Review of the Current Research in Sustainable Engineering

Nassar AL-Samadi

Abstract

The aim of this paper is to review the available literature on the current research in sustainable engineering. In order to do this, open source articles from Google Scholar were used. An attempt was made to select studies spanning the past few decades so as to analyse the evolving trends and research in sustainable engineering over the years. The focus was especially on recent years owing to the emphasis on sustainability in every field. Using a set of criteria, approximately 400 scholarly works were initially analysed and then reduced to a smaller number which were then explored in detail. It was found that there needs to be a focus on improving the education that engineering students receive in order for them to effectively address the complex and multidisciplinary issues that arise while working towards sustainable development. Additionally, an emphasis on resource efficiency, adopting a life cycle approach and engaging with social and environmental concerns rather than only the technical aspects of engineering would make the field more dynamic and robust enough to address the challenges of sustainable development. The need for policies mandating green and sustainable construction was also addressed.

Keywords: Sustainable engineering, sustainable development, engineering education

Introduction

Engineering plays a central role in every aspect of society. Due to its pervasive nature, the role that engineering can play in influencing sustainability cannot be undermined. The potential of engineering to impact sustainable development, however, also poses questions regarding its purpose and use. According to the World Federation of Engineering Organisations, incorporating considerations of sustainability within engineering would entail 'planning and building projects that preserve natural resources, are cost-efficient and support human and natural environments' (WFEO, 2002). Hence, there is a need for engineers to consider the impact of their profession in order to further the goals of sustainability along with responsible resource use.

Sustainable development, they state, requires technical solutions and innovations which is where engineering can contribute significantly. From green buildings to promoting energy efficiency, engineering can accelerate the pace towards achieving sustainable development. In order to achieve this, Bell, Chilvers and Hillier (2011) contend that there is a need to reframe engineering as a 'socio-technical profession' rather than a strictly technical one, in order to allow for the field to contribute to sustainability (Bell, Chilvers & Hillier, 2011:177). They explain that engineering is a dynamic and hybrid field which is well equipped to tackle and address the hybrid issues of sustainability. In this context, Rosen (2012) suggested distinct ways in which sustainability can influence and assist in developing a sustainable society. These are - sustainable resources, sustainable processes, increased efficiency, reduced environmental impact and the fulfillment of other aspects of sustainability (Rosen, 2012:2275). In addition to this, twelve guiding principles of engineering for sustainable development have also been developed by the Royal Academy of Engineering. These principles demonstrate the ways in which engineering can address considerations of sustainable development. These are as follows-

Table 1 - Adapted from The Royal Academy of Engineering (2005)

Guiding Principles of Engineering for Sustainable Development	Explanation
Look beyond your own locality and the immediate future	Identifying potential positive and negative impacts, not only locally but also outside the immediate local environment. To seek to minimise the negative, while maximising the positive.
Innovate and be creative	Since there is no one 'best' solution, alternative solutions may be identified, which are compatible with the sustainable development approach.
Seek a balanced solution	Trying to balance the adverse and positive impacts on economic, social and environmental factors.
Seek engagement from all stakeholders	This is with a view to incorporate various viewpoints and perspectives.
Make sure you know the needs and wants	Engagement leads to a better understanding of the needs and demands while also promoting sustainability within the building considerations.
Plan and manage effectively	Encouraging out of the box thinking while also keeping plans straightforward so as to ensure that all the stakeholders can approve the plans. Improve or maintain existing sustainability standards while planning.
Give sustainability the benefit of any doubt	Factoring in improved sustainability outcomes in the plans while also demonstrating a commitment towards sustainable development and resource efficiency.
If polluters must pollute... then they must pay as well	Minimising adverse environmental costs while also fulfilling Corporate Social Responsibility commitments.
Adopt a holistic, 'cradle-to-grave' approach	Using a whole life cycle approach in order to assess the social and environmental impacts, ensuring that materials used are reusable or recyclable and opting for non renewable materials only after exhausting all other renewable options.

