Resource-efficient construction: rethinking construction towards sustainability

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Abstract

Purpose – The purpose of this paper is to examine the topic of sustainable construction and provide an adequate discussion of the current thinking. Achieving a balance between economic, social and ecological aims is a challenge. Managing and implementing sustainability requires the commitment of all stakeholders and new ways of working, thinking and learning.
Design/methodology/approach – The methodology of this study consists of a literature review in the research field of sustainable construction and its associated impacts upon the climate, waste production and energy, materials and water usage. The aim is not to provide an in-depth, detailed analysis of specific processes and cases in the construction sector, but to present the need for rethinking sustainable construction in comprehensive terms.
Findings – The paper provides insights about the importance of sustainable construction. It suggests that all stakeholders at all stages should commit to sustainability to enable change in perception to start with.
Research limitations/implications – Further investigation on methods and techniques and interviews to construction companies will suggest a consistent framework for implementation "real-time".
Practical implications – The paper highlights the importance of a coordinated supply chain action in the construction sector and emphasizes the need for construction companies to train and invest in resource- efficient building methods and practices. This will manage the balance between stability and change.
Originality/value – This paper demonstrates the need to study further how resources efficiency can be adopted in the construction sector to further enable sustainability.

Keywords Sustainability, Construction, Circular economy, Resource-efficiency
Paper type Research paper

Introduction

Construction is an important sector in a country's economy, one of the largest market segments worldwide, an important player in a nation's GDP, and as a result, an important employer. According to Eurostat (2011), it contributes approximately 10 per cent of most European countries' GDPs and an approximate 7 per cent of the overall employment in the European Union (EU). The recent financial recession has dramatically affected a number of sectors, including construction. In countries such as Spain and Portugal, construction used to contribute almost 20 per cent to their countries' GDPs in 2004. These numbers have been considerably reduced as of late due to the recession. On the other hand, the recession gave further rise to the issue of sustainability in construction since construction has been charged as being one of the drivers for the collapse of the financial markets. The construction sector has been blamed for not properly using resources, energy and water; for contributing to the greenhouse effect (Dadhich *et al.*, 2014; Ding, 2008) and for accumulating endless volumes of waste, to mention just some of the major concerns about it.

Considering that construction projects demonstrate quality of life, economic growth and prosperity, a debate has been sparked about the costs of constructing such landmarks and whether these costs are outweighed by their operational benefits during their life cycle. There is greater awareness now on the increased value of resources and

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the importance of using them efficiently. Although the prices for natural resources have been rising over the past few decades, their consumption has not been reduced. This has led to a number of ecological, economic and social problems. Consequently, resource efficiency is high up on the political agenda. Nevertheless, there is still limited knowledge that relates to improving resource efficiency in different fields (DESA UN, 2008).

There are EU policies, but also national resource strategies, that support a shift away from the practices of the past. In a broader context, the European Commission (EC) (2011) presented the "Roadmap to a Resource Efficient Europe", which describes the challenges that our society is faced with and how we can deal with these challenges in order to convert them into opportunities. It concludes that a major transformation in energy, industry, agriculture, fisheries and transport systems, as well as producer and consumer behaviour, will be required. A step further, and more specific towards the construction sector, was the adoption of the European Commission (EC) (2014) of the "Resource Efficiency Opportunities in the Building Sector" report, the general objective of which is to reduce the environmental impact of buildings by improving their overall resource efficiency and, as a consequence, improve the related competitiveness of the construction businesses.

Based on the above, this paper aims to explore the topic of resource-efficient construction.

Methodology

The methodology of this study consists of a literature review in the research field of sustainable construction and its associated impacts upon the climate, waste production and energy, materials and water usage. The purpose of the review is to provide a presentation of the literature that is related to the different perspectives on sustainable construction, as well as the initiatives behind the concept of the circular economy. The purpose of this paper is not to provide an in-depth, detailed analysis of specific processes and cases in the construction sector, but to present the need for rethinking sustainable construction in comprehensive terms.

Sustainable construction

During the last few decades, there has been increased concern over environmental impacts, pollution and greenhouse gas emissions. Sustainability is one of the most frequently-used words in many different contexts; however it carries a lot of uncertainty as to what it really means. In this respect, there are initiatives at the national and international levels from both governmental and non-governmental bodies and industry to change policy, reduce overall environmental impacts and ensure a sustainable future.

