the building process, this is translated in a research of the fragile equilibrium between the constraints dictated by the conservation needs and the fulfillment of the requirements of the contemporary users.

In this context, within a performance-based approach, the introduction since the first stages of the building process the evaluation of different design alternatives is believed to be crucial, as it is highlighted by the new Italian Public Contract Code (D.Lgs 50/2016 as modified by D.Lgs. 57/2017). This means the necessity of providing the actors involved (the public administration from one side and a series of competitors on the other) of shared multi-criteria analysis tools able to compare different strategies aimed at the satisfaction of a complex framework of needs.

In this paper the application of an assessment and evaluation methodology able to support and provide continuity to the building process is presented with particular reference to the preliminary stages of adaptive reuse projects that are developed through a design contest aimed at the acquisition of the technical and economic feasibility project.

2. A resilience-based assessment methodology

An ongoing research within the Laboratory of Science and Technology for construction and Planning (STeP lab) in the Department of Civil Engineering and Architecture (DICA) of the University of Pavia recently settled the theoretical methodology Re³ (Resilient Restoration and Reuse) for the preliminary assessment of existing buildings [5]. The final aim is to define a repeatable procedure for supporting decision-making in the first stages of adaptive reuse processes and to provide a set of tools able to compare different design hypothesis on the basis of a standardized assessment grid. The evaluation method integrates the performance-based building design approach [6] with the principles of resilient thinking applied to the built heritage, by facing the functional compatibility and the transformative impact control issues. The main goal is to guide the stakeholders in the achievement of a preliminary reliable knowledge framework on the existing building in order to understand both its attitude of transformation and resilience thresholds. Therefore, the workflow is developed through the sequence analysis/diagnosis/evaluation and includes two assessment indices able to estimate the leftover performances of an existing building with regard to different intended uses (Performance Adequacy and Vulnerability – PAV) and the impact of the transformative actions put in relation with the estimated resilience thresholds (Resilience Threshold Evaluation – RTE).

The PAV index is composed by six indicators calculated as the average of several parameters and divided by classes of need. Aiming to pursue a synthetic overview of the state of the building under examination, Usability, Well-being, Safety, Accessibility, Conservation and Flexibility are considered, according to Table 1. Each parameter is measured on a scale that goes from 0 (missing) to 3 (good), with reference to its adequacy in accordance to specific ranges of values coming from the Italian regulatory framework and technical standards.

Table 1. Definition of the six performance indicators of the PAV.

Usability		
Dimensional suitability		Available / Required area
Distributive suitability	Horizontal	Area served by corridors / Total Area
	Vertical	Maximum distance between stairs
Well-Being		
Thermal		Effective / Required transmittance
Visual		Rooms that meet the wfr [%]
Safety		
Stability	Seismic risk	Vulnerability class (D.M. 28/02/17)
Safe use	Fire safety	Risk level (D.M. 03/08/2015)
Accessibility		
		Accessible / Total area
Conservation		
Material degradation		Percentage of degraded surface
Structural degradation		Entity of cracks and fractures
Flexibility		
Structural		Span / Structural layout
MEP	Vertical	Maximum distance between shafts
	Horizontal	Room with false ceiling [%]

The RTE index is a tool aimed at the evaluation of the impacts of possible project alternatives, with reference to both desirable and undesirable effects. Each driver of transformation is divided in eight macro-actions, four negative (Material removal, Structural alteration, Spatial alteration and Identity weakening) and four positive (Future adaptivity increase, Design for all, Carbon footprint reduction and Safety increase), which can be meant as Boolean questions in order to define a “decision tree” drawn by eight control variables. However, by considering the complexity involved in the design process, its reduction to a set of yes/no queries seems unsuitable. That’s why the final output of the RTE Index involves a multi-criteria analysis, which takes into account the mutual relationships between the control variables. This is achieved through the compilation of a matrix that activates a pairwise comparison [7].

The proposed methodology has already been tested for the assessment of a part of the built heritage owned by the University of Pavia by integrating it within a BIM (Building Information Modeling) based process. The parameters used for the definition of the synthetic indices were retrieved in a semi-automated way from the informative model, thanks to the implementation of a series of scripts designed with VPL (Visual Programming Languages) [8].

