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DURABILITY IN A RESILIENT DESIGN APPROACH

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Abstract
The relationship between architecture and time can be studied from different points of view, for example, concerning physical durability (maintenance, interchangeability), functional temporality (transformability, technological flexibility), aesthetic obsolescence (changes in style and fashion). Today, it seems to be a central topic in relation to the emerging concept of resilience. Considering durability as one of the design variables means being able to evaluate the architecture as an adaptable organism that responds to changing environmental needs. After discussing the topic of time in the culture of sustainable design, the text describes what declinations this topic can assume in relation to the advent of the concept of resilience, applied to architectural design and the present experimentations of Design for Disassembly.

Keywords
durability, resilience, design for disassembly, use, efficiency

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The adjective ‘sustainable’ and particularly its French equivalent ‘durable’ lend architecture a regenerative ability, a resilient character. This does not necessarily imply that architecture must last over time in order to be defined sustainable; the opposite is indeed a better representation of the reality. In countries with high or growing economic development, contemporary society shows an exceptional transformation skill: to achieve its goals it has conquered, occupied and used almost completely the portions of natural landscape and it continuously reconquers those already anthropized, ‘planning’ – in progressively more restricted times – increasingly sophisticated systems of intensive exploitation of the space resource. Modern and sophisticated green technologies, gardens and even ‘vertical woods’, or some other fake environmentalist banner have been used to continue this conquest, or reconquest, of space. It does not seem to matter that thanks to these politically correct eco-friendly methods the energy-consuming and highly criticized skyscraper, in its various contemporary reinterpretations, is still fashionable (Trabucco, 2019; Boeri and Muzzonigro, 2019). It might be true that our age will go down in history as a vanity fair of Redeemers (Sloterdijk, 2016).

By now the ability of our society to transform the environment is so strong to find in itself the main constraints to an appropriate and suitable development, not only in relation to the Object of its transformation, the environment but also to the possibilities and operational modalities of the transformation itself, starting from the Project stage. This ability implies not only an environmental problem but also a crisis of the Project, which has not always shown how to reconfigure itself with respect to boundary changes or has sought, for this purpose, easy short cuts that risk depriving it of meaning. On one hand, the contemporary succession of continuous spatial changes over time has found in architecture rigid and anachronistic responses of races against time. On the other hand, the unconditional surrender to change has produced event-spaces, site-specific artist projects, ephemeral structures, architecture-camps, perhaps self-managed, which are not always answers, but simple manifestations of the problem (Giachetta, 2004a).

The faster and faster transformation of space over time, which implies a careful evaluation of its environmental effects and puts the project in front of a need for reconfiguration, manifests itself through articulated and complex forms. The transformation processes, in fact, not only express themselves more and more quickly as rapid ‘transformations of transformations’ (outsourcing of abandoned industrial areas, centralization of peripheral city areas, transformation of urban centres and port areas into amusement parks, overlaps on the built existing, continuous changes of destination of use, reuse, restyling and make-up of buildings for commerce, etc.) but also find in themselves a sufficient justification to be implemented as ‘transformation for transformation’ (temporary structures, architectures as urban and media events), involving more and more actors to implement them, through a progressive ‘specialization’ and consequent multiplication of the project’s architects, not least the experts of the ecological approach (a true contradiction in terms). This multiplication produces an inevitable fragmentation of the designers' responsibilities and a loss of all their effective ability in directing and controlling the overall performance of the building, especially those related to the duration in time since it is considered secondary to the importance attributed to the first exterior appearance of architecture – rarely sector magazines deal with what happened to great architects' works some years after their construction (Giachetta, 2004b).

The transformation of the transformation, the transformation for the transformation and the specialization of the transformation processes are phenomena that are linked to both space and time. In particular, they are related to the ever-increasing speed of territorial and human-works changes in contemporary society, to the safeguarding or cancellation of meaning of the temporal content and history of these same works, to the temporariness and to the capacity of physical duration of the transformations, even to the convenience of the brevity of their life in time, as a consciously planned obsolescence that preserves the future possibility of building (something, indeed, more typical of the American or Japanese culture and less than the European one). The implications on the duration, or rather, on the durations of the architecture are many.

