Title	Engineering education for a zero growth economy
Author(s)	Johnson, Gearold R.; Siller, Thomas J.
Publication date	2021-06-14
Original citation	Johnson, G. R. and Siller, T. J. (2021) 'Engineering education for a zero growth economy', EESD2021: Proceedings of the 10th Engineering Education for Sustainable Development Conference, 'Building Flourishing Communities', University College Cork, Ireland, 14-16 June.
Type of publication	Conference item
Link to publisher's version	https://www.eesd2020.org/ http://hdl.handle.net/10468/11459 Access to the full text of the published version may require a subscription.
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Item downloaded from	http://hdl.handle.net/10468/11616

Engineering Education for a Zero Growth Economy

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Abstract

Engineering as a profession and its educational system grew up in parallel with the development of agrarian capitalism, industrial capitalism and finance capitalism. Engineering has participated heavily in the development and growth of fossil fuels both for materials production and as an energy source; land, sea and air transportation systems; manufacturing; communications; computing; the built environment and many others. Engineering has contributed to non-renewable resource extraction and materials innovations as well as developments in the rise and growth of mass industrialization. Now society faces the need for major changes if society is to survive the existential threats it is facing such as biophysical environment degradation, climate changes, health pandemics, and over population. All of these threats are a result of the economics of unlimited growth which is no longer tenable. How will these unknown threats and challenges affect the engineering profession and in particular engineering education? In this paper we will take a brief view of possible impacts to engineering education for the built environment as it could be affected in a zero growth economy. We hope that this paper will inspire and lead others to inspect other disciplines within engineering education for changes and innovations that a sustainable future may require.

Introduction

Is human society's interaction with the Earth's biophysical environment in an unsustainable state? This is a question that is being asked by many today. While there are skeptics and deniers, we accept the preponderance of scientific data that says that society's interaction with the biosphere is in an unsustainable state. For example, data supports environmental degradation through increased pollution in terms of greenhouse gas emissions, loss of biodiversity, both surface and groundwater pollution and the over pumping of groundwater, decreased fossil fuel and other mineral resources; data also supports both economic and cultural degradation from increased income inequality and inequity, over population and overcrowding, the general lack of racial and social justice, food and water insecurity, mass migrations of peoples and global health pandemics. Neoclassical politico-economists believe that continued unlimited economic growth and markets solve all problems. We do not believe this as evidenced by the current state of the biosphere as well as the recent history of the Great Recession of 2008-09. Obviously, unlimited growth is impossible when that growth consumes non-renewable resources and produces waste greater than ecosystems can service. It is time to admit that unlimited economic growth is no longer a viable system and accept a zero-growth, or perhaps even a degrowth, definition for a future sustainable society.

So why is it so difficult to accept zero-growth or degrowth as the future? For one thing zero-growth is considered to be a failure state in many situations. The growth of a country's GDP is what often keeps politicians in power, whether they be in European countries, China or the USA. This is also true for corporations. Rarely does a corporation hire a CEO to reduce a company's size -growth is the measure of success. This concept of growth being equated with success is so engrained in society, a movement to zero-growth, or degrowth, runs contrary to the fabric of most of society. Engineering is also complicit in this denial. Few engineers are interested in becoming experts at repairing existing artifacts -the attraction of engineering is in the design of something new. Conspicuous production and consumption and ‘designed obsolescence’ require a collaboration between business experts and engineers. There is also a question of social justice around the concept of zero-growth. Shall western societies reap the benefits accrued from years of growth but push developing countries to limit growth to help pay for the developed world’s excesses? But zero-growth is inevitable, the question is not if, but when!

In fact, if we accept Bonaiuti’s analysis (Bonaiuti 2018), and it seems very compelling, the U.S., Europe and Japan are already in an involuntary degrowth situation and China is probably only a decade or two behind (Li 2014). Unfortunately, voluntary degrowth or even zero-growth will not occur in the short-run by the developed nations. This may happen over time as living conditions become increasingly more difficult and even new forms of politico-economic systems may be introduced such as “climate capitalism,” “ecosocialism,” “green republicanism,” or as yet unknown socio-politico-economic-technological systems (Latouche 2009, Kirby 2017, Fremaux 2019).