3. The current legislative framework

The system of rules applied to public procurement and concession contracts in Italy has been recently reorganized with the issuing of the Legislative Decree 50/2016 as modified by Legislative Decree 57/2017. According to the texts, the design process is divided into three subsequent levels of planning: technical and economic feasibility project, final project and executive project (Art. 23). The characteristics of each stage of design are described in greater details in the draft of implementing decree called “Definition of the content of the design process in the three levels of planning” issued in December 2016. In particular, the first design stage could be defined into two steps:

- a. Identification and analyses of the possible alternative design solutions and draw up of the Feasibility Study of the Project Alternatives (DOCFAP). The DOCFAP shall consider also the so-called “zero option”, which is the hypothesis of non-intervention. In the cases of projects on existing building it should also highlight the impacts that each design strategy has on the context and on the historical, architectonic, structural and technological characteristics.
- b. Elaboration and development of all the investigations and the deliverables aimed at the identification of the dimensional, volumetric, typological, functional and technological characteristics and the relative financial framework of the project.

The attention is here focused in the case of intervention on the existing buildings and, in particular, in the preliminary phase of design, where the strategic choices on the project are taken and, therefore, where the implementation of a decision-making methodology is more effective.

The guidelines for the implementation of technical and economic feasibility project states that it can be developed inside the public administrations where appropriate internal professional skills in the subjects covered by the project are retrievable. Otherwise, as it happens in the vast majority of cases, the procedure of the design contest shall be activated. The procedure in all its stages is described in Art. 152 (D.lgs. 50/2016) and can be summarized as follows:

- The contracting authority publishes two tender documents focused on a performance based survey: the framework of needs (Quadro Esigenziale), which describes the specific qualitative and quantitative needs which have to be satisfied through the purchase, and the document of guidelines for planning (Documento di Indirizzo alla Progettazione), which identifies objectives to be pursued, functions to be performed, needs to be satisfied and performance to be achieved, along with the reference to potential technical proceedings or standards that the competitors are required to implement;
- In accordance with the tender documents, the competitors are called to draw up the Feasibility Study of the Project alternatives (DOCFAP), wherein a set of possible design solutions is identified and analysed under the qualitative profile by considering the environmental, technical and economical perspectives. In the delivery the alternatives should be identified thanks to descriptive and graphic outputs that highlight the key features of each proposal and a multi-criteria comparison based on a cost-benefit analysis is required in order to identify the most convenient solution;
- The contracting authority chooses the best design solution, by means of a commission, whose judgement shall express on each project on the basis of the criteria set out in the content notice with specific justification;
- The winner of the competition accomplishes its proposal and develops the design alternative that was selected by the administration and identifies for that one the volumetric, typological, functional and technological characteristics. In the end, the public contracting authority acquires the ownership of the project.

Although the regulation states that the first part of the design contest could take place in single stage, also then it is strongly recommended to perform an evaluation of the possible design alternatives.

4. The Re³ methodology in the current legislative framework

In the preliminary stage of the design process, corresponding to the publishing of the tender documents by the public administration, a consistent number of the most influential decisions on the project are taken [9]. That's why it become crucial to provide both sides with shared assessment methodologies and evaluation tools, in order to establish a chain of actions characterized by transparency and data integration. About this, with reference to the new Italian Public Contract Code some critical points to be filled with the present methodology are highlighted:

- The identification by the public administration of the most suitable framework of needs to be satisfied through the design process. In particular, the definition of the best intended use to be assigned with respect to the requirements of the community and the system of constraints related to the building and its context;
- The disclosure by the contracting authority of the constraints burdening on the planning, with reference to the conservation needs, the environmental context and the legislative framework, to be translated into a set of inadmissible design strategies;
- The multi-criteria analysis requested to the competitors for the evaluation of their design alternatives within the DOCFAP;
- The methods and the criteria of choice for the identification of the best design solution by the designated commission.

It is believed that all those findings could be fixed up by the introduction of a unique methodology of assessment and evaluation, able to equate both the investigation practices and the deliveries coming from the contracting authority and the competitors.

In view of the above and with reference to the case of reuse projects, the need for instruments that guides both administrators and designers in the achievement of a preliminary knowledge on the building is evident, in order to help understanding the performance adequacy and the attitude of transformation with its thresholds, with the aim of recognizing the impact that each transformative action could have on the existing building.

Figure 1 displays the integration of the Re³ methodology within the Procurement Code, with particular emphasis given to the actors involved and to the outputs of each phase. The numbered boxes along with their content will be examined in the following.