Do things right, having decided on the right thing to do	Retaining the focus on sustainability throughout the process is crucial. Keeping abreast of new technical and market developments and advancements regarding materials to be utilised.
Beware cost reductions that masquerade as value engineering	Avoiding having to sacrifice sustainability objectives incorporated in a design while assessing costs and attempting to reduce them.
Practice what you preach	Being accountable for one's own designs and engineering and improving upon them.

Sustainable engineering has evolved over the years along with ways to understand and implement its practices and principles. These will be discussed in the paper below.

Methodology

In order to find relevant research studies specific terms were used in Google Scholar. These were the following: Sustainable engineering, Sustainable development, Engineering education + sustainability, and Sustainable engineering + trends.

For each individual search term, 100 results were considered, for a total of 400 results. For these, an initial examination was conducted, using research studies that spanned several decades. An attempt was made to select research spanning the past few years so as to analyse the evolving and recent trends in sustainable engineering. The focus was especially on recent years owing to the emphasis on sustainability in every field. Using a set of criteria, approximately 400 scholarly works were initially analysed and then reduced to a smaller number which were then explored in detail. It was found that an emphasis on resource efficiency, adopting a life cycle approach and engaging with social and environmental concerns rather than only the technical aspects of engineering would make the field more dynamic and robust enough to address the challenges of sustainable development. Additionally, there needs to be a focus on improving the education that engineering students receive in order for them to effectively address the complex and multidisciplinary issues that arise while working towards sustainable development. Other related areas such as green infrastructure and green buildings were also found as key domains of upcoming research in sustainable engineering. These will be elaborated on in the following sections.

Results

The paper thus far has sought to provide an overview of what sustainable engineering is and what its principles are. In order to implement these principles, tools such as life cycle assessment, impact assessment, stakeholder analysis as well as environmental valuations may be adopted. For engineers to take into consideration sustainability concerns and the principles elaborated above, the introduction of sustainable development in engineering education plays a vital role (Ahrens & Zaščerinska, 2012). This is because understanding the role of engineering in promoting the Sustainable Development Goals rather than a mere focus on the techno-economic

aspects, can allow engineering students to appreciate the potential impact of their work and profession. In researching the changes to the curriculum of engineering students, Ahrens and Zaščerinska (2012) state that principle of resource efficiency are key along with instilling aspects of the environmental, social as well as economic effect of engineering. In addition to this, Bryne, Desha, Fitzpatrick and Hargroves (2010) emphasise on the need to incorporate policies and initiatives integrating sustainable development while assessing the curriculum of engineering students. They explain that engineers have the potential to address some of the biggest challenges facing the planet, which include demands for energy, drinking water and clean air. Sensitisation to such challenges and the need for sustainable development during their education is one effective way to equip them with the skills and knowledge they require in order to address these (Byrne, Desha, Fitzpatrick & Hargroves, 2010). Their review of the progress made internationally in including sustainability in engineering education revealed that universities have, for decades, debated whether to teach sustainability as separate modules or as a separate specialisation. Additionally, they trace the increasing calls from international bodies over the past two decades to incorporate dimensions of sustainable development in education at various levels.

Grimal et al., (2020) further researched the way engineering education incorporates sustainability. They found that most of the 'courses offered to future engineers are those that are related to their technological speciality with environmental considerations only being taken into account at the very end of their studies' (Grimal et al, 2020:766). They further argue that due to the specialised nature in which sustainability is taught to engineers, this mode of teaching in silos results in a lack of ability to address complex and multidisciplinary problems. Hence, just as Bell, Chilvers and Hillier (2011) had done, Grimal et al., (2020) also conclude their research by advocating for 'rethinking training' in order to relate their technical skills with pressing and 'current social issues' (Grimal et al, 2020:770).

In addition to the focus on engineering education and the focus on the curriculum of future engineers, green infrastructure or construction and green building have also emerged as areas of research and interest with regard to sustainable engineering. Examples of green infrastructure include green roofs covered with vegetation, rain gardens, wetlands, etc. Singh (2018) elaborates on green building more specifically and explains that the term refers to a building that 'is designed, built, operated, maintained or reused with objectives to protect occupant health, improve employee productivity, use wisely natural resources and reduce the environmental impact' (Singh, 2018:00107). Buildings, historically, have used up enormous amounts of energy and non-renewable resources while also contributing significantly to carbon emissions. However, green buildings, Singh (2018) contends, are a prime example of sustainable engineering in that it is a step towards allowing engineering to have larger positive social and environmental effects.