The rapid changes in lifestyles and relationships have significant implications on the 'functional duration' of architecture, or on the ability of current destinations to survive tomorrow's needs. The succession expressions and fashions have, on a linguistic level, consequences on the 'formal duration', on the resistance of the image of architecture. At the technological level, the de-responsibility of designers for the increasing complexification of ideational and construction processes (in spite of BIM) has sometimes disastrous consequences on the 'physical duration' of architecture (Giachetta, 2004a). The phenomena of precocious functional, formal and physical obsolescence of the building seem to put in crisis the axiom by which architecture must necessarily be a 'eternal' expression of time and the culture of men that generated it. This implies a radical change in the way of thinking of architecture, especially in relation to its durability. For this reason, it is very difficult for a designer today to use Kahn's motto: «Good building would produce a marvellous ruin» (Braghieri, 2005, p. 8), without looking like a dreamer out of time. And yet, in the contemporary scene, the reflections on this issue are very few and the problem is little considered in the debates on architecture, where the duration of architecture over time (for eternity) or, at maximum, a radical inversion of tendency towards the ephemeral and the virtual, is preached never questioning why and how.

It is thus evident that the expression 'sustainable architecture', intended as 'what can be sustained', 'durable' and not only in its translated and symbolic meaning, cannot refer so much to buildings destined to 'last' over the centuries (perhaps even unsustainable in terms of logic today). On the contrary, it regards buildings generated by projects that have been able to consciously consider the durability as a real project element. This does not mean to support the temporariness of architecture at all costs, it simply implies the recognition of a problem undeniable today that can become an incentive for the correct management of the building instead.

The ability to control the aspects of durability, can indeed translate into a more appropriate use of material and energy resources (buildings with very different temporal horizons should be conceived thinking of a use of materials, installations, constructive solutions and different economic resources) and involve a careful planning of the maintenance and even of the building disposal (with consequent development of disassembly strategies for recycling the building materials). Considering durability as a design variable can lead to looking at the building as a real living organism that is born, developed, transformed over time and in the end dies: all these moments in an architecture's lifespan can be part of the genetic code of a building and the coding can only take place in the design phase. The emergence of new concepts (e.g. resilience) and programmatic approaches (e.g. the design for disassembly) has led to a new concept of duration that does no longer refer to the process management from the cradle to the grave, but it foreshadows the resilience of parts, organs and the original body. All things considered one can easily claim that the concept of duration in architecture is no longer applicable.

Resilience, duration and durability | Due to the ongoing climate change, nowadays resilience is a key aspect of sustainability in architecture. In fact, if we think about the key concepts for sustainability governance systems, we need to focus on resilience. The concept of resilience, although it currently benefits from huge popularity, it has been known for a long time in physics and ecology (Holling, 1973). It has gained relevance in the scientific debate since the 1960s, but it is only since the second decade of the 2000s, with the growing interest in adapting to climate change, that the use of the term has become more popular. The original definition comes from physics in the context of which resilience means the ability of a material to absorb energy if subjected to elastic deformation, in opposition to the term fragility. In biology resilience is the capacity of an ecological system to return to its initial state, responding to a disturbance or a perturbation by resisting damage and fast recovering (Gunderson, Allen and Holling, 2010). From an ecological point of view, Holling (1973) suggests that resilience is the capacity of a system to maintain its relationships thanks to its ability to absorb changes in variables state, maintaining its functions despite suffering from disturbances and perturbations (Gunderson and Holling, 2001).

For UN Office for Disaster Risk Reduction (UNDRR) Resilience means «[…] 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» (UNISDR, 2007). The Environmental issue of climate change brings to a climate resilience definition: Intergovernmental Panel on Climate Change (IPCC) defines resilience as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change.