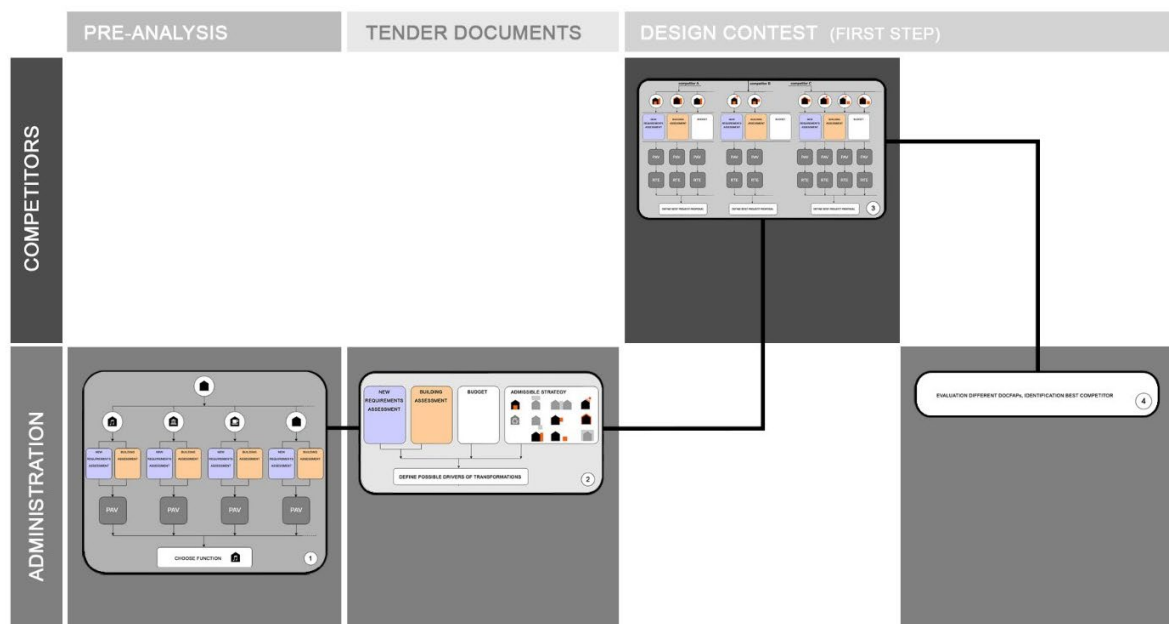


Figure 1. The Re³ methodology integrated in the design contest process.

4.1. Evaluation of the best function

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 with 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 building is crucial to balance the conservation needs and the transformation requirements expressed by needs' framework.

