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40 Editors

41 Regeneration of the Built
42 Environment from a Circular
43 Economy Perspective
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Preface

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

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

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



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

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Introduction

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

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

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



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

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

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

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

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

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



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

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

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

261 Sara Cattaneo
262 Camilla Lenzi
263 Alessandra Zanelli

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Contents

265

266	Socio-Economic Development and Regeneration of Territories	
269	A Research Programme on Urban Dynamics	3
270	Roberto Camagni, Roberta Capello and Andrea Caragliu	
271	Cultural Heritage, Creativity, and Local Development: A Scientific	
273	Research Program	11
274	Roberta Capello, Silvia Cerisola and Giovanni Perucca	
276	Urbanization and Subjective Well-Being	21
277	Camilla Lenzi and Giovanni Perucca	
278	EU Regional Policy Effectiveness and the Role of Territorial	
280	Capital	29
281	Ugo Fratesi and Giovanni Perucca	
283	Demolition as a Territorial Reform Project	39
284	Chiara Merlini	
286	The Evaluation of Urban Regeneration Processes	47
287	Leopoldo Sdino, Paolo Rosasco and Gianpiero Lombardini	
288	New Paradigms for the Urban Regeneration Project Between Green	
290	Economy and Resilience	59
291	Elena Mussinelli, Andrea Tartaglia, Daniele Fanzini, Raffaella Riva,	
292	Davide Cerati and Giovanni Castaldo	
294	The Technological Project for the Enhancement of Rural Heritage	69
295	Elena Mussinelli, Raffaella Riva, Roberto Bolici, Andrea Tartaglia,	
296	Davide Cerati and Giovanni Castaldo	
297	Real Estate Assets for Social Impact: The Case of the Public Company	
299	for Social Services “ASP City of Bologna”	77
300	Angela S. Pavesi, Andrea Ciaramella, Marzia Morena and Genny Cia	

Editor Proof



302	Reuse and Regeneration From a Resilient Perspective of Urban Spaces	
303	Participated Strategies for Small Towns Regeneration. The Case	
304	of Oliena (Nu) Historic Centre	89
306	Laura Daglio, Giuseppe Boi and Roberto Podda	
307	Living and Learning: A New Identity for Student Housing in City	
309	Suburbs	99
310	Oscar E. Bellini, Matteo Gambaro and Martino Mocchi	
311	PolimiparaRocinha: Environmental Performances and Social	
313	Inclusion—A Project for the Favela Rocinha	111
314	Gabriele Maserà, Massimo Tadi, Carlo Biraghi	
315	and Hadi Mohammad Zadeh	
316	Urban Renovation: An Opportunity for Economic Development,	
318	Environmental Improvement, and Social Redemption	125
319	Paola Caputo, Simone Ferrari and Federica Zagarella	
320	Regenerative Urban Space: A Box for Public Space Use	137
322	Elisabetta Ginelli, Gianluca Pozzi, Giuditta Lazzati, Davide Pirillo	
323	and Giulia Vignati	
324	Slow Mobility, Greenways, and Landscape Regeneration. Reusing	
325	Milan’s Parco Sud Decommissioned Rail Line as a Landscape Cycle	
326	Path, 2019	149
328	Raffaella Neri and Laura Pezzetti	
329	Nature and Mixed Types Architecture for Milano Farini	159
331	Adalberto Del Bo, Maria Vittoria Cardinale, Martina Landsberger,	
332	Stefano Perego, Giampaolo Turini and Daniele Beacco	
333	Rehabilitation Projects of the Areas of the Decommissioned Barraks	
334	in Milan, 2014	169
336	Raffaella Neri	
337	An Experience of Urban Transformation in Multan-Pakistani	
339	Punjab	181
340	Adalberto Del Bo, Daniele F. Bignami, Francesco Bruno,	
341	Maria Vittoria Cardinale and Stefano Perego	
342	The Transformation of the Great Decommissioned Farini Railroad	
344	Yard: The Research for a Modern Housing Settlement	191
345	Raffaella Neri and Tomaso Monestiroli	



