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Editors

Regeneration of the Built Environment from a Circular Economy Perspective

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Preface

The chapters included in this book give a kaleidoscopic selection of conceptual, empirical, methodological, technical, case studies and research projects, which implement the concepts of circular economy to the regeneration of the built environment. This means enhancing the understanding of sustainability to a broader paradigm, developing a number of practices concerning energy, raw materials, waste, health and society. In particular, a set of theoretical and methodological contributions introduce the theme of the socio-economic development of territories, while the three following sections deal with the challenge of closing the loops of the construction sector—on the one hand, focusing at the larger scale of urban regeneration and, on the other hand, deepening new ways of activating sustainable and resilient paths at the level of the building materials' production, and eventually foreseeing novel policies, tools and organizational models of the building performances' improvement through the reusing, recycling, up-cycling and remanufacturing strategies, applied to the built environment.

This book belongs to a series, which aims at emphasising the impact of the multidisciplinary approach practised by ABC Department scientists to face timely challenges in the industry of the built environment. This book presents a structured vision of the many possible approaches—within the field of architecture and civil engineering—to the development of researches dealing with the processes of planning, design, construction, management and transformation of the built environment. Each book contains a selection of essays reporting researches and projects, developed during the last six years within the ABC Department (Architecture, Built environment and Construction Engineering) of Politecnico di Milano, concerning a cutting-edge field in the international scenario of the construction sector. Following the concept that innovation happens as different researches stimulate each other, skills and integrate disciplines are brought together within the department, generating a diversity of theoretical and applied studies.

The papers have been selected on the basis of their capability to describe the outputs and the potentialities of carried out researches, giving at the same time a report on the reality and on the perspectives for the future. The cooperation of DABC scientists with different institutional and governmental bodies (e.g. UNESCO, UIA,

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EACEA, EC-JRC, ESPON, DG REGIO) as well as their participation to sectoral boards and committees (e.g. ISO, CEN, UNI, Network Android-Disaster Resilient, IEA, Stati Generali della Green Economy, Green Public Procurement, Associazione Rete Italiana LCA, Lombardy Energy Cleantech Cluster) and their dialogues with institutions (e.g. national ministries, regional government, local administrations) led and motivated the selection of the essays.

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Introduction

The regeneration of the built environment represents a prominent research field for all scholars and professionals interested in the creation, evolution and transformation of the urban environment and the relationships between urban, peri-urban and rural spaces. In spite of its well-established and long tradition, this field of enquiry has not yet become depleted but rather is receiving renewed attention and has become compelling in the scientific community for the co-occurrence of multiple trends and phenomena. First, recent times are characterised by an impressive rate of urbanisation, and projections forecast increased urbanisation for the future, especially in less developed and developing countries. Second, the increasing constraints on the widespread availability of economic, social and environmental resources push towards the ideation, prototyping and application of new solutions as to accommodate this quest for urbanisation. Third, the need to continue to take care of, adapt and maintain the heritage of historic cities, especially in advanced countries, and in the light of these constraints, require the experimentation of new approaches to the requalification and renewal, both material and functional, as well as new methodologies of intervention, more error-friendly and based on the reversibility of the current actions, in order to guarantee future generations the possibility of revising the approaches in view of more advanced tools and procedures.

This volume then aims to take on this challenge and proposes a reflection on the strategic importance and advantages of adopting multidisciplinary and multi-scalar approaches of enquiry and intervention on the built environment which are based on the principles of sustainability and on circular economy strategies. In fact, the regeneration of the built environment can represent an important cornerstone in the transition from a linear to a circular economy model through multiple actions that can take place at different scales, i.e. the recycling and reuse of building artefacts, products and components, the improvement of the quality and functionality of existing buildings, the valorisation of cultural heritage, the re-infrastructure and implementation of sustainable transport systems and the efficient use of local economic resources.

In order to address the abovementioned overarching research challenge, this volume identifies specific challenges according to a macro-to-micro unit of analysis

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ranging from the city itself as an aggregated unit of analysis, to the district/building, from sustainable innovative products and processes to be developed and deployed in the construction sector to multi-scalar strategies to improve building performances.