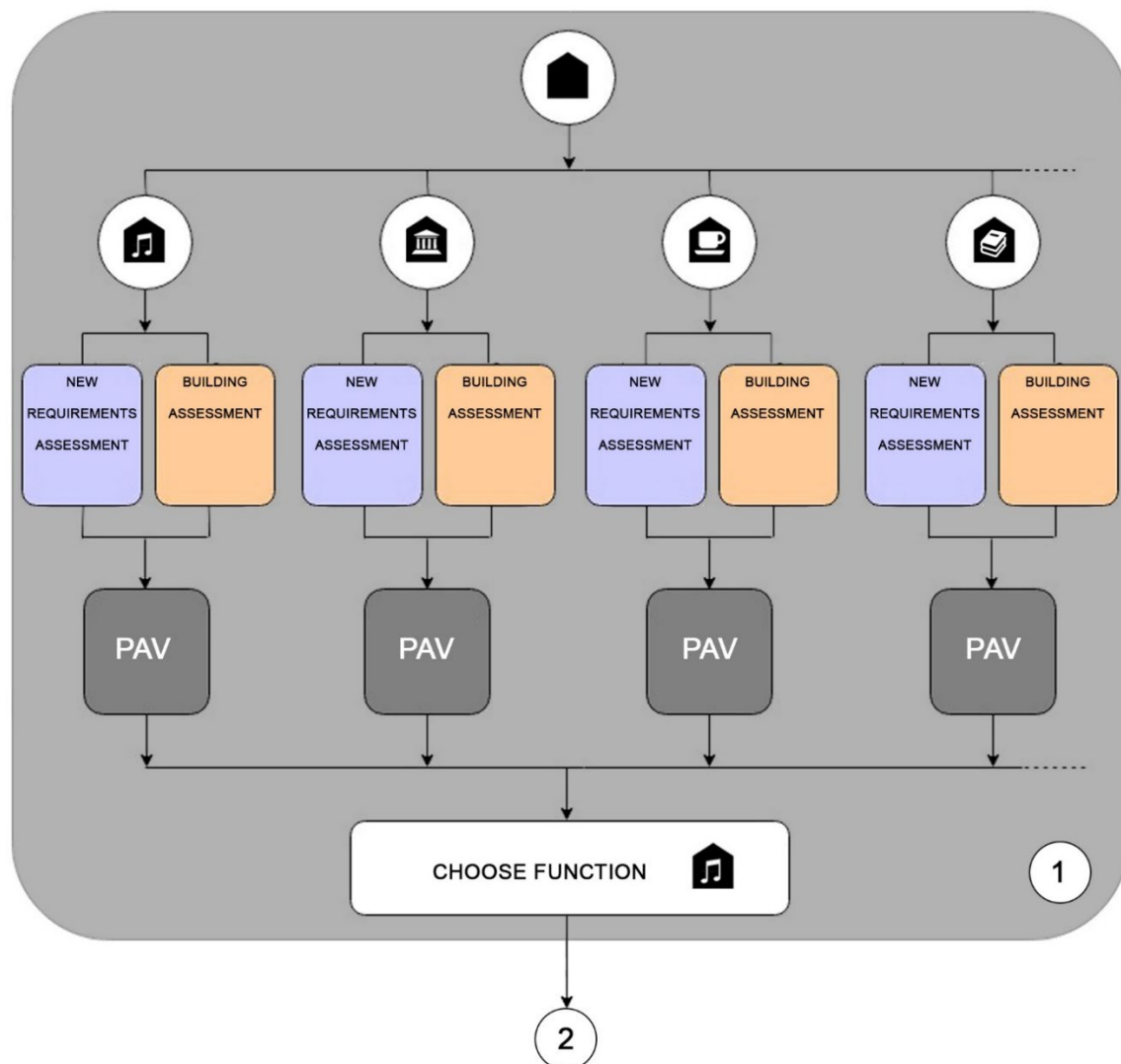


Figure 2. Proposed scheme of the meta-design phase.

This first stage is essential to start an effective process aimed at reuse projects, in order to be able to conceive design alternatives aware of their own impact on the building. The assessment on the grade of compatibility between the existing building and different intended uses is achieved by activating the same evaluation methodology for each possible solution (Figure 2). This passes through both new requirements and building assessment. The first is composed by the analysis of the requirements coming from the users, the regulatory framework and the energy saving necessity, while the latter includes the examination of the environmental, spatial and technological systems of building (Figure 3).

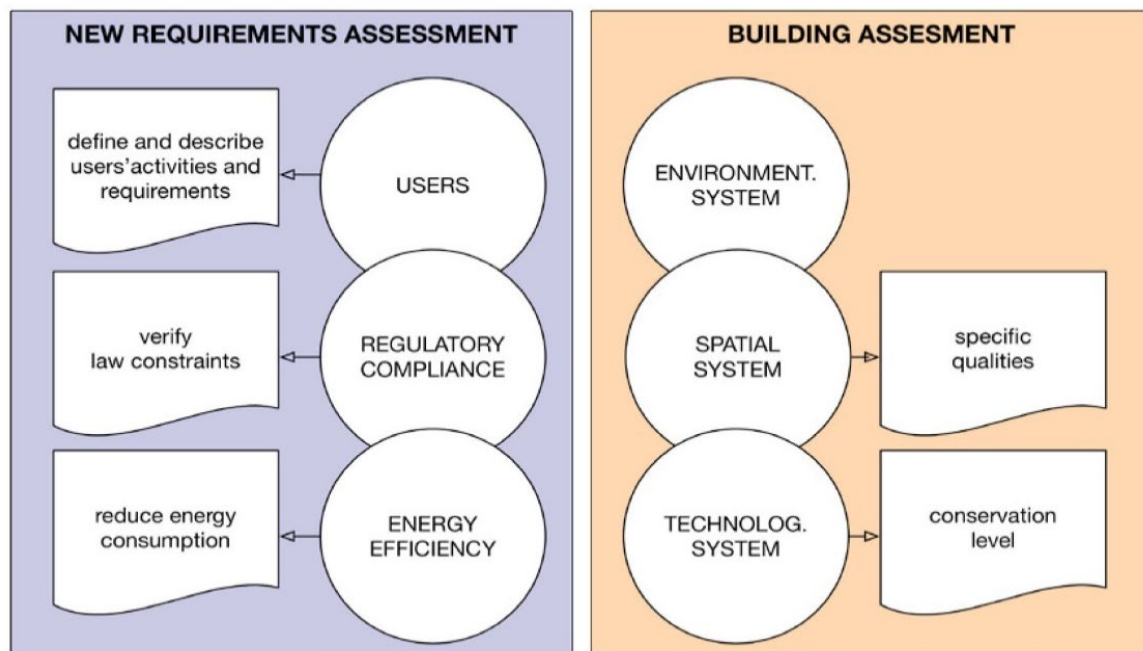


Figure 3. Specifications of the new requirements and building assessment.