346	Toward Sustainable Products and Process Innovation	
348	in the Construction Sector	
349	Design Strategies and LCA of Alternative Solutions for Resilient,	
350	Circular, and Zero-Carbon Urban Regeneration: A Case Study	205
352	Andrea Campioli, Elena Mussinelli, Monica Lavagna and Andrea Tartaglia	
353	Circular Economy and Recycling of Pre-consumer Scraps in the	
354	Construction Sector. Cross-Sectoral Exchange Strategies for the	
355	Production of Eco-Innovative Building Products	217
357	Marco Migliore, Ilaria Oberti and Cinzia Talamo	
358	Re-Using Waste as Secondary Raw Material to Enhance	
359	Performances of Concrete Components in Reducing	
360	Environmental Impacts	229
362	Andrea Tartaglia	
363	Bio-Based Materials for the Italian Construction Industry:	
364	Buildings as Carbon Sponges	237
366	Olga Beatrice Carcassi, Enrico De Angelis, Giuliana Iannaccone,	
367	Laura Elisabetta Malighetti, Gabriele Masera and Francesco Pittau	
369	Sustainable Concretes for Structural Applications	249
370	Luigi Biolzi, Sara Cattaneo, Gianluca Guerrini and Vahid Afroughsabet	
371	Closing the Loops in Textile Architecture: Innovative Strategies	
373	and Limits of Introducing Biopolymers in Membrane Structures	263
374	Alessandra Zanelli, Carol Monticelli and Salvatore Viscuso	
375	Performance Over Time and Durability Assessment of External	
376	Thermal Insulation Systems with Artificial Stone Cladding	277
378	Sonia Lupica Spagnolo and Bruno Daniotti	
380	Multi-scale Approaches for Enhancing Building Performances	
381	Circular Economy and Regeneration of Building Stock: Policy	
383	Improvements, Stakeholder Networking and Life Cycle Tools	291
384	Serena Giorgi, Monica Lavagna and Andrea Campioli	
386	Re-NetTA. Re-Manufacturing Networks for Tertiary Architectures	303
387	Cinzia Talamo, Monica Lavagna, Carol Monticelli, Nazly Atta,	
388	Serena Giorgi and Salvatore Viscuso	
389	Reusing Built Heritage. Design for the Sharing Economy	315
391	Roberto Bolici, Giusi Leali and Silvia Mirandola	
392	Public Health Aspects' Assessment Tool for Urban Projects,	
394	According to the Urban Health Approach	325
395	Stefano Capolongo, Maddalena Buffoli, Erica Isa Mosca, Daniela Galeone,	
396	Roberto D'Elia and Andrea Rebecchi	



397	A Development and Management Model for “Smart”	
399	Temporary Residences	337
400	Liala Baiardi, Andrea Ciaramella and Stefano Bellintani	
402	Extra-Ordinary Solutions for Useful Smart Living	347
403	Elisabetta Ginelli, Claudio Chesi, Gianluca Pozzi, Giuditta Lazzati,	
404	Davide Pirillo and Giulia Vignati	
405	Rethinking the Building Envelope as an Intelligent Community	
406	Hub for Renewable Energy Sharing	357
408	Andrea G. Mainini, Alberto Speroni, Matteo Fiori, Tiziana Poli,	
409	Juan Diego Blanco Cadena, Rita Pizzi and Enrico De Angelis	
410	Adaptive Exoskeleton Systems: <i>Remodelage</i> for Social Housing	
412	on Piazzale Visconti (BG)	363
413	Oscar E. Bellini	
414	Assessing Water Demand of Green Roofs Under Variants	
416	of Climate Change Scenarios	375
417	Matteo G. P. Fiori, Tiziana Poli, Andrea G. Mainini,	
418	Juan Diego Blanco Cadena, Alberto Speroni and Daniele Bocchiola	
419	Comparison of Comfort Performance Criteria and Sensing	
420	Approach in Office Space: Analysis of the Impact on Shading	
422	Devices’ Efficiency	381
423	Marco Imperadori, Tiziana Poli, Juan Diego Blanco Cadena,	
424	Federica Brunone and Andrea G. Mainini	

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469 TensiNet, the thematic network for upgrading the built environment in Europe
470 through tensile structures. She has been involved in many research projects
471 co-financed by national and international bodies, focusing on the sustainable
472 innovation of ultra-lightweight and flexible materials in both architecture and
473 interior design. She is the author of more than 180 publications and holds four
474 international patents.
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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

36 and the effectiveness of local development policies in different contexts charac-
37 terized by different territorial capital endowments.

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

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

52 In the second subgroup, Mussinelli et al. discuss public spaces valourization,
53 urban landscape requalification, adaptive regeneration of degraded areas and
54 advance a new approach to project development with the aim of targeting sus-
55 tainability and resilience to climate change. Next, Bolici et al. reflect on the rele-
56 vance of integrated and multidisciplinary approaches for peri-urban landscape
57 project development, for architectural heritage valourization and for agriculture
58 socio-economic value in the management of places. Lastly, Pavesi et al. propose a
59 case study analysis on the possible drivers and strategies to improve real estate
60 management, resources and processes and their valourization according to a social
61 and circular economy perspective.
62

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



Oscar E. Bellini

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

20 **Keywords** Social housing · Exoskeleton · Built environment · Integrated design ·
21 Resilience

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363

22 1 A New Strategy to Build In and On the Built

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

28 This important statement by the Italian architect Renzo Piano underlines the strate-
29 gic importance of intervening in the obsolete construction of our suburbs and intro-
30 duces the imperative and need to put forward new ideas to pursue the objective now
31 recognized on the political, economic and disciplinary level to intervene in the built
32 environment¹ (Murie et al. 2003).

