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Energy resilience of historical urban districts: a state of art review towards a new approach

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Abstract

The paper points out the opportunity to address the current need for energy retrofitting of the historical built heritage according to a long-term perspective. For this purpose, it focuses on the concept of resilience, through a state-of-the-art review of ongoing studies and researches. Particularly, it pays attention toward the historical urban districts as integrated systems, where economic, social and cultural values should be protected in order to persist during the time. Thus, it recommends "sustainable" strategies that, beyond the thermal improvement, should achieve a resilient vision linked with the dynamic capability to adapt to climate changes by energy self-sufficiency.

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Keywords: energy resilience; adaptability to the climate changes; historical urban districts; energy improvement

1. Introduction

Following the oil crisis and the high level of environmental pollution, all the countries are undertaking different levels of actions aiming to re-create a new balance between humankind and nature (Kyoto Protocol). Starting from the nearest goals of the 2020 European program, all the European production sectors (construction, environment, transport, energy and so on) have reacted to decrease the CO_2 emissions and to exploit all kinds of energy useful to ensure the human well-being. Within this context, the building sector represents a crucial case as responsible of about 40% of non-renewable energy use [1]. Moreover, some on-going studies have demonstrated that more than 55% of CO_2 emissions could be decreased by retrofitting the building envelope [2]. Even if all the targets are required for new and existing buildings, the historical heritage has an uncertain destiny. In fact, two different points

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of view have to be analysed. In one hand, historical buildings represent the culture and practice of the "*genius loci*". Consequently, the preserving attitude is widespread. On the second hand, in some European countries (such as Italy and Spain), they represent a relevant share of the total building stock (residential especially). Furthermore, comparing their energy use and their extent, the real incidence on the total consumption and the emerging necessity to reduce it can be understood.

Analysing the European legislative framework, such as the Energy Performance Building Directive (EPBD) 2002/91/EU, the energy improvement of buildings is the overriding strategy. However, a particular treatment has been committed to the historical buildings. In fact, according to the energy directive, after the transformation of such buildings, "*their cultural and social values could be jeopardized*". Therefore, the EPBD waived all the mandatory transformations to improve the thermal transmittance of the envelope for them. Looking at this double perspective, several European research groups have encouraged different strategies of action aiming to decrease the energy consumptions and to preserve cultural and social values of historical architectures. However, all the experiences were applied to singular case studies, often on public structures, which do not represent the previously described majority. Other initiatives have been promoted by National Institutions, such as the Italian guidelines on "Energy improvement action for historical buildings". Nevertheless, they still follow a case-by-case strategy.

Such relevant experiences, along with the necessity to improve at the smaller urban scale the thermal behaviour of the buildings and with the absence of a specific legislative framework merged into some new singular cases. These ones, even if technically correct, have been alienated from the "*unicum*" of the context. In fact, although all the buildings in the historical centres could appear unique, they are actually the result of a particular combination of morphology, typology, construction techniques and materials, namely the result of a relation with the particular context where they are. For these reasons, an integrated and coordinated approach is required to improve their energy performances, by safeguarding the harmonious identity of the whole historical districts. Furthermore, a focus on the time limit is paramount. According to the law, all the targets previously described have a due time. In fact, the EPBD forced all the state-members to revise the targets every 5 years, so that all the previous case studies have been transformed working toward these temporary targets. Thus, the interventions represented surely a new positive starting and undoubtedly. However, the real problem of thermal equilibrium to increase energy consumptions is the evaluation of the evolving boundary conditions such as the changing local climate. Due to the increasing temperature, especially in the Mediterranean Area [3], the great challenge relates to the future energy point of balance, which ensures firstly the actual energy target and the future capability to adapt to new energy necessities and climate. Therefore, the proposal aims to understand how historical buildings could react after such particular stress. In fact, considering the historical residential buildings and their aggregates as a particular macro-system, the "*energy resilience to the climate change*" could be explicated as "*the capability of the macro-system to adapt to the future energy requirements caused by the climate changes*", starting from the analysis of the state-of-the-art of the resilience meaning and its features in literature. The present study represents the first step of a wider research work for the definition of a framework of integrated actions for energy improvement of buildings in historical districts in a long-term perspective.

