Assessment framework to improve and manage LCT into building design practice

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Abstract

In view of the high impact of construction sector and of the Agenda 2030, the implementation of Life Cycle Thinking (LCT) and related methodologies in design practice represents even more an hotspots for the current state and a challenge for the next future. In this context, an assessment framework is proposed to integrate LCT into design process pointing out, based on current practice, the set of life cycle information and the connected actors in charge in order to support design firm in the shift both in thinking and in process. If properly fulfilled along the process by practitioners, the framework turns out to be a life cycle database of the facility in question to be exploited for the most varied purposes, providing a continuous built up of know-how not only with reference to design process phases, but also to the following phases of building process.

1. Introduction

The building sector is widely recognized as one of the most incisive and impacting sector at a global scale, involving heavily all three pillars of sustainability. From the environmental point of view, it yearly consumes about 3 billion tons of raw materials and it is responsible for 40% of solid waste and for 25-40% of global energy use. From the economical point of view, it collects total annual revenues of $10 trillion, accounting for about 5% of GDP and employing more than 100 million people worldwide. From the social point of view, it steadily shapes our daily life with a high impact on users health status and well-being (WEF, 2016). In this context, it represents a strategic field of action in which promptly intervene for the achievement of the Sustainable Development Goals within 2030.

To this end, the implementation of Life Cycle Thinking (LCT) and related methodologies into building sector represents a turning point to promote sustainable practice, encourage innovative strategies, lead decision-making and avoid shifting problems. However, due to the high construction impacts in the whole life cycle, it is pivotal to integrate LCT starting from the design phase since it strongly affects all the subsequent phases of the building process.

In this perspective, the paper points out the outcomes of a three-years research project aimed not only at the development of a new methodology for improving LCT into building process but also at its application in practice within the design firms, focusing therefore on the key actors responsible for the built environment.

2. Background

Nowadays, LCT is not so far established in building practice, since it requires a shift both in thinking and in process in a sector considered resistant to change. The shift in thinking demands to the variety of actors involved to switch their mindset from products/technologies to systems- and life cycle- thinking, calling for the advisement of the entire life cycle rather than of single phase. Instead, the shift in process ask the practitioners to adjust their way of practice, calling for a multidisciplinary and holistic process where all member need to integrate their work rather than design and operate in isolated silos (Boecker et al., 2009), with the aim to jointly achieve sustainable and high-performance buildings.

For this reason, the application of life cycle methodologies is now limited to a small percentage of building projects, where the main drivers are clients, followed in decreasing order of perceived impact by designers philosophy, codes and certifications requirements (Dalla Valle et al., 2016). In addition, surveying practitioners, several barriers arise concerning for instance the implementation of Life Cycle Assessment (LCA) in practice (Han and Srebric, 2015). The main barrier is the effort to find and collect data as well as the fact that LCA studies are too time consuming and expensive in face of a little market demand. Nonetheless, practitioners claim that to encourage its implementation in practice the challenge is twofold. On one hand, they recommend the development of simplified LCA tools in order to reduce time, especially for the inventory phase. On the other, they call for help to figure out how to use LCA during design process in a flexible way to really supports the decision-making in finding optimal solutions.

To prompt design firms and supply chain operators towards LCT, various LCA tools were developed over time in order to facilitate its application and introduce environmental efficiency as further decision-making criteria (Federal et al., 2015). However, the inherent complexity of buildings compared to other industrial products boosted the establishment in the construction sector of LCA tools with simplified calculation process. If this factor is advantageous to offer user-friendly software and to integrate LCA from the outset of the process, on the other, it contributes to create a “black box” of the embedded data. Moreover, besides transparency issues, these tools are generally used in practice only at the end of the process, when buildings are entirely detailed, not affecting therefore the decision-making process and the comparison of alternative design solutions.