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

44 2 Integrated Design in Social Housing: Looking for a New 45 Balance

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

¹In 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.

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

³The 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.

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

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

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

63 The adaptive exoskeleton can help interventions on a variety of levels: structural,
64 as a system for static and seismic strengthening; energetic, as a device used to reduce
65 consumption and the environmental impact and to increase living comfort; typologi-
66 cal, in terms of an opportunity to reorganize and redesign dwelling-sizes; function-
67 al, as an opportunity for the inclusion of new horizontal and vertical connections and
68 architectural, for the technological rethinking of the interface between the inside and
69 outside of the building.⁴

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

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

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

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

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

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

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

3 Objectives and Aims of the Research and Sourcing Process

The Departmental Study, financed by Aler⁵ 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.

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

⁶The urban block covers an area of about 5,500 m² 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.

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

158 The exoskeleton may perform both a two-dimensional action through the defini-
 159 tion of façade refurbishment (recladding, refitting and overcladding) and a three-
 160 dimensional action defined by volume additions (individual boxes, bioclimatic green-
 161 houses towers and continuous or overall additions) (Guidolin 2016).

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

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

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

⁸The 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.

⁹Instead 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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194 This leads to preventive practices that reduce structural vulnerability to seismic
 195 actions, planning methodologies that promote a rational use of resources, an
 196 enhancement of the built environment and the preservation of human life (Marotta
 197 and Zirilli 2015). Interventions that provide an alternative to the traditional “scrap-
 198 ping/demolition” and transcend the practice of “abandoning what does not work”. It
 199 is possible to exceed the ideological dilemma between demolition/conservation and
 200 inaugurate a “third way”. A design method which today is prefigured in Parasite,
 201 Rooftop and Hybrid architecture (Boeri and Longo 2012; Angi et al. 2012; Angi
 202 2016a, b; Montuori 2016).

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

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

221 4 Conclusions

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

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

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

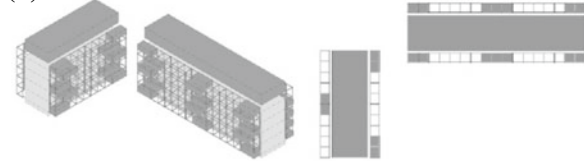
231 It allows for construction from outside the building minimizing inside work within
232 the housing unit. It is an “innovative device” to connect technological and social
233 issues in the organization of a particular building site management process. It allows
234 for the regular execution of building functions, thus containing the costs of the build-
235 ing site.

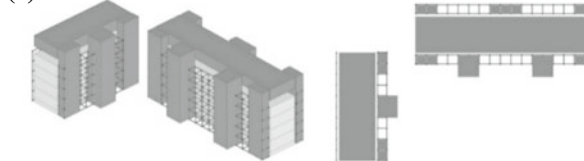
236 The exoskeleton systems can have different configurations. It allows users to
237 achieve sufficient settlement density, creating the possibility of carrying out new
238 housing. It is an external structural grid that gives the designer and user a certain level
239 of customization freedom, above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

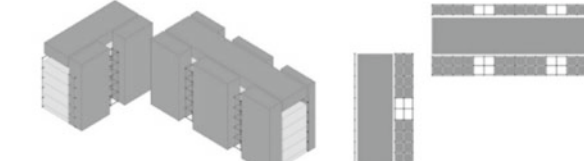
242 The adaptive exoskeleton systems are able to create balconies, greenhouses, etc.;
243 technological elements for shading control can be added; the architectural mor-
244 phology and typology can be reconfigured and some customized functions can be
245 considered. It is possible to get a new building: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

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

(a)  Solution for two-dimensional exoskeleton application solution, in which to apply rooftop architecture, façade refurbishment, recladding, re-fitting, overcladding for retrofit.

(b)  Solution for three-dimensional exoskeleton application, where the concept is to build rooftop architecture, punctual box-shaped (box, loggias, balconies, greenhouses etc.) and to redesign indoor dwellings.

(c)  Solution for three-dimensional exoskeleton application, where the concept is to build rooftop architecture, new boxes, loggias, balconies, greenhouses etc., to redesign indoor dwellings and staircases, lifts etc.

(d)  Solution with a three-dimensional exoskeleton application, where the concept is to build rooftop architecture, to double up floor levels creatinine a new gallery,

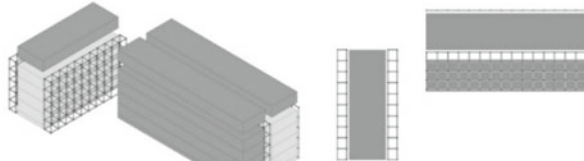
(e)  Solution with a three-dimensional exoskeleton application, where the concept is to build rooftop architecture, doubling floor levels with a central corridor building type and new dwellings increasing urban density and residents

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

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