Nomenclature

EPBD	Energy Performance Building Directive
UNISDR	United Nations International Strategy for Disaster Reduction
CRPP	Cities Resilience Profiling Programme
ACCCRN	Asian Cities Climate Change Resilience Network
MCEER	Multidisciplinary Centre of Earthquakes Engineering Research

2. Resilience meaning and the climate change challenges

Holling firstly introduced the concept of resilience [4], according to the ecological perspective, as the feature of a system "*to absorb changes of state variable, driving variables, and parameters, and still persist*". Thus, he underlined the capacity of the system to undergo disturbances and maintain its functions and controls [5]. Some following authors transposed the concept according to the engineering point of view, as the capability of a system to return in equilibrium upon a perturbation, without the possibility to think about other boundaries of the system.

Presenting this concept in complex systems, such as the social ones, the resilience has been strongly connected with the notion of "change", which is both what causes the perturbation and what characterizes the resilient behaviour. Walker [6] firstly defined that "*adaptation and transformation are essential to maintain resilience, as a prerequisite to persist*". Thus, the "*persistent system*", featured by a combination of adaptability and transformation, is able to reach a new state of equilibrium that could be different than the starting one or, better, it might be in higher thresholds.

Therefore, the new concept of "resilience" has been defined as "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks*" [6].

Starting from that, this concept has been also applied in other sectors defining the ecological urban resilience [7,8,9], the economic recovery [10,11] and the disaster recovery [12,13]. From those approaches, the widespread meaning of resilience is "*the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions*" [13].

This definition actually includes in the scientific literature the wider topics on the linkage between disaster and human well-being. Actually, all the disasters have been defined as the consequence of the climate change and the human responsibility on the environment. The key challenge is to understand both how to preserve human safety against hazardous disasters and to prevent disasters themselves. Moreover, a particular focus is on the urban environment and its evolution that represents the milieu where all the human activities take place. As commonly known, the cities represent a complex system and the planning strategies are closely related to the actions that make them resilient to the disasters. All the authors agreed to face the topic by a holistic approach taking into account the multidisciplinary aspects and the multi-dimensional identity of the cities, where social, economic, cultural and environmental problems interact with each other in a dynamic way.

2.1. Urban resilience experiences

The United Nations International Strategy for Disaster Reduction (UNISDR) and UN-HABITAT represent the international organizations, which gave the greatest contribution to the urban resilience. Actually, such non-academic institutes have produced research and practical activities that merge in a system of guidelines and best practice. The most relevant campaign promoted by UNISDR is 'The Making Cities Resilient: 'My City is getting ready!'' in 2010 [14]. It proposed a framework of actions to support the local governments for the disaster reduction in urban activities and the human safety in urban life through "10 Essentials" characters. In detail, the urban resilience has been conceived as the overlapping of infrastructural, institutional, economic and social sub-categories of the macro-problem.

Similarly, the ongoing "Cities Resilience Profiling Programme" (CRPP) of UN-HABITAT organization, is overcoming the conventional approaches to 'risk reduction', delivering a forward-looking, multi-sectorial, multi-hazard and multi-stakeholder model for building resilience that recognizes the complexities and unique value of the cities, as well as the inherent interdependencies of each part within an urban system. The goals of the program are essentially five [15]:

- equipping urban managers with tools and information to calibrate and measure resilience in order to make informed governance and investment decisions;
- mobilizing transformational, sustainable improvements to the physical, spatial, and functional elements of the cities as safeguard against multiple hazards (both natural and anthropic) and ensure continuity of urban processes and services;
- empowering the cities to 'do more with what they have' and catalyse new finance opportunities by promoting resilience as a criterion for investment;
- improving accountability in local level policy and budgetary decisions;
- providing a common, global understanding of urban resilience through the development of indices and standards.

Simultaneously, academic researchers are trying to develop a system to quantify urban resilience. However, the results still focused on particular problems of the whole city such as urban infrastructures and transportation networks [16].

Furthermore, both research organizations started working on the connection between disaster risk and climate change. However, no study is facing the problem of the energy resilience for the built environment to solve the equilibrium between human well-being (social, economic and comfort) in the dwellings and the uncertainty of the future climate conditions.

2.2. Resilience of historical sub-districts

Considering the historical centres as a part of the whole city, with a particular focus on the residential stock, specific features can be often drawn. According with the land taxonomy by the Italian city planning, all the post II World War buildings are included in the historical centres and traditional construction techniques distinguish them from the remaining residential buildings of the cities. Actually, 24% of the total residential stock in Italy was built before 1945 and 34% between 1945 and 1980 [17].