With the aim to assist the implementation of life cycle approach into building design practice, LCA tools are even more conceived not as stand-alone software but as software integrate with the tools currently adopted for design, especially Building Information Modelling (BIM). Indeed, through the development of LCA BIM plug-in or LCA tools BIM interoperable, the effort is to bring forward their application in practice and to avoid as much as possible data re-work. Furthermore, since the integration between LCA and BIM is of growing interest, several studies were developed to show practitioners how to exploit them, suggesting a set of workflow procedures (Anton and Diaz, 2014). The building quantitative data extracted from BIM model are therefore matched, in a more or less automatic way, with the environmental data of LCA database. In addition, LCA methods are not only correlated with BIM but also with the so-called Green BIM, exploring the wide range of possibilities towards building sustainability. BIM-based LCA methods go therefore beyond, including for instance energy analysis, lighting simulations, green building certification and Life Cycle Costing (LCC), fostering a broadening of perspective as well as a system- and life cycle- thinking.

3. Framework as design practice supporting tool for shifting towards LCT

In building sector, despite the international pressure and the available tools and methods towards LCT, design firms are still far from adopting a life cycle approach in the way of practice. Indeed, as personally experienced exploring in depth a sample of case studies of an established design firm, actually design process takes into consideration very few life cycle information. To provide a synopsis, the topics that more affect the decision-making process are production materials and energy use (100% of projects). They are followed by operational water and maintenance materials (70%) and in turn by replacement materials (55%) and repair materials (40%). Less popular in the decision-making process are use emissions (30%), waste construction and recycled materials (15%). Anyway, it is important to note that the accounted life cycle topics depend on buildings complexity and requirements, they are not considered continuously during the decision-making but only in specific design phases and they are not explored in their entirety but focusing only on the main technological elements.

In this context, to effectively support building design practice towards a LCT-oriented decision-making, an assessment framework was developed interrelating theory and practice. Theory is represented by the knowhow developed in the field of research, deepening LCT and the related methodologies. Practice is represented by the examination of the field of practice, deepening the design process and the information flow of a reference design firm. In this way, the effort is to bridge the gap between theory and practice in order to endorse design firms in launching the required shift both in thinking and in process towards LCT.

The assessment framework results from a matrix vertically established by life cycle perspective, breakdown in the different stages from cradle to grave, and horizontally by the different phases of design process (AIA, 2014). In particular, to put into effect LCT, that represents a general mind-set, LCA standards were taken as a reference frame (EN 15978:2011; EPD PCR 531:2014), demanding however a re-elaboration of the life cycle information to make more explicit their contents to practitioners according to: materials, energy, water, transport, waste and emissions. Starting from this matrix and based on current practice, the framework points out the life cycle information required and the connected actors in charge for implementing LCT into design decision-making process.

It is worth mentioning that the framework represents the detailed version of a preliminary framework (Dalla Valle et al., 2018) here deepened through its application in practice. Indeed, to bridge the gap between theory and practice, an ethnographic approach was adopted, demanding a personal involvement within a joined firm to knowledge about and in the construction sector. Since the partnership agreement was signed with a design firm, the process is narrowed from the originally adopted building process to the design process, excluding thus construction, in use and end of life phases. Moreover, whilst the original version focused on life cycle information, actors and tools, the in-depth version puts in the background tools issues, to not limit the implementation of life cycle-oriented practice, since they are closely related to firms resources. Based on current practice, the preliminary framework was thus further developed, adjusted and tailored to fit the most demanding projects, represented by new healthcare facilities with federal mandates and called for LEED certification. In this way, it recommends and supports the establishment of the most virtuous life cycle-practice feasible at current state, not valid in absolute terms since its implementation depends case by case on how deeply life cycle perspective aims to be integrated into design process, according to projects complexity.

3.1. Shift in thinking: progressive implementation of life cycle information into design

To feasibly integrate LCT in practice, the framework solicits along the process, on one hand, a progressive implementation and, on the other, a progressive detailing of the life cycle information according to the process development.