Through the use of the PAV index, in fact, it is possible to estimate the residual performances of the building in relation to the needs expressed by the new users and relative functions. The comparison of the calculated indices (Figure 4) is intended to be a support for the decision-making process of the contracting authority, which will identify the most suitable reuse function to be included as an element of the procurement within the tender documents, as it will be described in the next subsections.

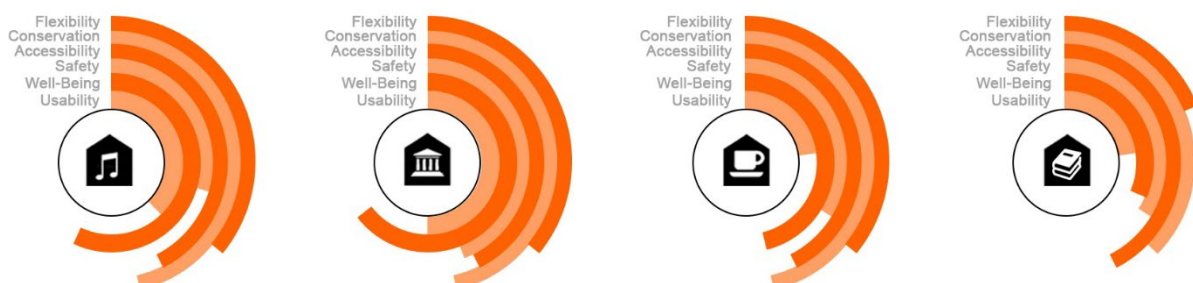


Figure 4. Example of a possible output for the comparison between the values of the PAV.

4.2. Definition of the design contest tender documents

After the accomplishment of phase 1, where the choice of the most suitable function takes place, the administration proceeds to define the set of already mentioned tender documents made up of contest. The new requirements and the building assessments are here incorporated from the previous stage along with the financial limits and a set of possible design strategies [10]. The strategies has been classified in eleven cases divided in three main clusters with regard to the relationship they generate among the existing building and the proposed project: Addition, Insertion and Recladding [11] (Figure 5).

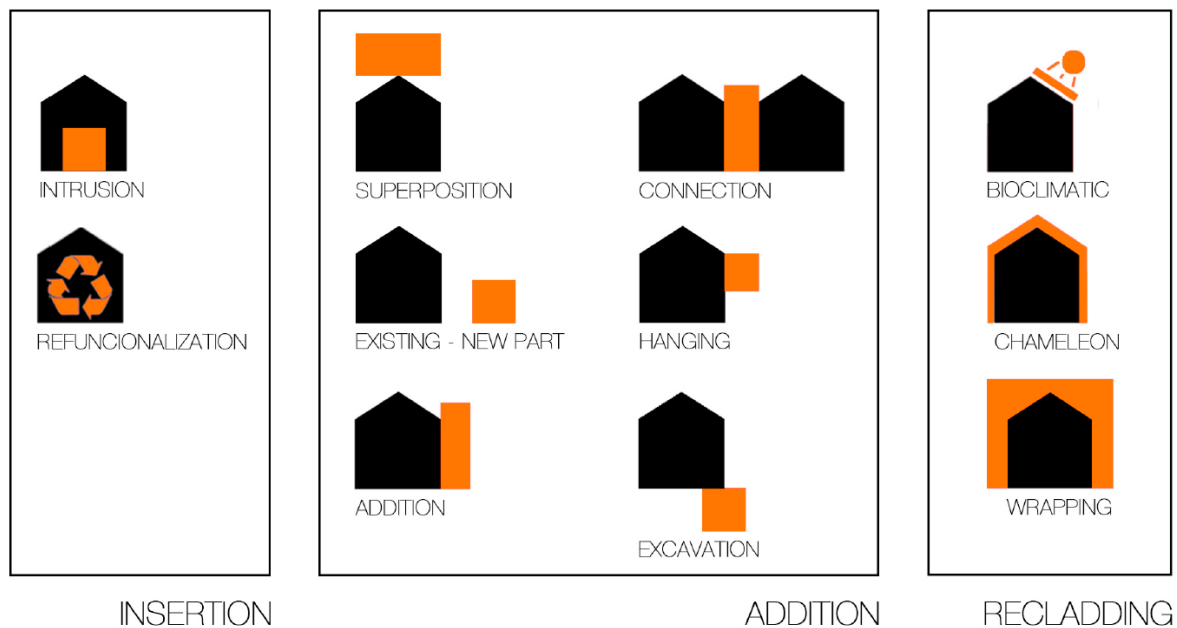


Figure 5. The eleven design strategies divided into three clusters.