As human beings, we are part of the ecosystem on which depends our survival and with which we trade on a local and global scale. Resilience is a feature of these connected socio-ecological systems. The ability to anticipate changes and to influence future processes of governance allows us to improve the resilience of a system, and, in this case, of our society. Even in the absence of traumatic events, such as environmental catastrophes or conflicts, the conditions of a system can gradually change, for example, air pollution that can slowly exceed the threshold levels, depriving the system of a negative response and damaging the ecosystem services we benefit from. Such damage to ecosystem services cannot always be restored, or restoration can be complex and costly (Canepa, 2018).

If we consider the project from a resilient point of view, the variable of duration takes on a completely different value. Duration as time assumes a fundamental role for the resilience of a system since it represents the indispensable element to be able to return to its equilibrium after a period of perturbation. The time variable also determines the difference to the term resistance that mainly measures the entity of the impact, although referring to a condition of disturbance (Holling, 1973). The more limited the time interval to restore equilibrium, the more resilient the system. The extension of this short time interval is decisive for establishing the degree of resilience or, on the contrary, the vulnerability of a system or, from an architectural point of view, of a building.

The time variable becomes even more relevant if we consider the current acceleration observed in climate changes. These natural transformations are increasingly stressed by human action causing our society to be in a difficult situation. This phenomenon can be read as an inversion of scale between historical times, typical of the socio-economic sphere (time-society), and biological times (time-nature), belonging to ecosystems (Tiezzi, 2005). The complexity of our society and the environmental issues increase the difficulty to make our social, economic, and ecological systems sustainable and resilient. Our society must face new adaptation challenges, but at the same time confront the forecast uncertainty of the perturbative events by which it has been affected – sudden climatic events, conflicts, migrations, economic crises.

Regarding the architectural design, the concept of resilience can be applied to different scales from urban level to building. The concept of urban resilience has also deep roots. There is a real historical narrative linked to the partial or total destruction of cities and their reconstruction and recovery following wars, devastation and traumatic events. This process is not linear. The signs of destruction can be reintegrated into the new organization and acquire a different meaning (e.g. historical ruins). They can be monumentalized, parts of cities can be abandoned or re-functionalized in an incessant mechanism of resilience that can be assimilated to a sort of creative destruction. Reconstruction can also manipulate memory, erase or modify traces of the past (Vale and Campanella, 2005). Any material and component are subject to gradual destruction as a result of entropy and perturbative impacts (external and internal). However, the technical and functional longevity of buildings is continually less dependent

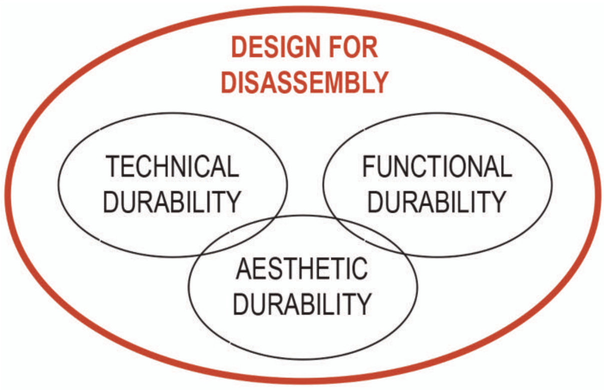

Fig. 1 | Design for Disassembly (DfD) and Durability.

on them: other factors increasingly assume the role of longevity reducers, as planned obsolescence, fashion trends, changing uses (Celadyn, 2014).

The initial perspective of sustainable development has always put into place strategies that will mitigate environmental problems through long-term processes. The failure to achieve the goals and the increasingly alarming forecast scenarios, just think of the latest IPCC 2018 and 2019 Reports, have meant that the idea of adaptation has become increasingly important. In the end, the system may not have the same identical characteristics, and this is where its adaptability lies; therefore, its resilience and adaptability certainly influence the durability of a project (e.g. through the degree of flexibility). The sustainable architecture led to different approaches to deal with durability, which can be considered as the capacity of buildings to provide useful spaces during a changing period of time, ensuring its technical, functional and aesthetic longevity. In order to be defined as durable, a project must be resilient and be able to transform itself according to the needs linked to physical uses and cultural variations, thus being truly able to support biological and historical times. This can only be done by fully thinking about the design strategies and seeking flexibility that accompanies life from birth to disposal.