For this purpose, the framework is deepened in compliance with the standard design process, defined by the minimum submission requirements and the sample of project case studies. In particular, requirements allows to identify the design tasks typically required along the process, whereas the case studies analysis lets to figure out the main technological elements currently faced by design. In this way, construction materials are divided into: structure, cladding, envelope, walls, floors, finishes, equipment and furnishing; while building system into: HVAC, plumbing, electrical and renewables systems. Based on this breakdown, in the product stage, the framework figure out the progressive materials specifications of the technological elements, retracing the increasingly implementation and level of detail commonly achieved in practice.

With reference to the committed elements, the framework specifies to practitioners the technological elements to be considered for each life cycle topic of each life cycle stage. In some cases, they encompass all the set of architectural and engineering elements, such happens for transport, while others include them only partially, since the life cycle topics affect only certain building elements, like for maintenance process. Finally, in other cases, the technological elements are summarized with a generic denomination, since the subdivision into parts is not meaningful for the topics at hand, as for the energy used for products installation.

Once defined the technological elements, the framework points out the related life cycle information to be progressively accounted by the design team along the process, taking an approach by parts. The information are mapped for each phase, distinguishing the ones already considered in practice, based on the decision-making of the reference case studies, from the ones to be implemented to turn into a life cycle-oriented practice. The targeting of the life cycle information is established starting from the now available information and depicting the connected life cycle topics to be included in the different process phases. For instance, it is possible to include in finishes decision-making not only aesthetic and economic issues but also VOC emissions. Likewise, in construction materials comparison, the design team can embrace maintenance and replacement issues as well as end of life issue within the set of adopted criteria. Moreover, if available in literature or within database or if expressly required by LEED certification, supplementary life cycle topics were added, as happens for construction waste.

In this way, for each life cycle information recommended, the design team is expected to integrate within the framework the relative life cycle data according to the design phase in progress. Thereafter, to boosting the optimization of the process, the whole set of life cycle quantitative data embedded in the framework turns out to be the thresholds to be not exceeded in the following process phases.

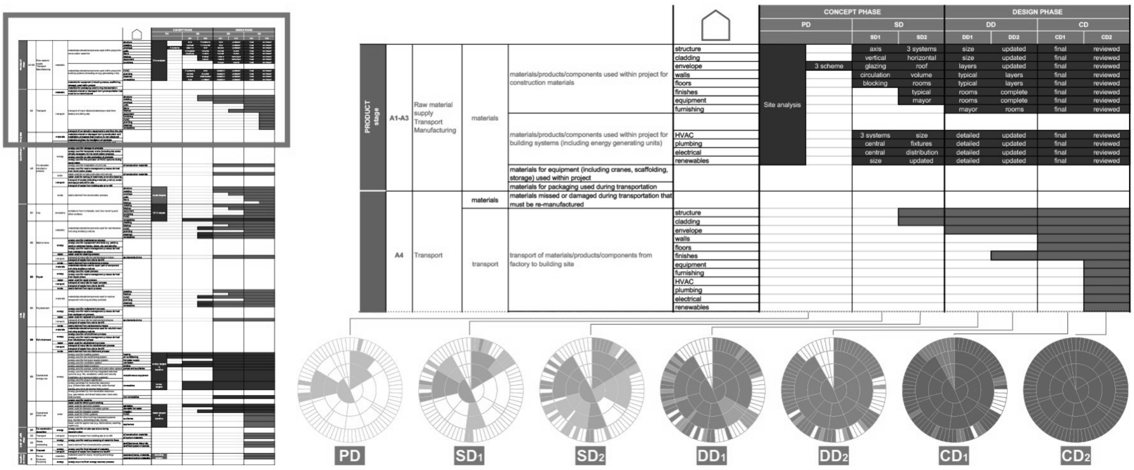

Figure 1: progressive life cycle information deepening of the product stage

3.2. Shift in process: assignment of life cycle tasks to all design team

Due the broad spectrum of information required towards LCT and the wide range of competences involved into building design process, the framework is established in order to share the roles of gathering the recommended life cycle information to all design competences.