Starting from the most aggregated level of analysis, the first specific challenge addressed in this volume refers to the possible strategies to relaunch socio-economic development in urban environments through regenerative processes. The key concern, then, is how the regeneration of the built environment can promote not only economic growth processes but also the efficient use of local economic, social and environmental resources, from a circular economy perspective and consistently with sustainability principles.

The second specific challenge relates to the regeneration of urban spaces from a resilient and circular perspective. The key concern in this case is how regeneration of the built environment can be achieved through the reuse and requalification of existing buildings by developing efficient, structurally adequate, resilient, adaptive, flexible and convertible building systems; through the requalification of abandoned and peri-urban areas by planning construction and demolition, by managing and/or reusing building waste, by promoting sustainable buildings, by limiting land use, by activating virtuous and innovative circular processes between primary and secondary materials; and through the requalification of the urban fabric in minor centres by promoting the history and identity of rural villages and peri-urban areas as to favour their conservation and resilience with respect to risk factors such as earthquakes.

The third specific challenge is associated with the development and the deployment of innovative products and processes in the construction sector in the effort to move towards sustainable and circular principles. The key concern then refers to the ideation of new components, products, systems and processes starting from the reuse of existing products and materials that can lead to changes in the construction sector filière as well as to the use of innovative materials aimed at promoting the development of structural requalification technologies and techniques based on the use of materials that have been recycled or can be easily recyclable/convertible, according to a circular economy perspective.

The fourth and last specific challenge is linked to the development of multi-scalar (i.e. from the building to the city) approaches for enhancing the performances of the existing building stock, as well as of the new buildings. This concerns multi-scalar strategies as to mitigate climate change effects by limiting local metabolism, by improving energy efficiency practice, by integrating locally available resources, by diffusing smart buildings, systems and grids as well as by implementing actions to improve the existing buildings and public spaces with the aim of reducing risk factors for individual and collective health, of promoting built environment quality from both a social and environmental perspective along all phases from the project, to construction, from use to maintenance and dismantling.

Addressing these complex fields of research requires the availability and the integration of multiple disciplines that span from engineering to architecture and regional and urban economics and studies. Such multidisciplinary, in fact, enables to disentangle and to unpack the multidimensional nature of all processes impacting

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on built environment regeneration. The Department of Architecture, Built Environment and Construction Engineering (DABC) of Politecnico di Milano, with its multidisciplinary faculty composition, is well-equipped to address all these research subjects and has launched over time a series of national and international research projects that explore and analyse in depth how these challenges can be addressed. Additionally, the international openness of the studies conducted at DABC enables a comparison with the most advanced research—basic, applied, technological and project-based—conducted abroad.

In particular, this volume offers a rich and kaleidoscopic selection of the most prominent conceptual, empirical, methodological, technical, case study and project-based researches conducted by the members of DABC and that are the outcome of national and international research projects carried in collaboration with other universities and research centres, also on behalf of institutional and governmental bodies (e.g. UNESCO, UIA, EACEA, EC-JRC, ESPON, DG REGIO); of participation to sectoral boards and committees (e.g. ISO, CEN, UNI, Network Android-Disaster Resilient, IEA, Stati Generali della Green Economy, Green Public Procurement, Associazione Rete Italiana LCA, Lombardy Energy Cleantech Cluster); of dialogues with institutions (e.g. national ministries, regional government, local administrations).

The design of this volume follows the challenge logic sketched above. Accordingly, the volume is organised in four main sections, each addressing one of the four specific challenges listed above and opening with an introduction written by the volume editors. Given the multidisciplinary nature of this volume, the allocation of each contribution in a specific section is not watertight but, in our view, the proposed structure of the volume serves as a useful structure of central themes in the research field on the regeneration of the built environment from a circular economy perspective.

Sara Cattaneo
Camilla Lenzi
Alessandra Zanelli

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About the Editors

Stefano Della Torre who graduated in Civil Engineering and in Architecture, is a Full Professor of Restoration at the Politecnico di Milano in Milan, Italy, and Director of the ABC Department (Architecture, Built Environment and Construction Engineering). He is the author of more than 360 publications. He served as an advisor to the CARIPLO Foundation (Cultural Districts), the Italian Government and Lombardy Region (policies on planned conservation of historical-architectural heritage). He has been President of BuildingSMART Italia – the national chapter of BuildingSMART International (2011-2017).