Design for Disassembly as a durability strategy | To tackle new environmental challenges, such as climate change and resource depletion, the design of the built environment needs to shift towards a life cycle thinking. Some concepts, such as deconstruction, recyclability, and Design for Disassembly (DfD), suggest potential improvements in the post-use management of buildings. Besides, Design for Disassembly is a strategy not only to prolong the use of materials and to improve resource efficiency but also to change the usual design thinking into a more resilient approach to face environmental and anthropic changes (Fig. 1). Therefore, designers play a key role to define long-term and future scenarios for our built environment.

Design for Disassembly is not a new concept. Brand (1995) points out that light-

Name	City	Country	Construction year	Type of building	Area (m^2)	Design approach
BRIC	Bruxelles	Belgium	2017	Demonstrator	50 to 70	Design for Disassembly
Chiaravalle House	Milan	Italy	2018	Cultural	50	Design for Reuse
Housing in Svartlamon	Trondheim	Norway	2018	Residential	60	Design for Reuse

Table 1 | Main characteristics of the selected case studies.

construction buildings, such as the first 'balloon frame' houses in the early XIX century, suggested the idea of ephemeral construction techniques, easy to disassembly and reuse over the time. However, in the last few years, Design for Disassembly has increased its popularity thanks to the growing debate on circular economy and the adoption of circular principles in national and international programs (European Commission, 2015). Design for Disassembly supports the circular economy by facilitating the adaptability of buildings and the recovery of building materials in the end-of-life phase. This practice might increase the economic value of the buildings, as well as decrease the environmental impacts, by reusing and recycling building elements and materials. Indeed, urban mining, which is the process of recovering resources from the anthroposphere avoiding the depletion of natural ones, is interconnected with the concept of Design for Disassembly.

Design for Disassembly includes not only functional adaptability of the buildings but also technological adaptability of the building system and subsystems. Functional adaptability enables buildings to satisfy new purposes and to reshape themselves during their lifetime. However, technological adaptability is important to facilitate the substitution of different building components during the adaptation process of the building, as well as the upgrade of the technical equipment and the improvement of the energy efficiency performance. Design for Disassembly principles also promote the use of renewable, recycled and reused materials. For instance, a material investigation by Gorgolewski (2018) shows that wood has the most reuse potential compared to other traditional materials, such as concrete, brick and glass. Coupling bio-based materials (bio-economy) and circular economy principles appear to be an effective strategy to lower the environmental impacts of the built environment (Corrado and Sala, 2018). According to bio and circular economy principles, keeping bio-based materials within the technosphere could answer to both climate change mitigation and resource efficiency, for example prolonging the carbon storage in the biomass and offsetting the increasing demand of bio-based products and forest resources.

Several institutions are currently providing guidelines to promote DfD principles in the building sector, but a limited number of buildings has already included DfD strategies in the projects (Rios, Chong and Grau, 2015). However, Design for Disassembly is expected to be a growing trend in building design in the near future, providing innovation and new economic opportunities for the stakeholders involved in the