Indeed, in our age of specialization, one person cannot address all data and meet all buildings aspects: different competences must be involved, bringing their specific knowledge and interacting each other to look at the whole considering the entire life cycle. The set of life cycle information have to be shared among different actors, in order to affect as much as possible the related decision-making process. For this purpose, the framework explains based on current practice the competences responsible for each technological element. In particular, the actors in charge turn out to be the following: architecture for cladding, envelope, walls and floor decisions; interior design for finishing and furnishing; health/laboratory design for equipment; structural engineering for structure; mechanical engineering for HVAC systems; plumbing engineering for plumbing systems; electrical engineering for electrical systems; building energy design for renewables systems and building operational energy use; and environmental design/sustainability for building operational water use.

In this perspective, to enable the shift from traditional design practice to life cycle-oriented practice, each of these competences is committed to design the assigned technological elements including life cycle criteria in the decision-making. Indeed, the framework supports the appointed actors in the accomplishment of the life cycle tasks, setting out for each competence the information required at each phase of the process for each technological element.

Moreover, to not overburden their assignments, since each competence is entrusted with one or more technological elements and with the connected life cycle information, the framework endorses a progressive implementation of the information and a growing level of detail and accuracy of the related data in conjunction with the process development.

To encourage the different team of actors in adopting a systemic approach for life cycle design, personal worksheets are inferred from the framework, switching from the overall set-up to the specific set of specifications demanded to each competence. In fact, the worksheet are referred to each actor in charge, pointing out for each technological element the main life cycle topics at issues according to the design phases. In this way, they distinctly establish the life cycle criteria to be implemented step by step during the decision-making process, calling the engaged actors for finding design solutions by accounting and collecting the committed life cycle information and data. Note that in this context the progressive implementation of life cycle information can be seen by practitioners as the minimum submission requirements demanded at each design phase for internal purpose (voluntary process put into effect by design firms to support the development of a life cycle-oriented practice) or external purpose (mandatory process if required in the near future by project requirements).

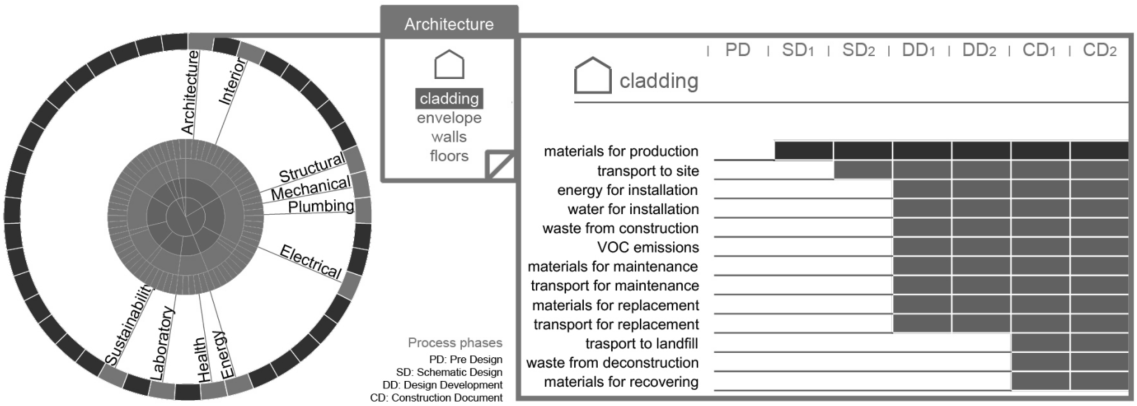

Figure 2: architecture worksheet with life cycle tasks for cladding design solutions