The paper focuses on that 58% for two reasons:

- first of all, the ecological and sustainable importance of reusing existing buildings to prevent form new land-use, as well as of saving the potential energy for their demolition and re-construction;
- on the second hand, the cultural, social and economic values that such buildings represent and that the Italian law strictly safeguard.

Several researches have faced the above-mentioned topics separately. However, re-use of available resources and persistence of inherent values should be closely related to ensure the "resilience" of the historical heritage, where, according to John Ruskin "*the use of it ensures that it persists*" [18].

Therefore, the system of the historical built heritage might be described as a social, economic and cultural sub-system of the whole city, which copes with the climate change challenges too.

Therefore, this kind of construction has to guarantee the high quality and sustainability of life, even by changing itself. The academic literature faced with the complexity of such cases by analysing singular case studies or the whole sub-system and by trying to transform it beyond traditional techniques and materials. Though such examples faced the energy efficiency for historical buildings, the current energy law pertains to the short period. On the contrary, the idea of the persistence of values for such building heritage has to encourage the research towards transformations and actions that take into account the future uncertain conditions linked with the climate changes. Therefore, the energy resilience of the historical urban districts arises in such a dynamic and multilevel context, starting from the required high life quality and persistence of the historical building heritage.

Along with the well-being and the preservation, a new acceptation of "disaster" caused by climate change could be introduced in this new perspective of "urban resilience".

2.3. Historical districts resilience features and indicators

Historical architectures, as result of "genius loci" activities, are featured by three factors that became important to ensure their resilience:

- interaction with the local and current climatic and socio-economic conditions;
- interaction with the evolving environment during the time;
- social belonging to the places and the material and immaterial culture they represent.

Therefore, the resilience of the historical districts involves three macro-levels:

- socio-cultural resilience, referring to the widespread knowledge, from the habits to the building cultures, that bets on the identity of each community for each place; analysing this feature in the present city, the assessment of the social and cultural identity of each historical building becomes the key to cope the external disturbances and to ensure smart activities of transformation, as well as its management;

- socio-economic resilience towards the "*self-sufficiency*"; this aspect in the present city is a crucial problem, due to the legislative protective restrictions. It concerns the possibility to use some of the buildings as workplaces and commercial activities in order to revitalize the districts, as well as the opportunity in order to implement energy renewable systems for self-sufficiency. However, the self-sufficiency will go beyond the oil-dependency (according with the sustainable vision) and the necessity to link with the whole energy distribution grids of the city;
- environmental resilience aiming to cope with the climate change as the increasing future temperatures and the heat island effect in the city; this aspect is also linked with the energy self-sufficiency but it represents the cornerstone of long period actions to face the uncertainties of the future environmental conditions.

Within this framework, previous studies [19,20,21] in each sector, analysed the most relevant factors which influence their area of interest. Their interdisciplinary influences can be underlined in Table 1, considering the impossibility to make a focus on single areas and the necessity to explain some effects introducing the relation with others.

Table 1. Socio-economic, socio-economic and environmental factors for three focus on "resilience" problem.

	Socio-Economic	Socio-Cultural		Environmental	
	[19]	[19]	[20]	[20]	[21]
factors	nature of markets	migration	demography	informal urban spaces	infrastructures
	environmental variability		knowledge		institutions
	stability of livelihoods				

In order to guarantee the well-being and the preservation of the historical built heritage, two features have to be studied to make the historical building system resilient: flexibility to the transformation and adaptability.

Walker included these two characters in the concept of resilience, as it follows:

- "*Adaptability is the ability of actors in a system to influence resilience*". For that reason, adaptive capacity can be considered as the attitude to conserve the internal features of the system despite the external stresses;
- "*Transformability is the capacity to create a fundamentally new system when ecological, economic or social structures make the existing system untenable*". Thus, transformability can be considered as the opportunity to recreate a new sustainable system featured by a new equilibrium.

Beside those definitions, some sub-categorizations were proposed by other researches, within the ACCCRN program [22] that includes different fields of interest as urban infrastructures, Disaster Risk Reduction and International Development. Similarly, the Multidisciplinary Centre of Earthquakes Engineering Research (MCEER) [23] considers a particular field of action. In spite of their different research areas, Table 2 underlines how some features are narrowly linked to the other issues of the resilient experiences for every implementation field.