Sara Cattaneo has been Associate Professor of Structural Engineering at Politecnico di Milano since 2011, where she received both her MS and PhD in Structural Engineering. Since 2017 she has also been an Associate at the Construction Technologies Institute, Italian National Research Council (ITC-CNR). Examples of her wide-ranging research interests include fracture and damage of quasi-brittle materials, constitutive behavior, and the structural response of high-performance and self-consolidating concrete. She has been involved in a number of research projects at the national and European levels. Since 1999 she has spent periods at the Department of Civil Engineering of the University of Minnesota (Minneapolis, USA), where she has been a Visiting Professor. She is the author of more than 100 papers in international journals and international conference proceedings and serves as a reviewer for several international journals.

Camilla Lenzi has been an Associate Professor of Regional and Urban Economics at Politecnico di Milano since 2015. She holds a PhD in Economics from the University of Pavia and a Master of Science in Industry and Innovation Analysis from SPRU – University of Sussex, UK. From 2005 to 2008, she was a postdoctoral fellow in the Department of Economics of Bocconi University and CESPRI (now I-CRIOS). Her main research interests are in the fields of regional and innovation studies, urban economics, highly skilled worker mobility, and

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entrepreneurship. She has participated in several EU-funded projects and has published in various international refereed journals, such as the Journal of Urban Economics, the Journal of Regional Science, Urban Studies, Regional Studies, Papers in Regional Science, and Small Business Economics.

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Socio-Economic Development and Regeneration of Territories

Sara Cattaneo, Camilla Lenzi and Alessandra Zanelli

Introduction

This section of the volume focuses on the first challenge identified in the Introduction, in particular, on the possibility to relaunch the socio-economic regeneration and development of territories as to achieve sustainability and circularity goals (and not simply competitiveness ones). From this perspective, then, the regeneration of the built environment requires the capacity to gauge economic growth processes and the efficient (and circular) use of scarce local resources, where scarce resources include not simply economic ones, but also environmental ones.

Accordingly, the analysis of territorial regeneration requires a multidisciplinary perspective and the integration of different scientific competences including competences in spatial economic analysis, urban studies, evaluation studies, sustainable technological project design and development.

This section of the volume, thus, proposes a selection of contributions that covers all these different disciplinary fields. The contributions collected in this section are organized according to the perspective adopted, namely a comparative analysis at the aggregated urban scale across cities vs an in-depth analysis of single cities and areas within cities.

The first group of papers sets the analysis at the aggregated urban scale by adopting a comparative perspective on European cities. In particular, Camagni et al. provide a historical outlook on the evolution of economic thought concerning the development of cities and their performance with particular reference to the European context. Next, Capello et al. investigate the role of culture, cultural heritage and creativity as territorial assets and their impact on the socio-economic development of cities. Lenzi and Perucca complement these perspectives by examining the impact of urbanization, city size and city development on residents' well-being in European cities and for different types of cities. Lastly, Fratesi and Perucca propose an analysis of the role of different territorial endowments, i.e. territorial capital, for the resilience of European territories to the economic crisis

and the effectiveness of local development policies in different contexts characterized by different territorial capital endowments.

The second group of papers sets as well the analysis at the urban scale while focusing on single areas/neighbourhoods within cities. Within this group, two subgroups can be identified depending on the specific dimension emphasized in the analysis. The former focuses on the analysis of territorial transformation in specific areas of a city while the latter concentrates on the technological project dimension of such transformations.

In the first subgroup, Merlini offers a conceptual reflection on the relationship between territorial regeneration and demolition. She proposes a new interpretation of this link that departs from the view of demolition as reparation or precondition for a valourization project. Instead, she proposes a view on demolition as a project tool for the reconfiguration and transformation of the built environment. Sdino et al. propose an overview of the state of the art of evaluation methods for the economic assessment of urban transformations complemented by the analysis of a peri-urban transformation in Italy.

In the second subgroup, Mussinelli et al. discuss public spaces valourization, urban landscape requalification, adaptive regeneration of degraded areas and advance a new approach to project development with the aim of targeting sustainability and resilience to climate change. Next, Bolici et al. reflect on the relevance of integrated and multidisciplinary approaches for peri-urban landscape project development, for architectural heritage valourization and for agriculture socio-economic value in the management of places. Lastly, Pavesi et al. propose a case study analysis on the possible drivers and strategies to improve real estate management, resources and processes and their valourization according to a social and circular economy perspective.