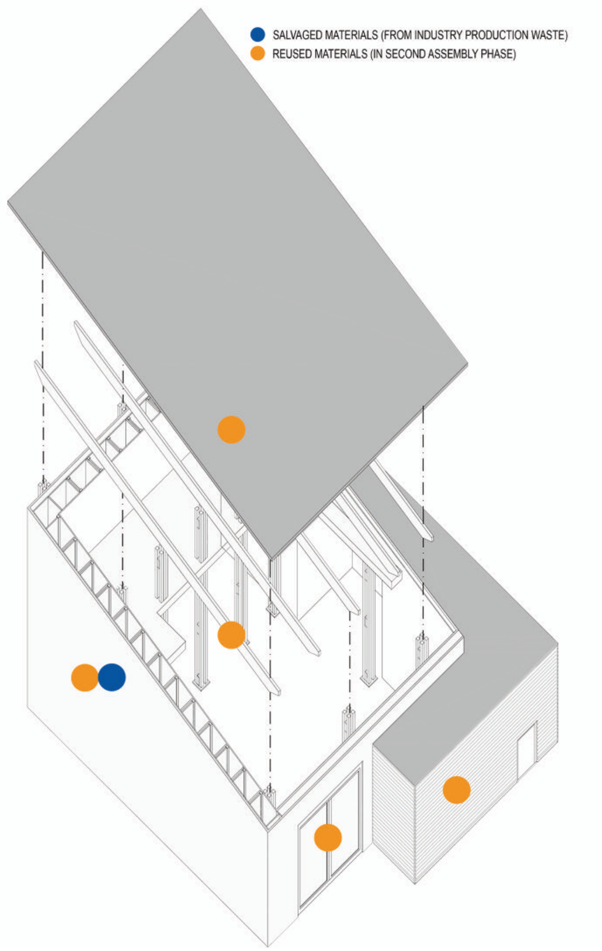

Fig. 2 | Exploded axonometric diagram of BRIC (Build Reversible in Conception) with material origin (the diagram is a version by C. Piccardo based on original project drawings).

building process. For this reason, the analysis of existing practices and case studies adopting DfD principles is important to increase the knowledge and to learn from experiences. To analyse DfD implications for the design process and resource efficiency, we select three representative case studies: BRIC – Building Reversible In Conception (Bruxelles, Belgium), Chiaravalle House (Milan, Italy) and Housing in Svartlamon (Trondheim, Norway). The case studies consist of buildings adopting design strategies for the future recirculation of building materials or, alternatively, for including recirculated materials into the new buildings (Table 1). Detailed informations on the case studies have been gathered from literature and personal communications with designers and promoters of the projects.

BRIC, Building Reversible In Conception (Fig. 2), is a full-scale two-storey building prototype designed to be disassembled on a yearly basis. The prototype has been