Table 2. Features of Resilience experiences of ACCCRN [22] and MCEER studies [23]

	[22]	[23]
Features	Flexibility	
	Redundancy	Redundancy
	Resourcefulness	Resourcefulness
	safe failure	
	Responsiveness	
	Capacity to learn	
	Dependency of local ecosystem	
		Rapidity
		Robustness

Therefore, adaptability and transformability - and their sub-features - are the keywords for the persistence of whichever system. However, in the case of historical urban districts, the two macro-actions have to be applied at three levels of resilience, namely socio-economic, socio-cultural and environmental, and by two steps, namely:

1. understanding the likelihoods and the "values" to preserve and the consequent activities to ensure their capability to adapt and to persist at external strains;
2. studying the opportunities of transformation aiming to create an integrated system of actions which could renovate it.

So, according with the aforementioned overview of studies, the crisis of the system and the resilience experiences must be considered above all as an opportunity to change [24] toward a more suitable equilibrium.

3. New strategy for historical districts resilience

Previous studies validated strategies to ensure the desirable balance between improvement requirements and preservation principles applying them on singular buildings or on a restricted number of buildings. Moreover, the energy upgrading capability was analysed in terms of actual performances of the envelope components and their thermal features required by law. Nevertheless, these approaches underlined the necessity to operate mainly on ceilings and walls sub-systems, investigating both traditional and innovative retrofitting materials and technologies. Particularly, innovative solutions seem to be the key to achieve the highest effects in energy improvement even if the special analysis of their integration in the historical envelope was required [25]. A particular focus was on summer conditions that represent the emerging challenge for energy improvement in Mediterranean climate [26].

The energy assessment and, consequentially, the strategy of integrated actions at the district scale represented the second level [27] to validate the feasibility of transformation, through the safeguard of the embodied historical values. The transition from the single building to the whole district scale has overcome the common "case by case" approach. In fact, such an approach might cause fragmented and isolated actions within the historic urban districts where, despite some distinctive architecture, the built heritage is the result of a common process of construction, transformation and adaptation.

Starting from them in a long time perspective, according to the meaning of resilience, a new approach, as the first step of the whole research, is proposed as it follows (Fig. 1):

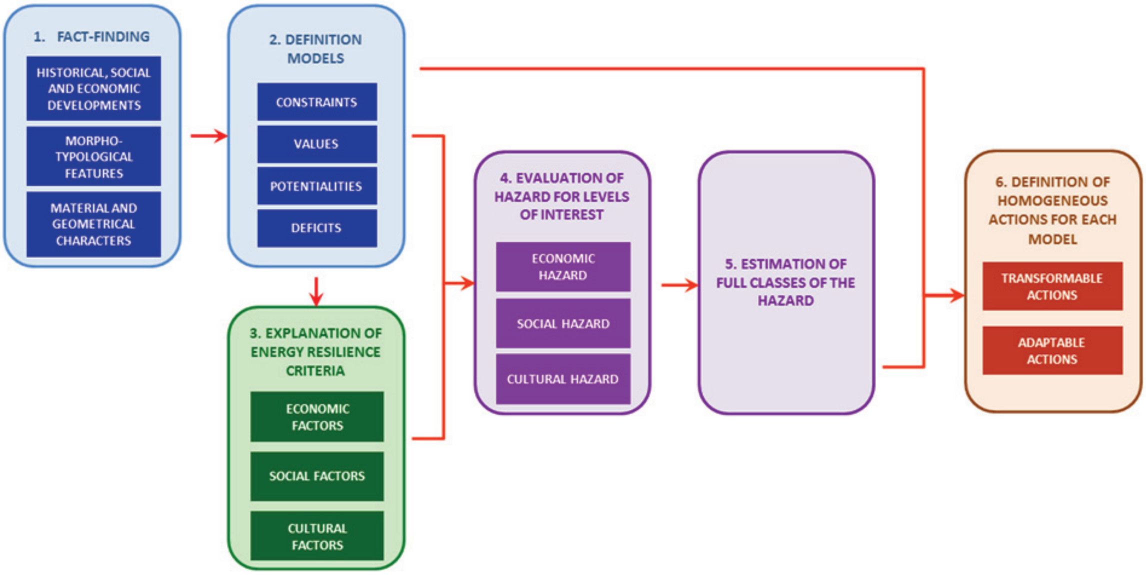

Fig. 1. Flow chart of the approach

1. first point fact-finding phase. It is an assessment step aimed at the collection of analytical, historical and experimental data of a representative sample of Mediterranean cities. It results in an informative system on:

- historical, social and economic developments of the districts;
- morpho-typological features;
- material and geometrical characters;

2. second point definition of models, starting from the taxonomy of the collected data. It delineates the classes of constraints, potentialities, values and deficits for each sample in order to understand how the same features could be integrated toward an harmonized transformation;

3. explanation of energy resilient criteria, transposing the urban resilience features described in the previous chapter, in order to identify the hazard factors for each level of interest (economic, social and cultural);

4. evaluation of sub-classes of hazards for levels of interest, starting from the hazards of each factor to the total of them for each area of interest in order to understand some preponderant factors;

5. estimation of the full classes of hazard, overlapping the sub-classes as a sum of effects or as a weighted average according with the necessity and the previous results;

6. definition of systems of homogeneous actions for each model, for each factor and for each hazard level, according with the uniform identity of each historical district, by separated adaptable and transformation actions.

In particular, the first phase embodies the preliminary investigation on the historical districts at four levels. At the site level, geographic data, local energy regulations, safeguard codes and biophysical configuration will be studied to create a first overview of the place. At the second level, the district analysis will be carried out in terms of historic, social and economic evolution of the settlement, typology of buildings and bioclimatic quality. Sequentially, the sub-district level will be evaluated based on available aggregate data on population density, supply by electricity, gas, water grids and energy consumptions. Finally, at the building scale, all the information about dimensions and materials, construction techniques, HVAC systems, state of conservation and previous maintenance or refurbishment works will be collected to complete in detail the investigation.

This study is useful to collect and to assess the values and the potentialities, as well as the deficits of the historical district that should be checked to define the transformation and adaptation feasibilities and "*invariants*" to preserve.

In the second phase, all the above-mentioned features will be combined to define a finite number of models, which represent the whole district. For example, within the models, all the buildings will be described in terms of physical performances (thermal transmittance), as shown in the tower house model from a previous study (historical centre of Molfetta in South of Italy) in Fig. 2. There, the influence of each performance on the heating and cooling saving could be evaluated by means of iterative heat transient simulations. Moreover, by the models, all the features linked to the invariants (material, typological, technological) could be represented and the whole historical districts could be outlined as a system of a limited number of "*Types*" of buildings and energy behaviours.

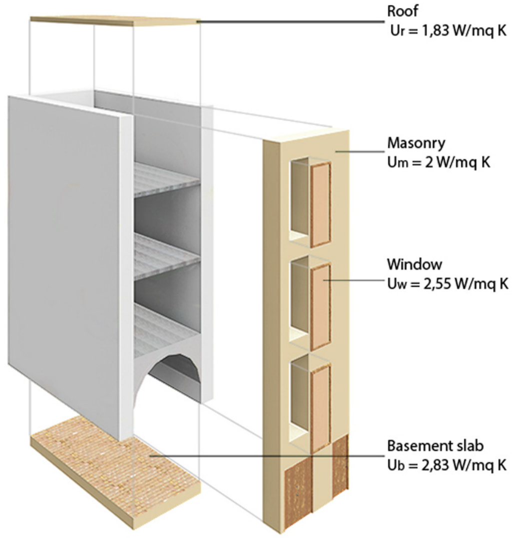

Fig. 2. Example of a model of the tower house and his thermal features in Molfetta historical district (Italy).

Such a geo-clustering method for the whole district will surely help the analysis and the management of the studies at the large scale.

At the end, the process analyses and quantifies the hazards in three levels of investigation (social, economic and cultural) aiming to plan strategic actions to decrease hazards in homogeneous parts of the district. Furthermore, it will really help the administrations manage the complexity of each real case and simplify the decision-making actions.

4. Conclusion

Starting from an overview on the concept of "resilience" in the scientific literature, the paper focuses on the role of the historical buildings in a resilient perspective, linking the actions toward their energy improvement to the climate changes effects, adapting the features of resilient cities and focusing on the social, economic and cultural consequences.

The paper represents the preliminary step of the whole research that aims to define a framework of integrated actions that could decrease the hazard of historical buildings in accordance with their energy improvement and preservation, at the macro-scale, also ensuring the homogeneous identity of the whole sub-districts. This research will be integrated with the analysis of the real factors of energy resilience that were herein briefly discussed, underlining the interconnections that might exist between them.

The final goal could certainly help public administrators in the decision-making support. In fact, a computerised system of management might be useful to identify the actions and to store data of each particular case study; that might foster a virtuous cycle with the exchanging of data and knowledge.

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