In an attempt to interpret the concept of sustainability in the construction sector, it can be said that sustainable construction aims to meet present-day needs for housing, working environments and infrastructure without compromising the ability of future generations to meet their own needs in times to come. The concept of sustainability is based on the objectives of economic efficiency, environmental performance and social responsibility and it covers issues such as materials performance; building design, construction technology, operation and maintenance; flexibility in building use; stakeholder participation; energy and resource efficiency; long-term monitoring; innovative financing models; and many more (Holcim Foundation, 2015; Shen *et al.*, 2010).

According to the European Commission (2014), the construction sector generates about one third of all waste, half of all extracted materials and consumed energy and about a third of all water consumption. These are significant quantities that arise not only during construction, but at different stages of a construction project's lifecycle;

this clearly creates an enormous pressure for reductions and more efficient use (to reduce, e.g. a building's overall environmental impact throughout its full life-cycle). Therefore, resource efficiency should be applied during product manufacture, design, construction, operation, refurbishment, and disposal. By improving construction and the use of buildings in the EU, it is estimated that 42 per cent of the final energy consumption, about 35 per cent of the greenhouse gas emissions and more than 50 per cent of all extracted materials could be reduced, and it could assist in saving up to 30 per cent of all water usage (European Commission, 2011).

According to WRAP (2015a), a not-for-profit company with an aim to accelerate the move towards a sustainable resource-efficient economy, resource-efficient construction makes the best use of materials, water and energy over the lifecycle of built assets in order to minimise embodied and operational impacts. Operational impacts are the impacts that arise from use, whereas embodied impacts are the impacts that arise during manufacture/construction/disposal, or as properties of a material. Most resources have operational and embodied impacts, particularly energy, water and waste (EC, 2011).

WRAP (2015a, b) also sets as a priority, in a resource-efficient construction, carbon reduction. It reinforces that such action can be achieved by:

- reducing material consumption and wastage;
- increasing re-used and recycled content;
- using products/resources with low embodied carbon and embodied water, and no scarcity or source security issues;
- optimising durability and lifespan;
- reducing energy and water use during construction; and
- enhancing energy efficiency and water efficiency during use.

Until recently, about 80 per cent of the carbon that was emitted from buildings was associated with operational emissions and about 20 per cent with embodied emissions. Lane (2007) notes a shift in the ratio between operational and embodied carbon in the UK, which, by the time he presented his research, was closer to 60-40 per cent for an average building. Currently, embodied carbon is a dominant factor, as Wallbaum *et al.* (2012) explain. WRAP, for example, as seen from the list of priorities that is presented above, considers operating energy to be a field in which considerable knowledge and know-how has been gained; thus, it is excluded from the list of carbon reductions. One reason might be the fact that operational emissions are typically measured and regulated (Sturgis and Roberts, 2010). It is worth noting that one of the milestones that was set by the EU (EC, 2011) is that all new buildings will be nearly zero-energy and highly material-efficient by 2020. However, although important, focusing so much on operational emissions may be a rather narrow approach; hence, attention has been gradually given to embodied carbon as well.

A number of studies have been initiated in order to evaluate the environmental impacts of buildings, as well as their constituent materials, components and systems, and to explore any opportunities to reduce their environmental impacts. The case of lifecycle studies is one of them. Chau *et al.* (2015) illustrate three subdivisions of the life cycle studies as follows: the Life Cycle Assessment, the Life Cycle Energy Assessment and the Life Cycle Carbon Emissions Assessment. They discuss that all three subcategories can be used in order to evaluate and compare the environmental impacts of building designs, although they acknowledge that there are drawbacks to all three which can weaken their usefulness as decision-making support tools.

Holger *et al.* (2014) calculate the natural resource use of 22 technologies, products and strategies and analyse their resource efficiency potential. They identify over 250 technologies, strategies, and products which are regarded to be resource-efficient. They proceed a step further and assess the life-cycle resource use of a selected number of subjects by using their material footprint as a reliable indicator. The results that are presented in their paper show significant resource efficiency potential for many technologies, products and strategies.