Adaptive Exoskeleton Systems: *Remodelage* for Social Housing on Piazzale Visconti (BG)

Oscar E. Bellini

Abstract To promote the renewal and sustainable requalification of social housing in Lombardy means to carry out research in order to identify solutions as efficient and effective as possible, which do not involve the demolition of the building but promote its enhancement. Today it is possible to intervene on existing buildings with new strategies which give all-round and multipurpose solutions to the general issues, using techniques that go beyond punctual interventions and extend the useful life cycle of the built environment. The seismic upgrade must be at the basis of every project within construction. Thanks to an adaptive exoskeleton system it is possible to innovate the architectural image, to support an equitable and sustainable development based on the prevention and risk management connected to unexpected seismic events and to guarantee aspects of structural safety and physical integrity of the users, to improve the morphological, spatial and typological organization of buildings. By using an exoskeleton system, it is possible to innovate the architectural make-up, to support an equitable and sustainable development based on the prevention and the risk management connected to unexpected seismic events. A way to take into due consideration the now unavoidable aspects of structural safety and physical integrity of the users. This paper, part of a Departmental Study, presents the first guidelines to the renewal of social housing buildings owned by Aler Bergamo, Lecco, Sondrio on Piazzale Visconti in Bergamo.

Keywords Social housing · Exoskeleton · Built environment · Integrated design · Resilience

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1 A New Strategy to Build In and On the Built

> We are an extraordinary and beautiful country but at the same time very fragile. [The landscape is fragile and Cities are fragile, especially suburbs where no one has spent time and money to maintain them. But it is precisely the suburbs that are the city of the future, […] one that we will bequeath to our children. We need to carry out a monumental project of "mending" and we need ideas. (Piano 2014)

This important statement by the Italian architect Renzo Piano underlines the strategic importance of intervening in the obsolete construction of our suburbs and introduces the imperative and need to put forward new ideas to pursue the objective now recognized on the political, economic and disciplinary level to intervene in the built environment[1] (Murie et al. 2003).

Few are the designers who have the skills and professionalism to know what to do about the enormous, at least in terms of size, built heritage present in these realities starting from the great real estate assets, such as public housing. This enormous building heredity, which dates back to the second post-war period, now constitutes a significant part of our suburbs in terms of quantity, and it must be "adjusted", in line with a much needed responsible initiative.[2] This paper describes a pragmatic proposal for the redesign of post-Second World War buildings based on the most recent international experiences and provides an operational instrument for the "integrated" and "adaptive" redevelopment of built environments: on a structural, technological, typological, morphological, functional, performance, economic and social level of social housing real estate.[3]

2 Integrated Design in Social Housing: Looking for a New Balance

According to scientific literature, there are different ways of intervening on built environments without resorting to demolition. These methods can be traced back to key attitudes, which must absolutely be integrated with one another, so that the

[1] In 2017, the European Union Prize for Contemporary Architecture—Mies Van der Rohe Award was awarded to a Dutch project for the renovation and rental of a social housing building. The award was given to NL Architects, XVW Architecture kleinburg DeFlat, Amsterdam, 2013–2016. Although in Italy social housing is less developed than in other European countries, it still represents a far from negligible asset with performance deficits that are largely the same as those of private assets. This means the study field should extend to include the entire housing sector.

[2] Building rehabilitation projects are interventions to create new dwelling habits, new uses, new functions and new aesthetic and architecture solutions.

[3] The European Committee for the Promotion of Housing Rights considers social housing as services provision for those without access to the housing market in order to reinforce their position within the community. It is possible to associate the term "social housing" with the public housing sector.

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project intervention can have value (Zambelli 2004; Grecchi 2008; Malinghetti 2011; Ascione 2012; Perriccioli 2015; Paris and Bianchi 2018).

The priority intervention concerns the structural system of the building. In a country with a high seismic risk like Italy, it is essential to approach constructions by facing this criticality, in which many situations present itself as a priority that could undo all the other retrofit actions of the building, starting from economic ones. An adaptive exoskeleton can be used to improve this aspect, promoting these actions and improving the situation. It is a device inspired by the external structure of certain invertebrates, similar to medical prosthetic support, which intervenes in the deteriorated parts, restoring and implementing its characteristics and performance.