Within this phase the identification of some selected strategies could be intended as a further recommendation or a technical procedure specified by the implementing regulation (Art. 3 Section 4). In order to establish the frame of constraints determined with regard to the urban context and to the building itself, a scheme containing the matrix of admissible/non-admissible design strategies will be provided (Figure 6).

The choice of several design strategies among the whole is strictly related to each specific context and is aimed at the exclusion of those deemed difficult to be developed or not feasible under different profiles. That's why it will takes place in a qualitative way, by considering several factors: the legislative framework (environmental, urban, economic, structural, and energy saving) and the potentialities derived from the building and its performance assessment.

At the end of phase 2, the set of tender documents narrows the domain of the project actions, addressing it towards the achievements of specific objectives by the administration. However, the freedom to decline the single strategy or their combination is left to the designers through one or more project proposals that will be formulated, developed and analyzed during the next phases of the design contest.

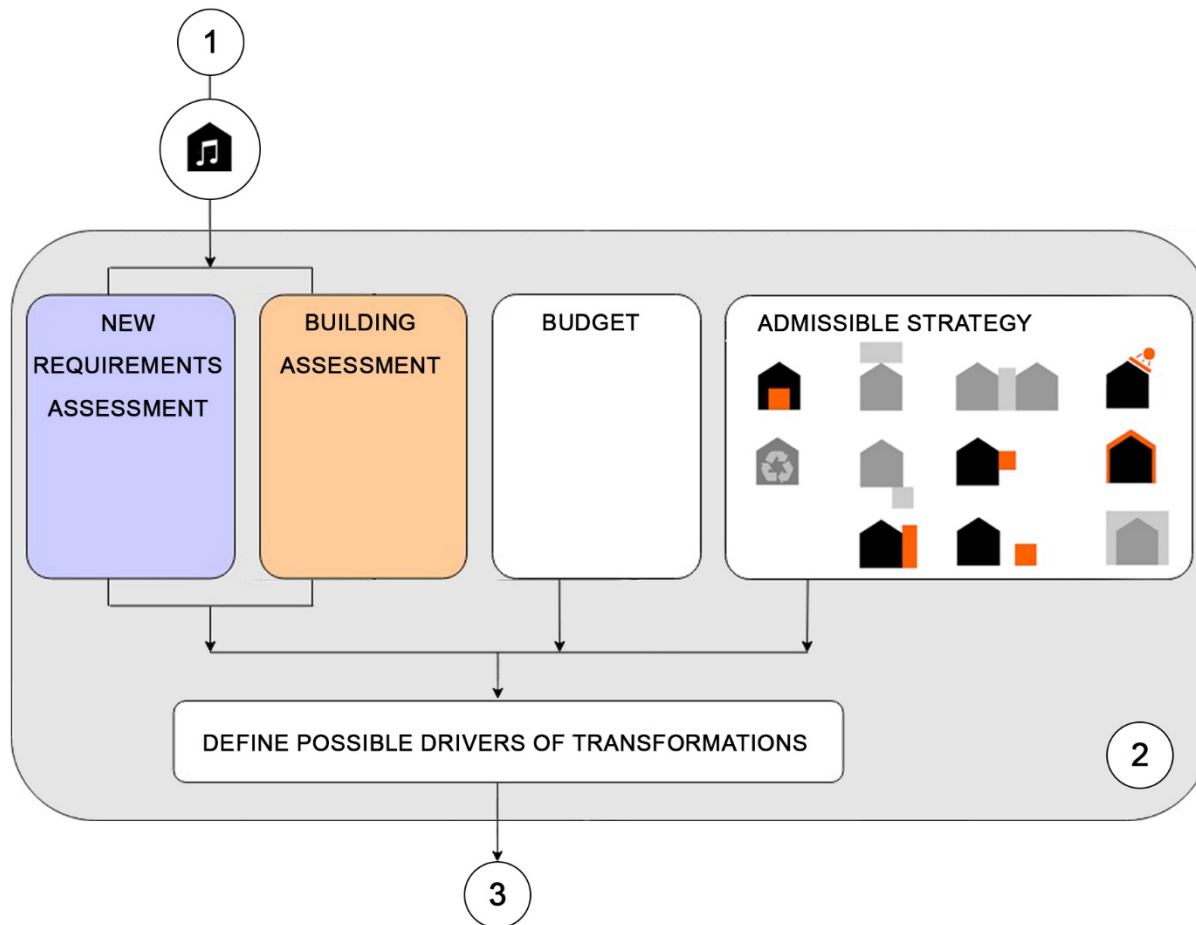


Figure 6. Scheme of the composition of the tender documents according to the Re³ methodology.

4.3. Design contest

In the design contest, the competitors involved are called to develop and analyze multiple design solutions (including the so-called “zero option”) 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. The competitors, with respect to the design strategies admitted in phase 2, develop projects that consider a single strategy or combinations of them. In this phase, the participants are asked to recalculate the PAV for a new assessment in relation to different design alternatives. Subsequently RTE index is evaluated in order to understand the impacts of the project actions with reference to the transformability thresholds of the building. It is the task of the single designer to choose in the range of the proposed solutions which is the best project alternative, in relation to the two indices and the financial limits (Figure 7).

The final DOCFAP, which each competitor should deliver at the end of the first phase of the competition, shows all the considered proposals, highlighting the one identified as the preferred one with the relative calculation of the PAV and RTE indices (Figure 8). In this way, the administration has the opportunity to compare quickly and easily the different proposed projects and to recognize which is the best one, with the aim of choosing the winner of the competition.

Thereafter the selected contractor will be called to complete his proposal in the next phases as defined in the implementing regulation within Art.8-14.