However, this is all in the future. So, if one of the main roadblocks to a future sustainable state is the question of economic growth then our question is: If the transition to a sustainable society means zero economic growth or even a de-growth scenario, what are some implications for engineering education? Clearly the answer will partially lie in curricula. Engineering curricula has responded to previous major events such as the launch of Sputnik in 1957, but the sustainability crisis lacks that clearly defined ‘moment’ in time that mobilizes a majority of educators.

Of course, engineering education is a hugely complex topic and is only cursorily approached here. Technological development (progress) must be decoupled from economic growth. Most technology advancements that result in productivity gains have always been systematically transformed into greater output rather than reducing the effort required which would result in workers having to work fewer hours. Witness the entrepreneurial movement that emphasizes new products. Changing the outcome from greater output rather than lessening workload is a change in mindset. This change will be very difficult for many engineering faculty members to accept and thereby address in their classes. And there are other mindsets holding engineering education back. For example, few engineering programs emphasizes the depth of interdisciplinary effort that is required to effectively work towards a sustainable future. Engineers maintain a mindset that they are ‘the problem solvers’ instead of members of much, much broader teams (Siller, Johnson et al. 2016). Engineering has always suffered from a lack of an underlying philosophical basis. A sustainable future may force engineering to adopt a new ontological and epistemological underpinning. (Siller, Johnson et al. 2018)

In the next section we will look at an example of changes that could take place in civil engineering with respect to maintaining the built environment.

The Built Environment Example

The meaning of a zero-growth, or degrowth society, changes the meaning of the world of the built environment. Most engineering education focuses on the design and implementation of new artifacts. Rarely does engineering education focus on the reuse of existing artifacts. Yes, there are recycle programs everywhere, but too little effort is spent on the refurbishment of existing artifacts. This is especially true of the built environment such as buildings, roads, and bridges. As growth halts, the need for different types of facilities does not go away but the effort should shift to existing structures, not new ones. Existing buildings need to reduce current energy use, roads and bridges will need to accommodate modern, energy efficient vehicles. To reduce the consumption of non-renewable materials existing facilities should be refurbished instead of building new facilities. Existing building need to be considered resources not waste to be eliminated.

The majority of engineering education programs, at least in the U.S., continue to focus on designing new artifacts. The lack of formal education programs for refurbishment was recognized early in this century, as articulated in the preface of the CISM course on refurbishment describing the reason for the course "… in view of the relatively scarce availability of similar advanced educational programs in regular courses held at university," (Mazzolani et al., 2002).

Underlying the need for education about refurbishing of existing facilities is the implicit acknowledgement that this type of engineering work requires technical skills beyond that found in traditional curricula. Mazzolani (Mazzolani 2002) discusses topics such as material compatibility between existing building materials and new materials being considered for refurbishment. While many engineering materials related courses focus on basic strength and deformation properties. Mazzolani also discusses system-level approaches not typical to new design, such as the need for new building additions to be reversible, i.e. additions that can be removed if necessary. These types of systems engineering processes are still lacking in most curricula. Further, he presents a classification of refurbishment starts with safeguarding of structures -this is already a temporary technique with regards to safety issues. His second classification, repair, is also a common technique to maintenance engineering functions, but his other two classifications are related to our concern of retrofitting existing building for a new future: reinforcing and restructuring for new purposes. These latter two are what is needed for a zero-growth future. Both of these approaches serve the purpose of continuing the use of a structure either for its original intention but possibly expanded, and the latter is effectively the 'reuse' of the building for a new purpose. Either way, the result is using existing facilities instead of the more common tear down and build new approach.

Before moving to examples that require new technical skills it is worth mentioning how existing skills can be used along with a different design philosophy to make it easier to use existing facilities. Both of these examples come from Hill and Martinez-Diaz (2020). The first case involves a rail corridor in southern California, United States. The pylons were strengthened such that the bridges could be raised if future flooding became worse. A second case involves Dutch seawall construction. The foundations for the seawalls were over-built such that if future sea level rise is larger than planned, the structures can be safely raised. Both these examples do not require new skills but a new mindset -build for now and include flexibility to adapt in the future. These examples show how flexible design can better allow for adaptation later instead of replacement being the norm.