Applied to buildings, it defines an independent volumetric expansion, thanks a structure of autonomous foundations, to be juxtaposed to the façades, where it creates new spaces and volume. It can act as a support to a new rooftop architecture, additional shaped boxes or new floor surfaces to rethink dwellings.

The adaptive exoskeleton can help interventions on a variety of levels: structural, as a system for static and seismic strengthening; energetic, as a device used to reduce consumption and the environmental impact and to increase living comfort; typological, in terms of an opportunity to reorganize and redesign dwelling-sizes; functional, as an opportunity for the inclusion of new horizontal and vertical connections and architectural, for the technological rethinking of the interface between the inside and outside of the building.[4]

In order to use the exoskeleton system, we must carry out an accurate analysis with regards to feasibility analysis and convenience of the intervention, not only for economic reasons but also for an ecological opportunity, in order to take into account, the environmental "costs" resulting from any demolition or reconstruction (Boeri and Longo 2012). In terms of energy eco-efficiency, adaptive exoskeletons are to be preferred to a "radical construction solution"—which demolishes in order to reconstruct—since they minimize, from the initial stages of the design, the use of raw materials and reduce yard waste debris.

Today, the main techniques for seismic reinforcement are referable within a local approach, which consists in the consolidation of the structure with a punctual strengthening of the frame nodes, beams and pillars and in the global approach, in which the building is retrofitted using the addition of earthquake-resistant elements.

While punctual reinforcement interventions are very expensive, invasive and destructive, the adaptive exoskeleton is applied from the outside of the building and can be economically more convenient if integrated with other retrofitting interventions. The exoskeleton structure can be added to buildings working from the outside in the form of a double skin. This can be designed in two alternative ways: (a) integrating additional bracing walls within the exoskeleton (walls solution); (b) designing the exoskeleton itself as an earthquake-resistant box-shaped system (shell

[4]This constructive solution is very similar to the design research and the works of the French architects Lacaton and Vassal.

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solution). The choice of the structural solution depends on the initial stiffness of the building and may be conceived as over-resistant or dissipative. The box-shaped solution allows for the reduction of the stresses in the elements, by reducing the thickness of the additional skin and the adoption of specific elements with the double objective of improving energy efficiency along with the safety of the building. The wall solutions include, among others, the use of braces or walls with rigid or dissipative connections, walls hinged at the base, rocking walls, adaptive seismic walls and dissipative braces. The shell solution involves the creation of a new skin, a diaphragm in which the entire façade structure becomes an earthquake-resistant element (e.g. upgrade of grid shell and curtain wall or coating with resistant panels) (Marini et al. 2016; Passoni 2016; Scuderi 2016).

These techniques, integrating and overlapping on a holistic basis, can produce a lot of effects and benefits at different levels. They (a) allow for the upcycling of the building structure, improve seismic resistance and resilience; (b) reduce the environmental impact associated with seismic risk; (c) increase real estate value; (d) protect the long-term economic investment, which could be compromised by the damage caused by earthquakes; (e) reduce the cost of restructuring due to increased resilience; ensure the coexistence in a single construction site of the architectural, structural and energy renovation; (f) cancel out costs for the relocation of residents during the work by intervening on the outside; (g) allow for the addition or expansion of housing (rooftop, addition, etc.), thanks to new indoor and outdoor surfaces, the sale of which can partially compensate the renovation costs; (h) promote urban densification policies, through volumetric expansions, by reducing the consumption of land; allow for the morpho-techno-typological redefinition of the building, that can be redesigned in its vertical and horizontal connecting elements; (i) promote urban regeneration; create more pleasant, sustainable and resilient environments (Bellini et al. 2018). To increase the environmental value of the renovation, it is fundamental to reconsider the operational approaches within the life cycle thinking, aiming at maximizing performance and minimizing the impacts and environmental costs of the building life cycle (Antonini et al. 2011; Bellomo and Pone 2011; Paris and Bianchi 2018).

In addition to protecting the static aspects and monitoring the borderline states of the system (performance-based design), the structural design refers to the choice of materials—eco-efficient and recyclable—and technologies—prefabricated, dry, reparable and adaptable—according to principles of minimization of the environmental and economic impacts (life cycle assessment and life cycle costs), implementing the concepts of system sustainability and resilience (Bellini et al. 2018).