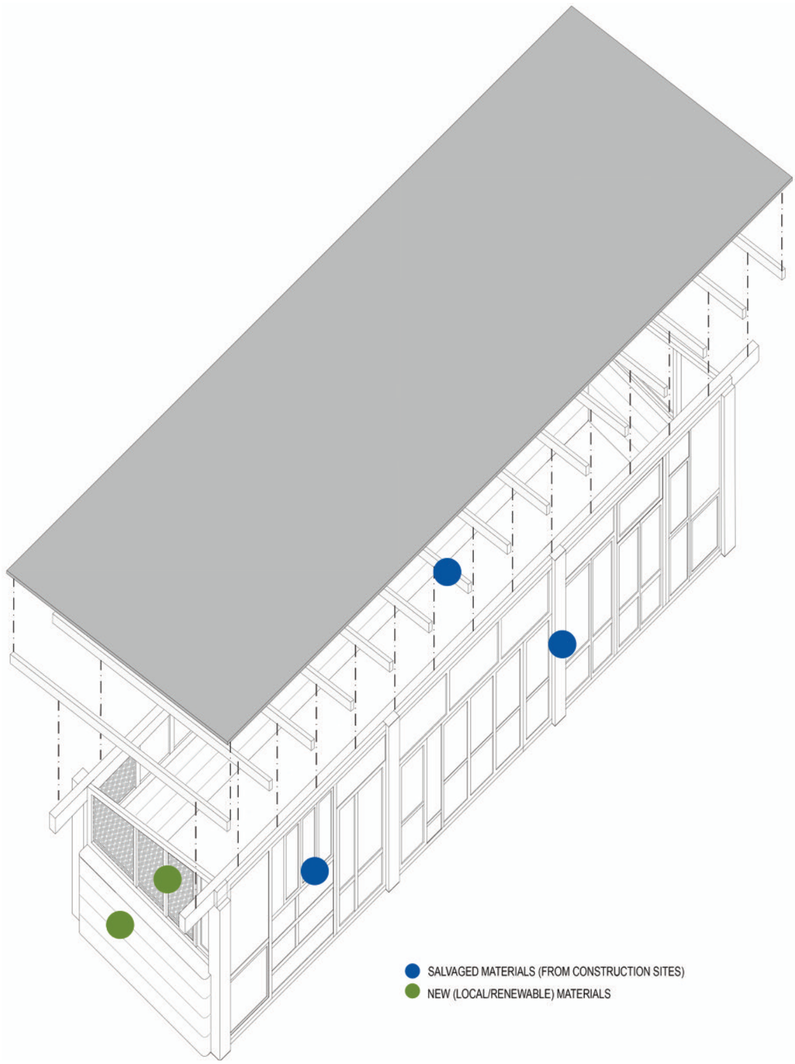

Fig. 3 | Exploded axonometric diagram of Chiaravalle House with material origin (the diagram is a version by C. Piccardo based on original project drawings).

promoted by the training centre Espace Formation PME (EFP) in Belgium, within the European project BAMB (Buildings As Materials Banks), to provide students with new skills in circular building practices. The load-bearing structure consists of a post and beam structure with bi-directional columns realised by assembling four single wooden profiles, and it is conceived to adapt its shape for future transformations. The walls are made of interchangeable self-supporting prefabricated wooden caissons insulated with cellulose. The reversible connections rely on high-resistant metal joints since the de-

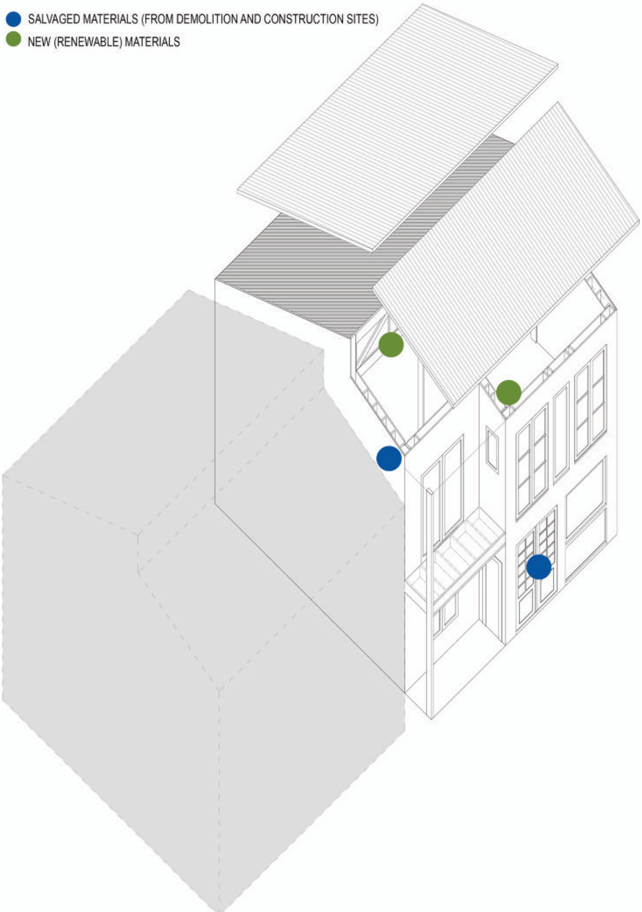

Fig. 4 | Exploded axonometric diagram of Svartlamon Housing with material origin (the diagram is a version by C. Piccardo based on project photos).

sign of ad-hoc joints would have been costly. The prototype has already been entirely assembled and disassembled two times, generating only mc 4 of waste.

Chiaravalle House (Fig. 3) is an experimental building developed within the workshop LearnBIØN – Design and Build with Økm (local and recycled materials), organized by the European network BIØN – Building Impact Zero Network, involving students, immigrants, unemployed people and NEET. Chiaravalle project consists of a small building with massive walls made of earthbags on the Northern, Eastern and

Western sides and a light wooden structure on the Southern side. The Southern façade is a glass regular façade adopting bioclimatic principles. Further details are provided by (Altamura and Baiani, 2019). No DfD strategies are included. However, the building materials (e.g. wood, glass and plexiglass) and elements (e.g. windows) have been recovered from local construction and demolition sites. The experience has resulted in a low-cost circular project, as well as several social benefits. The reuse of building materials has reinforced the workgroup during the design process, and included demolition companies, developing a new ecosystem.