As an example, architects are in charge of the development of cladding solutions, being entrusted with the connected life cycle information stated by the specific worksheet and included as further criteria within the decision-making process. Following the recommendations, they have to select the best building scheme considering, beyond context, architectural and functional issues, the amount of construction materials that, due to the preliminary phase and the no definition of envelope materials, is initially represented by the cladding area. After subdividing the envelope in glazing and massive parts, the team have to evaluate different cladding materials including, beyond the performance metrics and aesthetic features, the required quantity of materials as well as the distance from factory to building site. Thereafter, specifying and detailing the selected cladding solutions, they have to embrace further life cycle criteria, entering in the framework information about: the amount of construction waste, the VOC emissions as well as the materials and related transport required for both maintenance and replacement process. Furthermore, based on the adopted technological solutions (e.g. dry or wet, prefabricated or produced on-site) and on literature data, architects have to estimate the expected energy and water use for the installation of products. Finally, in the last design phase, they update all the previous claimed life-cycle oriented data for cladding, providing additional specifications on the end of life stage, including transport of waste from building site to landfill, waste derived from deconstruction process and potential materials used for reuse, recycling and energy recovery. At the end, attached to the complete drawings, fully coordinated with the other disciplines, all details have to be clearly communicated to contractor as minimum requirements for the bidding phase.

3.3. Shifting outcome: building life cycle database

If the proposed framework is properly fulfilled by the committed actors and compiled during the design process, it turns out to be a building life cycle database of the project at hand. In fact, following the framework recommendations, all the actors in charge and/or allowed contribute information to and extract information from it, providing a long-term vision of the facility.

The framework life cycle database allows the establishment in one-record of the project-based and well-framed set of life cycle information of the building in question, stressing its divergence from typical practice. Indeed, contrary to current practice where the life cycle information are recorded in the most varied design documents, being thus difficult to retrace, in a life cycle-oriented practice they are established by means of the framework in a single-record. Moreover, actually the life cycle information are not or randomly arranged along the process, whilst through the framework they result well-framed and organized. Finally, unlike current practice in which the considered life cycle information are literature or database data, the framework progressively encourages the definition of data related to the specific building at hand. In fact, unlike other industrial products, buildings are extremely complex systems, not replicable and strongly influenced by the context, resulting unique and derived from singular process.

In addition, in line with the trends currently underway in construction sector and design practice, the framework database is envisioned in a BIM-oriented working environment. In this way, the whole set of life cycle information entered by the actors is directly linked to the building virtual model and if possible to the specific components, including thus both graphical and non-graphical information. Moreover, as shared platform of exchange among different practitioners and stakeholders, the BIM-oriented life cycle database of the facility fosters a systemic vision of the project during the whole life cycle, representing an added value for the design firm as well as for clients and a continuous built-up of know-how, also with reference to next projects.

4. Conclusions

The proposed assessment framework support design practice in the improvement and management of LCT into design process, realizing in a single-record a project-based and well-framed life cycle database of the facility. On one hand, from life cycle perspective, it results particularly valuable since it helps in the data collection required to perform the inventory phase of LCA but also LCC studies, encouraging practitioners in their application in practice, since it is considered the most demanding and time-consuming phase. Nevertheless, the life cycle information embedded in the framework can be exploited by designers not only for the development of the standardized life cycle studies, but also for the most varied design analyses, assuring the inclusion of the updated information and thus increasing the reliability of results. On the other hand, from design process perspective, it support the implementation of LCT in practice, encouraging designers and practitioners in the shifting both in thinking and in process to endorse life cycle design and operations and to orient the related decision-making and optimize the process in line with life cycle perspective.

Moreover, it is worth mentioning that the potentialities of the framework are not limited to the design process but they are extended also on the other phase of building process, starting from the construction phase. Indeed, the framework focuses only on life cycle quantitative information, since they represent the type of information directly demanded by AEC firms and therefore to bear in mind during the design process, where the embedded data become the threshold to be not exceed in the following phase. In this way, the final design data can be included in the construction specifications, placing constraints on the selection process of the bidding phase and in turn on the management and end of life process. Its implementation aims therefore to assist building process during the whole life cycle, switching from current to life cycle-oriented practice and representing the first step solicited to bridge the gap between theory and practice.

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