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3 Objectives and Aims of the Research and Sourcing Process

The Departmental Study, financed by Aler[5] Bergamo, Lecco, Sondrio and entitled "Preliminary guidelines for seismic resilience and urban regeneration, through an adaptive exoskeleton, of the settlement of public social housing on Piazzale Ermes Visconti", aims to explore the possible technical solutions to improve the housing, quality and technological performance of the buildings in Bergamo, without resorting to total demolition and subsequent reconstruction from scratch.[6]

The Aler's need is above all to identify constructive guidelines to be used on buildings without having to relocate the tenants residing in their own homes.

In this context, after a series of studies and analyses of the buildings, a multifaceted approach was proposed to Aler. The aim of the work is to investigate the solutions and systems to rehabilitate Aler real estate and to verify how it could be implemented by adopting an innovative strategy: a sort of prosthesis, an *adaptive exoskeleton* to be applied to the social housing buildings.

Aler wanted to use a paradigmatic solution that was adaptable to its decaying buildings. A solution that can easily be modified over time to integrate new social, economic and urban conditions. An open system that helps buildings respond to environmental, economic, functional and social challenges. Not a solution that crystallizes the building's image and prepares it for its future obsolescence but a "radical solution". A design process and method that increases the settlement density of the urban block, without consuming new ground. The guidelines proposed to use an adaptive exoskeleton: an independent but collaborative anti-seismic structure.[7]

The first step is to improve the quality of the buildings and to facilitate the new functional and typological layouts required over time by the local users. This system is designed to extend the building's life cycle through a gradual adaptation that reduces the effects of environmental stress on the building and spreads it out over a longer time span. This system is a structure of metal scaffolding that can be applied and connected to the buildings that require rehabilitation. It is important to emphasize how this technology relies on "dry assembly" and reversible technological solutions that allow for cost reduction and recycling of building materials and provide a viable alternative to the building replacement and its high environmental impact.

[5] ALER (Agenzia Lombarda Edilizia Residenziale) is an Agency that promote and manage social housing in the Lombardy Region.

[6] The urban block covers an area of about 5,500 m^2 and occupies a strategic position at "Villaggio degli Sposi". It has a regular shape and a good supply of vegetation. The urban block is entirely occupied by social housing which are not well maintained nor well preserved. The buildings are arranged in an L shape and are composed of 24 (16 + 8) houses with stairs and no elevators. The buildings were built with a masonry structure made of blocks of load-bearing bricks in the early '50s and they are critical from an energetic, structural and technologic point of view.

[7] Norme tecniche per le costruzioni, NTC, 2008. D.M. January 14, 2008.

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The exoskeleton may perform both a two-dimensional action through the definition of façade refurbishment (recladding, refitting and overcladding) and a three-dimensional action defined by volume additions (individual boxes, bioclimatic greenhouses towers and continuous or overall additions) (Guidolin 2016).

The guidelines proposed by Visconti aim to be a pursuit of cross-disciplinary design instruments for the achievement of "holistic and integrated regeneration" for public social housing. They want to be an articulated map of mediations and insights about strategies to build in and on the built environment, based on two fundamental aspects: the first is supported by sociological positions according to which a refined and careful designed environment produces a sense of place implicitly as its own, it follows that the rehabilitation action assumes a value of raising the social position even before the economic value of the area or of the building. The second—the maximization of resources—is part of the broader theme of respecting the environment which is supported by actions such as attention to land use and the definition of technical/technological solutions aimed at active and passive energy saving.

The rehabilitation project has shown that the interpretation of emotional and physical roots of the inhabitants in relation to their everyday life becomes a plus towards both the housing and the urban landscape transformation if in addition to these results there are clear and well-defined strategies in terms of execution, reliability, management and funding. This study's primary aim is to show the feasibility of the building rehabilitation approach not only in energetic terms but primarily in relation to the quality increase of structural safety and housing services.