What is important to stress is that, the efficient use of resources and sustainable construction depend largely upon design decisions, material selection, waste recycling and re-use, reduced energy-use and emissions during the whole life-cycle of a project. Thus, it is more than just building more efficiently; it is also about finding new and better ways to achieve the same or better functionality, new materials and new technologies without ignoring the importance of aesthetics. As Ding (2008) supports, the design of the project is an important factor towards sustainability but these considerations should start even earlier at the concept stage before any detailed design has started or even before a commitment is made to go ahead with a development.

In sustainable construction, there is a strong emphasis to have co-ordinated supply chain action and effective resource management planning (WRAP, 2015a). Although there has been a lot of research in the field, there are still lessons to learn. The whole value chain of the construction sector should be engaged and there is a need to engage and encourage construction companies to train and invest in resource-efficient building methods and practices (WRAP, 2015a). Construction and its sustainability can be further supported by processes such as BIM, Lean (Marhani *et al.*, 2012), and offsite construction which can provide not only savings, but also reductions to business risks.

Although there are a lot if initiatives towards sustainable construction, it is clear that there are great difference in the perspective of sustainability between developing and developed countries. In the latter case, as examined in the previous paragraphs, there is awareness of the mismanagement of resources, whereas in the former case, the emphasis tends to be on the provision, and thus development of, housing instead of environmental issues (Gan *et al.*, 2015). Economic performance is the objective and there is less attention paid to environmental and social performance. Gan *et al.* (2015) discuss the difference between developed and developing countries and the critical factors that obstruct owners from adopting sustainable practices in their developments. It is realised that although the value of sustainability in construction in developing countries is acknowledged, owners still do not integrate it into their decision-making and business practices. The importance of the role of government in such cases is discussed further in countries such as China with the aim to support and promote sustainability in construction, but also to ensure that all regulations are enforced.

The built environment is continuously increasing. This aspect should remain in the discussion of sustainable construction. Enlarging the context creates a different perspective and although improvements towards resources and energy efficiency are fundamental, ensuring overall sustainability in a realistic context should not be neglected (O'Brien *et al.*, 2011).

Reflections on climate, materials, water, energy and waste

There are environmental and economic incentives for reorganising construction in a more environmentally friendly direction. In the EU, 2.7 billion tonnes of waste is thrown away each year, 98 million tonnes of which is hazardous, and an average of only 40 per cent of the solid waste is re-used or recycled, the rest going to landfill or incineration (EC, 2011). According to the European Environmental Agency (2010), construction and demolition activities account for about 33 per cent of the waste that is generated annually and it is the largest consumer of raw materials in the EU.

EU policies such as the Roadmap to a Resource Efficient Europe (EC, 2011), the EU's 7th Environment Action Programme (7th EAP) (European Commission (EC), 2013) and the Waste Framework Directive (European Commission (EC), 2008) recognise the need for waste prevention. The Roadmap to a Resource Efficient Europe states that, by 2020, waste generation should be in a decline. EU Member States have to meet the target of 70 per cent recycling by 2020 and pertinent measures include increased landfill charges for construction and demolition waste. Osmani (2012) discusses the recent intent towards the "zero waste" strategy but he goes further by investigating the applicability of such a strategy in construction and its challenges. Ideally, in order to achieve a "zero waste" result, all stakeholders should be involved and committed to reducing waste at the source and appropriate waste management strategies should be developed by reusing and recycling materials and components. Naturally, the reduction of construction waste can happen at the various stages of a project's lifecycle and it can primarily come from the main stakeholders of the construction industry such as clients, designers, contractors and suppliers.

Osmani's (2012) research is based in the UK and the current situation there in terms of waste minimisation warrants change. He explains that the UK Government published its strategy in 2008, the basic targets of which are to improve built environment performance with a focus towards reducing carbon emissions and resource consumption in new buildings. In accordance with EU policy (EC, 2011), the ultimate target is that, by 2020, there will be zero construction waste sent to landfill. In the meantime, waste reduction, re-use and recycling are to be enforced. However, what he discusses in his research is that despite these measures, the amount of waste production has not been reduced, at least not significantly, and he believes that in order to improve such performance, the effort should start from the early design stages and the initial design approach to minimise waste. This is based on the supposition that it is far more effective to reduce a project's waste through design, rather than implementing waste minimisation measures later on during construction. His proposal is that instead of viewing waste minimisation as a threat which is expensive and requires advanced technologies, it should be viewed as an opportunity to cut costs and improve performance.