Housing in Svartlamon (Fig. 4) is a pilot project in Trondheim to provide five self-built and low-cost houses for the Svartlamon community. The architectural concept has been developed for two years by NØYSOM architects in collaboration with Trondheim municipality, the Svartlamon Housing Associations and the existing Svartlamon Resident Association. Trondheim municipality played a key role to regulate Svartlamon as an experimental urban area with some local autonomy. The Housing Association was responsible for the administration and maintenance of the houses. The local community supported the pilot project. To increase the profitability of the construction work and to enhance the self-builders, some building elements (i.e. exterior and interior cladding, roofing, windows and doors) are from reused materials. This was appreciated by the local community as an improvement of the lifestyle.

Although these three case studies are only a sample of the buildings currently adopting DfD and circular economy principles, while an increasing number of initiatives is flourishing around Europe, it is clear that this kind of design approach is still at the experimental stage. The analysed case studies highlight the importance of increasing the technical knowledge among designers, builders and demolition companies. All the case studies include a learning activity. The reuse of building materials requires designers to adapt the project to the quality, size and shape of recovered materials, differently from the usual practices. DfD strategies require a careful design of construction details, as well as of architectural layout, and long-term project management. In both cases, the creative and resilient ideas play a key role in the design process.

Furthermore, including Design for Disassembly and circular economy principles in the design process needs a strong collaboration between all the stakeholders, who are part of a new learning process. For example, in Svartlamon housing, a strong network between the stakeholders succeeded in completing the pilot project. There is also a need to connect new constructions and demolition sites through standard practices, as well as to develop long-term urban planning including a systemic view of urban activities. For instance, in all the case studies, the recovery of post-use materials was organized as a special activity, without standard practices or institutional channels. Finally, the case studies show that DfD and circular buildings can provide several benefits, where environmental, economic and social domains are interconnected. Environmental and economic benefits come from the potential reuse of the buildings and, next, of the building components and materials. To support DfD and circular buildings, new business models should be developed. Social benefits come from new business models and the opportunity to improve the design quality of the buildings over time.

Conclusions | From the sustainability point of view, the duration can be considered as a value linked to the technological durability of the project and materials that, if prolonged, guarantees a limitation of the material consumption and embodied energy. At the same time the advent of perturbative elements, as climate change consequences, required a sort of correction – a tendency not only towards mitigation but towards the adaptation of the project in relation to technical and functional durability. Since architecture can be affected by both physics and social perturbative events, technical and aesthetic durability is necessary. In other words, for a modern-day architecture to survive it should possess both a technological and aesthetic adaptability.

The built environment is far from being resilient and the design approach is still dominated by a static rather than a dynamic view of buildings. This highlights the importance of increasing knowledge on resilient design to inform the next urban changes. The historical narrative shows a circular process of partial or total destruction and recovery of cities, where the signs of destruction are integrated into the new organization and gain different meaning (Vale and Campanella, 2005). Other phenomena (e.g. shrinkage) show that the development and decline of cities is a 'natural' process whereby urban change results from a lifecycle (Jacobs, 1969; Martinez-Fernandez et alii, 2012). Therefore, the built environment is an open-air laboratory, where both spontaneous and predetermined design activities give proofs of concept.

Design for Disassembly case studies exemplify how bottom-up and innovative design practices can embrace new socio-cultural values to tackle collective issues, anticipating top-down and standard practices. At the same time, top-down institutions (e.g. Universities, Municipalities, etc.) play a key role in making these architectural and urban happenings identifiable and replicable. Therefore, urban changes under a resilient design approach can also inspire sustainability scientists to translate design processes into research methodology.

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