The definition of the metadesign intervention for the "Remodelage"[8] of the Aler lodgings on Piazzale Visconti was based on the following aspects: (a) general aspects: the process of building rehabilitation can be an interesting topic from several points of view because it is closely related to other issues such as economic recovery and employment, urban regeneration, cohesion and social participation. The recovery of social unease in the social housing of Piazzale Visconti must be tackled minimally with the simple building recovery of dwellings bordering on the urban decay. The provision of outdoor collective spaces in agreement with the dignity of the person and designed for "public social housing" can lead, as well as to social assistance programs, to an improvement of their condition. (b) Technical aspects: the energy aspect is only one important variable in the process as it has many funding opportunities, but at times, it can seem to limit.[9] Thus, the first action that has been proposed to Aler concerned the structural system of the buildings on Piazzale Visconti (Figs. 1 and 2).

[8]The team was created by Roland Castro for the regeneration of the Grands Ensembles in the French banlieues. Castro and Denissof (2005), [Re]modeler, Métamorphoser, Le Moniteur, Paris.

[9]Instead the systemic approach is most evident in this project: the REHA-PUCA French program which aims at identifying innovative solutions suitable for building rehabilitation of sample buildings through a competition open to groups made up of designers and contractors. Three guidelines are identified: diversification, management and densification, interpreting the economy of territorial space in order to avoid further land use.

Fig. 1 Urban block of Piazzale Visconti with five buildings dedicated to public social housing. The three identical buildings are owned by the Municipality of Bergamo; the others belong to Aler

Fig. 2 Topographic survey of the Piazzale Visconti block and quantification of the new building volume. The entire block is intended for public housing

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This leads to preventive practices that reduce structural vulnerability to seismic actions, planning methodologies that promote a rational use of resources, an enhancement of the built environment and the preservation of human life (Marotta and Zirilli 2015). Interventions that provide an alternative to the traditional "scrapping/demolition" and transcend the practice of "abandoning what does not work". It is possible to exceed the ideological dilemma between demolition/conservation and inaugurate a "third way". A design method which today is prefigured in Parasite, Rooftop and Hybrid architecture (Boeri and Longo 2012; Angi et al. 2012; Angi 2016a, b; Montuori 2016).

The project contents go beyond the conventional methods that define sustainability as related just to an energy upgrade, by introducing solutions on the structural safety and stability aspects relating to the increasingly frequent seismic phenomena as well (Marini et al. 2016). The sustainability of an intervention is also related to the impacts of damage and collapse due to possible earthquakes during the life cycle of the retrofitted building (Murie et al. 2003; Feroldi 2014; Belleri and Marini 2016).

In the disciplinary debate, ranging from "scrapping" to "mending", it appears reasonable to use the potential of the adaptive exoskeleton system (Marini et al. 2017). In this way, it is possible to integrate a design approach that allows to implement the resilience of buildings. This device improves the performance, through an external supporting and cooperating prosthesis, which is not simply earthquake resistant, but also technological, considering that it facilitates the realization of "double integrated skin solutions" with which to obtain a new frontier between exterior and interior, in order to improve energy efficiency and promote the architectural restyling of the building (Guidolin 2016). The use of the exoskeleton facilitates the morpho-techno-typological rethinking of the existing structure and allows for the activation of urban densification policies (Boeri and Longo 2012) and for the urban regeneration of the social and functional substrate (Di Giulio 2013).

4 Conclusions

The research on social housing buildings on Piazzale Visconti aims to demonstrate the potential to use innovative technical strategies for the rational maintenance of real estate directed at the architectural recovery and reconfiguring of social housing stock, improving the performance and quality of the environment built.

Today, it is possible to apply retrofitting processes in opposition with demolitions and reconstructions, above all in terms of social and environmental costs.

We have articulated social, economic and technological critical situations, in which it is possible to adopt external structures to help the integrated refurbishment. This device is the exoskeleton system.

It allows for construction from outside the building minimizing inside work within the housing unit. It is an "innovative device" to connect technological and social issues in the organization of a particular building site management process. It allows for the regular execution of building functions, thus containing the costs of the building site.

The exoskeleton systems can have different configurations. It allows users to achieve sufficient settlement density, creating the possibility of carrying out new housing. It is an external structural grid that gives the designer and user a certain level of customization freedom, above all in terms of the morphological and functional configuration of the façade, which can be read as an interface system between private interior space and public space.

The adaptive exoskeleton systems are able to create balconies, greenhouses, etc.; technological elements for shading control can be added; the architectural morphology and typology can be reconfigured and some customized functions can be considered. It is possible to get a new building: a new architecture (Fig. 3).