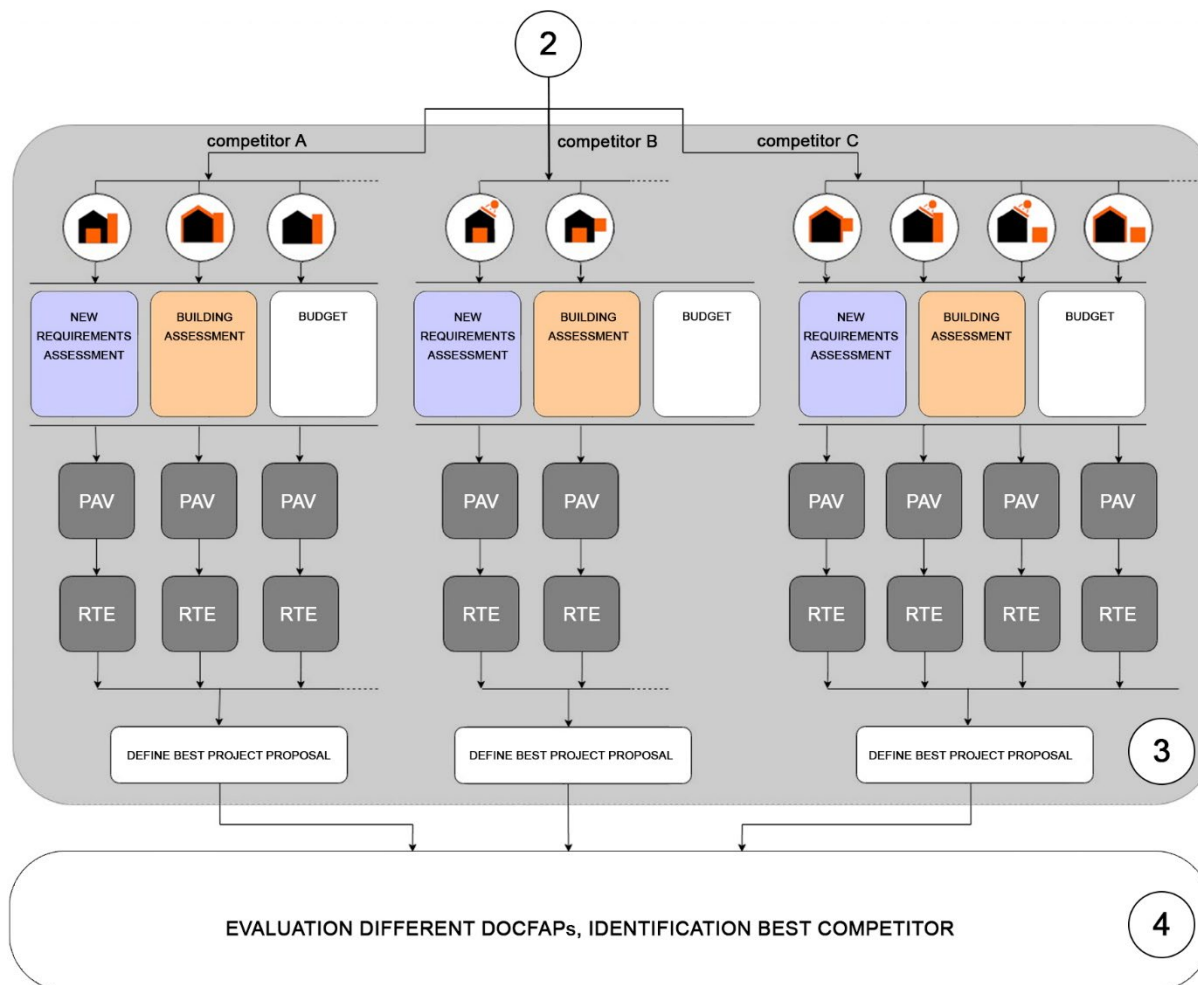


Figure 7. The methodology proposed for the design contest in order to select the best DOCFAP.



Figure 8. Possible results of the comparison between the RTE indices.

5. Conclusion and further developments

The research here presented allowed to identify and analyze the role that the Re³ (Resilient Restoration and Reuse) assessment methodology could have when integrated within the Italian Procurement Code (Legislative Decree 50/2016), especially with reference to the evaluation of different design proposals in the cases of adaptive reuse projects. The purpose is to provide the contracting authorities and the competitors involved in the design competition of a shared and standardized workflow in order to realize a more integrated and transparent process within the evaluation of different design alternatives.

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

References

- [1] Hassler U and Kohler N 2014 Resilience in the Built Environment. *Building Research and Information* **42**(2) 119–29
- [2] Holling C S 1973 Resilience and stability of ecological systems. *Annual review of ecology and systematics* **4**(1) 1-23
- [3] Folke C, Carpenter S, Walker B, Scheffer M, Chapin T and Rockström J 2010 Resilience Thinking: Integrating Resilience Adaptability and Transformability *Ecology and Society* **15**(4) 20–28
- [4] Bullen P A and Love P E D 2011 Adaptive Reuse of Heritage Buildings *Structural Survey* **29**(5) 411–21
- [5] Morandotti M, Besana D, Cecchini C and Chiesa A 2018 Il concetto di resilienza nel riuso del patrimonio costruito *Atti del convegno internazionale ReUSO Messina 2018* **2** 1879-90