The Green Building Council in the UK has identified construction as one of the most emission-intensive industries, accounting for around 50 per cent of greenhouse gas production in the UK (Godwin, 2011). There is increased awareness of the adverse impacts that are caused by the excessive use of energy that is also associated with the production of climate change-inducing greenhouse gases (Godwin, 2011). Dadhich *et al.* (2014) demonstrate how emission "hotspots" across the lifecycle of products such as plasterboards and their supply chain can be identified and analysed using different intervention options within the supply chain in an attempt to reduce greenhouse gas emissions. For their research, they use lifecycle assessment (LCA) techniques in order to analyse the product's supply chain and propose renewable sources of energy in warehousing as major decarbonisation interventions. Ding (2008) also examines environmental building assessment methods which determine building sustainability as applied in different countries. The research discusses the concept of developing a sustainability model for project appraisal based on a multi-dimensional approach that will allow alternatives to be ranked.

Godwin (2011), in his research on traditional buildings, presents a number of traditional materials and techniques to meet the emerging standards for sustainability and energy conservation. He describes that these buildings behave in a way that meets sustainable criteria and can be further enhanced to be more sustainable without harming their character. This is an important issue in many European countries which have a considerable number of historic buildings, and as such, there is significant pressure to reduce carbon emissions.

Magnusson *et al.* (2015) examine resource efficiency by describing material flow and management practices for urban excavated soil and rock. They develop a conceptual model for the urban flow of excavated soil and rock and undertake an extensive literature review concerning the management of quarried construction materials.

In the construction sector, concrete and cement are the most popular construction materials; they are used with increasing demand because their strength and durability allow them to be used for a number of applications such as buildings, roads and bridges. According to O'Brien *et al.* (2011), the global production of cement is approximately 2.5 billion tons per year and it is increasing, with China being the world's largest producer of cement.

It is relevant to mention that cement and concrete production have two weaknesses: they exert a considerable negative impact on the environment in terms of carbon dioxide emissions and they are also responsible for the exhaustion of the world's most valuable fossil energy resources (Kartik *et al.*, 2003). This necessitates the exploitation of sustainable construction materials, new approaches in the production of cement and the re-use of its wastes. Karim *et al.* (2011) review an energy-saving strategy of consuming waste materials such as slag, fly ash and ash from timber as a supplement and/or ingredient of cement and concrete. The authors conclude that the effective utilisation of these wastes as a supplement for cement or constituent of concrete would be a constructive and valuable way of saving energy, as well as exemplifying sustainable construction.

In the overall evaluation of sustainability and construction, the increasing urbanisation which is transforming built environments and the consequences that increased populations which are gathered in cities cause should not be overlooked (Shi *et al.*, 2014). Increased energy consumptions, carbon emissions from vehicle travel and materials being transported considerable distances because local sources are exhausted are just snapshots of reality. Solutions such as green walls and green roofs could significantly assist in reducing the atmospheric burden and can be used for absorbing greenhouse gas emissions during the production of new building materials or during the use of new infrastructure/building technologies (Boyle *et al.*, 2013) but they need to be augmented with additional solutions.

It is also important to note that using more renewable energy resources will naturally reduce energy consumption and emissions but this approach is, if not narrow, only part of the concept. The vision of resource-efficient construction is to reduce energy demands long-term (O'Brien *et al.*, 2011) with all of the inter-related consequences and to engage all stakeholders to adhere to the same commitments. It should be acknowledged that the introduction of sustainability initiatives during commercial development has its challenges. The idea of the circular economy seems to embrace every sustainability concern, as is demonstrated in the following section.