This is because they incorporate some of the twelve principles already discussed in earlier sections and focus on - first, utilising renewable resources; second, reducing their carbon footprint; third, using energy efficient appliances; fourth, increased efficiency; next, reduced environmental impact; and lastly, prioritising the 'use of recycled building materials' in their construction (Singh, 2018:00109). These considerations are incorporated both in the pre-building as well as the post-building stage. Hence, green building allows for the principles of sustainable engineering to be operationalised and utilised.

Other examples of green infrastructure may also be used as a way to protect against natural disasters and build resilient communities. Instances of this are provided by Tyler (2016) below -

Table 2 - Adapted from Tyler (2016)

Green Infrastructure	Description	Benefits
Green Roofs	Building roofs covered with vegetation and soil	Absorbs rainwater, thereby preventing and reducing runoff
Rain Garden	Vegetated areas to collect and absorb storm and rain water.	Reduces storm water runoff
Green Streets	Streets that are designed with natural resources in order to store and move the collected storm water.	Reduces storm water runoff

These are some examples of green infrastructure other than green buildings as well as their use in promoting not only sustainable development but also assisting in disaster mitigation. Despite the many advantages to green infrastructure, however, there are some challenges that impede the wide scale construction of green infrastructure and buildings. Some of these challenges will be discussed in the next section.

Discussion & Conclusion

The review paper thus far has sought to elaborate on the need for sustainable engineering as well the crucial role that engineering can play towards achieving sustainable development. In making engineering sensitive to sustainability goals and needs, there is a need felt to sensitise young engineers while they receive their education. In the absence of this, they are hindered from developing their ability to address the complex and multidisciplinary issues that face the planet today.

Green buildings have also been discussed in this paper as an example of operationalising the twelve principles of sustainable engineering. However, there are certain challenges that impede the large-scale adoption of green buildings and other pathways to sustainable engineering. One key challenge that is faced in this regard, is the lack of research. There is often either a lack of research or the existence of competing research regarding sustainable and efficient resources and materials that may be used for green buildings as well as for other green infrastructure and construction. Related to this is the need to emphasise and improve life cycle performance of materials and focus on the use of alternatives that are renewable and recyclable. In addition to this, there is a lack of policies mandating the construction of green buildings, and the adoption of sustainability standards in engineering (Singh, 2018). In order to address this, policy makers must mandate green guidelines for construction and implement them in order to ensure their adherence. This may be in the form of regular audits, carbon taxes as well as tax exemptions for projects utilising green infrastructure. Another challenge of sustainable engineering is that of the lack of awareness about the role that engineering can play in promoting sustainability and in furthering sustainable development. It is for this reason that there is a need to promote sustainability education for engineering students.

Mention must also be made here of the need for technological advancements and innovations to promote sustainability in the field of engineering. In spite of the recognition of the need for green to promote sustainability in engineering, there is also a need to ensure that its social and environmental impact is considered during innovations and not just the technical aspect of it. This is because engineering, as a hybrid discipline, has the potential to solve hybrid challenges posed by sustainable development (Bell, Chilvers & Hillier, 2011). While on the one hand, sustainable development requires cultural, social, political and economic changes, on the other hand, sustainable engineering can assist in hastening the process of change for the better.

This review paper can be concluded by stating that there is a clear need for sustainable engineering in order to achieve the Sustainable Development Goals. There is a need for engineering to be understood as a dynamic field rather than one that is strictly technical. In doing so and in balancing the technical aspects of the field with the social and environmental costs of engineering, there is scope to address the needs of sustainable development. Although challenges persist, there is a need for further research in understanding how green infrastructure has the potential to promote resilience against natural disasters along with ways to influence policy to enforce strict guidelines for green construction. Compiling context specific case studies and replicating successes will go a long way in further the sustainability agenda. Lastly, there is a need for outreach and awareness generation. This is not only for engineering students but also for the wider public. This is so that they can generate a demand for green infrastructure by fully understanding the need for it as well as its value.

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