- [6] Kalay Y E 1999 Performance-Based Design Automation in construction **8**(4) 395–440
- [7] Morandotti M 2018 Planning the re-use: sustainability through resilience evaluation of existing historical buildings *Innovative Built Heritage Models* 3 ed. Van Balen K and Vandesande
- [8] Morandotti M and Cecchini C 2018 BIM-based decision-making process for resilience assessment in adaptive reuse *HERITAGE* 2018 (Granada) pp 1439-49.
- [9] Petersen S and Svendsen S 2010 Method and Simulation Program Informed Decisions in the Early Stages of Building Design *Energy and Buildings* **42**(7) 1113–19
- [10] Besana D 2017 *[RICH*] Reuse and Improvement of Cultural Heritage* (Pavia: Aracne Editrice)
- [11] Besana D 2014 Re-writing historical buildings: strategies of intervention *REHAB2014. International Conference on Preservation, Maintenance and Rehabilitation on Historical Buildings and Structures* **1** 63-72
- [12] Besana D, Greco A and Morandotti M 2018 Resilience and sustainability for the reuse of Cultural Heritage *TECHNE - Journal of Technology for Architecture and Environment* **15** 151-159
- [13] Gigliarelli E, Calcerano F and Cessari L 2017 Heritage Bim, Numerical Simulation and Decision Support Systems: An Integrated Approach for Historical Buildings Retrofit *Energy Procedia* **133** 135–44
- [14] Morandotti M 2017 Riuso sostenibile. Un approccio basato sulla resilienza, *ReUSO Granada 2017* **1** 381-389
- [15] Wang H J and Zeng Z T 2010 A Multi-Objective Decision-Making Process for Reuse Selection of Historic Buildings *Expert Systems with Applications* **37**(2) 1241–49