The integrated rehabilitation actively involves users and designers, through a device that connects technological innovation and social need for involvement, in order to assign an active role to the user in a process through which they are strictly interested in providing a new aesthetic identity to buildings. A design process that requires significant disciplinary skills: skills that today Department of Architecture, Built environment and Construction engineering of the Politecnico di Milano can provide.

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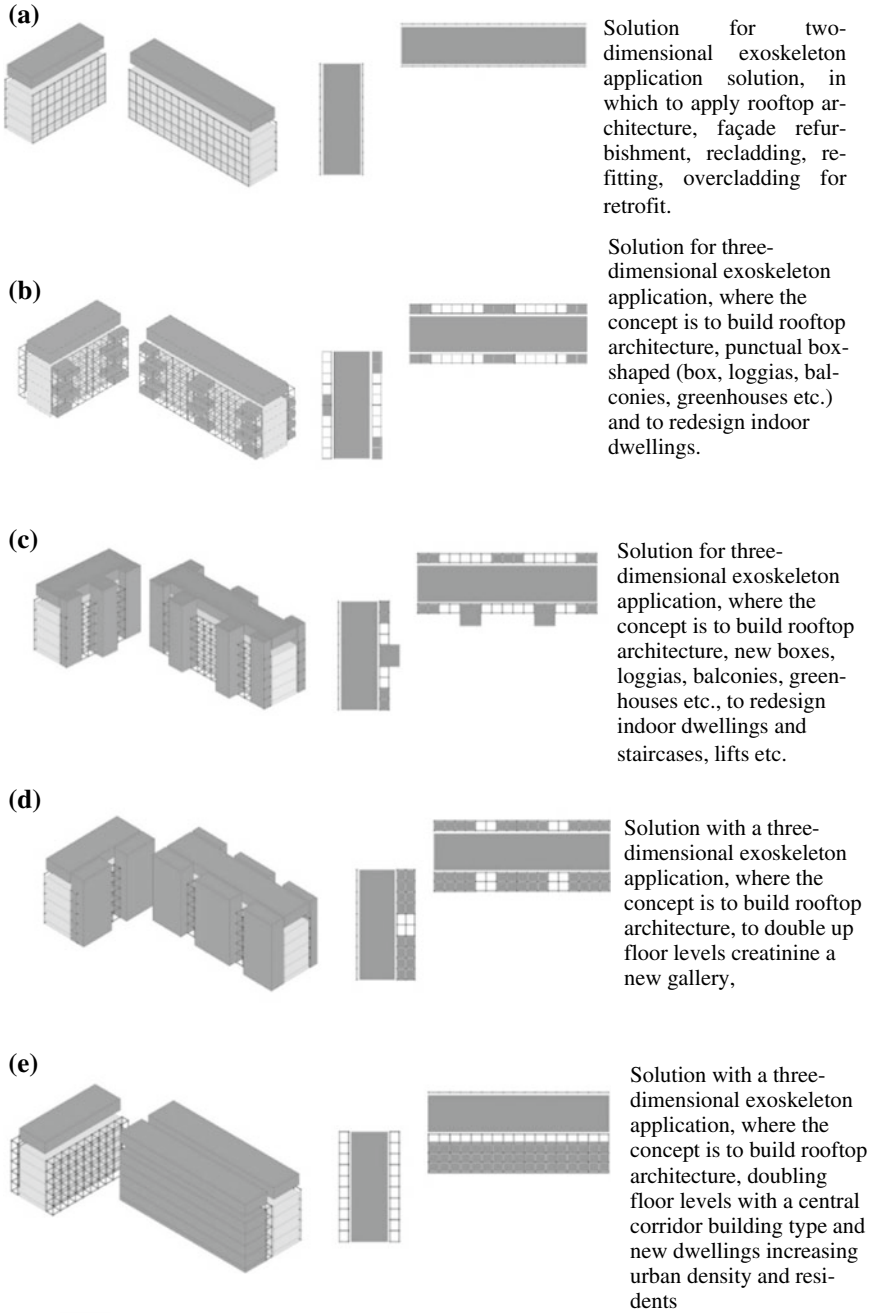

Fig. 3 Five morpho-techno-typological solutions obtainable by adaptive exoskeleton system

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