As an example of the need for technical skills in the world of refurbishment, we look first at the area of building foundation engineering. The second author of this paper has taught the topic of foundation engineering numerous times over his 32-year career in academia. Upon reviewing the materials in the CISM course related to foundation refurbishment (Mandara 2002) it became clear that the techniques discussed were not topics commonly covered in foundation engineering courses. This is supported by the lack of coverage in popular textbooks in the U.S. for foundation engineering such as (Das and Sivakugan 2017). Of the three techniques covered by Mandara (Mandara 2002), underpinning, base widening, and soil improvement, only soil improvement is discussed by Das and Sivakugan (2017). And soil improvement in the textbook focuses on new construction and not on refurbishment of existing structures. The techniques of implementing soil improvement for existing structures entails very different technical aspects. New construction generally allows for easy access to implement techniques as no existing structure is in place to block access. To improve soil below and existing structure using techniques such as grouting often requires drilling through the base of existing foundations (Mandara 2002). Engineering students are not taught techniques for soil improvement that may require potentially compromising the integrity of existing foundations. The intermediate stage where the existing structure is temporarily compromised before the final improved state presents different challenges that new construction.

The other techniques for refurbishment, underpinning and base widening require techniques not even hinted at in the traditional curricula/textbooks. Again, these techniques create temporary risky situations where current systems have to be supported while additional structural elements are added to the system. Undergraduate engineering education presents problems that start with a clean starting point. Students are not prepared to deal with complex existing systems.

There is some good news in terms of the profession moving forward in the direction of modifying existing buildings. An encouraging recent trend has been the retrofitting of large skyscraper buildings. As stated by Al-Kodmany (Al-Kodmany 2014) there are advantages to retrofitting the existing building stock than tearing down and building new "… renovating older buildings could be 'greener' than destroying them and rebuilding new ones. While some demolition and replacement may remain a necessity to meet contemporary needs, there are significant opportunities to reduce carbon emission and improve existing buildings' performance by retrofitting them rather than constructing new ones." Similar to Mazzolani, Al-Kodmany also recognizing that the skills of engineers must also change:

"Overall, required technical expertise on the part of the project team—architects, engineers, building managers, tenants and energy service companies—continue to be lacking."

A key methodology for restoring existing buildings is to reduce energy use. (Ma, Cooper et al. 2012) This is one area where new and refurbished structures are similar -efficient energy use is a goal of both. But again, similar to foundation engineering, in existing buildings, installing new energy systems may require very different design approaches than the clean slate of a new structure. The first large building to attain LEED Gold certification due to retrofit or refurbishment was the Empire State Building in New York City, New York, USA. (USGBC 2020) This certification was obtained in part due to increased energy and water use efficiency. But this is only one success story with skyscraper retrofits. According to Al-Kodmany the following buildings, in addition to the Empire State Building, had made significant changes as of 2014

- Willis Tower, Chicago, IL, USA: recently became the tallest building to get Energy Star designation meaning it uses at least 35% least energy than a typical building
- Taipei 101, Taipei, Taiwan: earned LEED Platinum certification
- Adobe System Headquarter Complex, San Jose, CA, USA: retrofit included upgrades to reduce both energy and water use
- Glastonbury House, London, UK: retrofit lead to 50% in energy saving and 40% in water reduction
- The Joseph Vance Building, Seattle, WA, USA: heating, lighting, and water systems all upgraded
- Hanwha Headquarters, Seoul, Korea: the proposed changes for this building include the façade replacement.

Each of these could form the basis of a case study for new courses in civil engineering.

Conclusion

We, engineers, have played a significant instrumentalist role in the current biophysical environment crisis and any changes in engineering education must start with a thorough examination and reflection on engineering's role in the creation of a sustainable society. This requires a close examination of engineering education through the lens of zero growth. Design courses need to be altered to emphasize renovation rather than always designing something new. Engineering students should be taught the value of embodied carbon, embodied energy, embodied water and materials and embodied culture. We should also emphasize innovation combined with entrepreneurship focused on social, cultural and environmental entrepreneurship rather than economic entrepreneurship. Our students also need to learn about complex open systems to understand how technological interventions need to be continually adapted within a changing system. The paper provides an initial examination of engineering curricula intended to identify what we include in our curriculum that aids or hinders the required transition to a sustainable society.

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