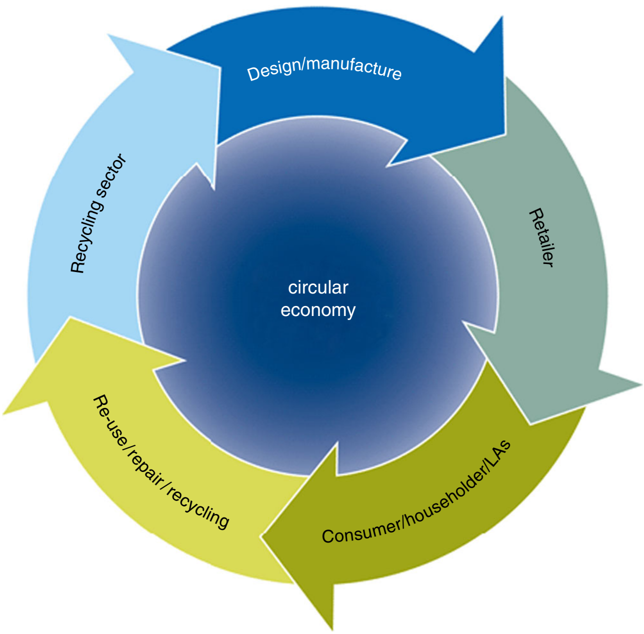
Circular economy

As Fadhil (2013) explains, businesses and industries are trying to understand the environmental impacts of their activities and what would change if sustainable practices were to be applied. The European Commission, acknowledging all of the environmental considerations and economic concerns, adopted the communication, "Towards a Circular Economy: A Zero Waste Programme for Europe" to establish a common and coherent EU framework with which to promote the circular economy (European Commission (EC), 2014a). Turning Europe into a more circular economy means the following:

- boosting recycling and preventing the loss of valuable materials;
- creating jobs and economic growth;
- showing how new business models, eco-design and industrial symbiosis can move us towards zero waste; and
- reducing greenhouse emissions and environmental impacts.

The circular economy is described as moving away from the current linear economy (i.e. make – use – dispose) towards one in which the products, and the materials that they contain, are valued differently, creating a more robust economy in the process (Environmental Audit Committee, 2014). According to WRAP (2015b), a circular economy is about valuing products differently and creating a more robust economy in the process. By assessing how we design, make, sell, re-use and recycle products, we can determine how to get the maximum value from them, both during use and at the end of their lives. An indicative graph of how the circular economy works is illustrated in Figure 1.

In order to improve sustainability performance, key players need to understand the drivers of both the costs and revenues that are involved in sustainable development. An influential report which was produced in 2012 by the Ellen MacArthur Foundation (2012), "Towards the Circular Economy", illustrates the benefits of moving towards a



Source: WRAP (2015a)

Figure 1.
Schematic illustration of circular economy

restorative circular model. The report finds that over US $1 trillion a year could be generated by 2025 for the global economy and 100,000 new jobs could be created over the next five years if companies focused on encouraging the build-up of circular supply chains to increase the rate of recycling, reuse and remanufacture. This would maximise the value of materials when products approach the end of their useful lives.

The idea of the circular economy is associated with concepts such as "from cradle to crave" and "industrial ecology"; the idea of optimising the use of resources in this respect is not new. As illustrated in Figure 1, in a circular economy, a range of "cycles" is repeated where resources are repeatedly used and their value is maintained to the extent that this is possible. What used to be waste can be turned into a resource, thus engendering better resource management throughout the product's life cycle. Therefore, resources are not used for one purpose only, which benefits both the environment and the economy. This improvement of resource management not only makes better use of resources, but it opens up new markets and jobs, enables less dependence on raw materials and impacts less upon the environment.

Conclusion

Sustainable construction aims to reduce the impact of a project on the environment over its entire lifetime while optimising its economic viability without compromising aesthetics, comfort and safety. The shift from traditional construction towards sustainable development and resource efficiency has received a lot of attention; consequently, a number of concepts, techniques, evaluations and assessments of resources have been discussed. However, it seems that there are still knowledge gaps regarding how to develop effective and efficient strategies in different fields, integrating all pertinent factors.

Construction projects are diverse and complex. They consist of a number of stakeholders (clients, designers, contractors, suppliers), undergoing a number of stages (design, construction, operation, maintenance), using a number of materials and approaches (concrete, cement, wood, steel), with an intense use of resources and large volumes of waste produced throughout the stages and for a long time thereafter. Investment in training and new technologies, together with thoughtful and proactive design from the early stages of the project, is imperative for all construction companies. It seems, however, that we have to go a step further and shift our way of thinking. We have to rethink construction. We have to rethink how we design, manufacture, operate and maintain a construction project and how we can efficiently utilise all of the resources (materials, energy, water, land) that are required so as to produce the least possible waste, not only during their useful lives, but after their lifecycles have ended. Most of all, we have to change our attitudes and act sustainably. Why not? Using resources to their highest potential throughout the product lifecycles – manufacture, design, construction, operation, refurbishment and end of life – may involve extra initial costs, but the environmental measures that will be incorporated in the process will lead to a long-term recurrent cost reduction and potential increase on asset valuations.

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