**A TERM PAPER ON SUSTAINABLE DEVELOPMENTS AND INNOVATIONS: SPECIAL OPPORTUNITIES AND CAREER PROSPECTS IN CIVIL ENGINEERING**

**BY**

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**ABSTRACT**

Sustainable development is a major opportunity and challenge to engineers: it requires rethinking of the entire industrial sector to such an extent that the environmental impacts on the life cycle of goods are reduced by a factor of five, whilst simultaneously increasing both economic gains for the industry as well as social benefits. This cannot be achieved without radical change in business operations and the adoption of innovations in all industrial sectors. The construction industry is considered to be a priority in order to achieve global sustainability. The sector has the highest intensity material usage of the entire economy, consuming from 40 to 75% of the total value of materials extracted and accounts for up to 15% of the GDP. Along its supply chain, waste generation is proportional to the total value of materials consumed. Likewise, following a life cycle assessment of construction products consisting primarily of buildings and roads, it became apparent that these are responsible for a significant share of total energy consumption. Buildings themselves in the “in-use” phase are responsible for about 25% of total CO2 gas emissions –, resulting from the production of energy [Price et al. 2006]. The production of cement generates about 5% of total anthropogenic CO2 emissions, and the proportion is growing [United Nations Environment Programme 2007]. The social aspects of sustainability must not be ignored; this will also require the construction industry to become increasingly heedful to its responsibility in respect to quality of life and social welfare. If current business practices and technological solutions are not changed it is certain that the construction industry’s share of contributions to environmental loads will steadily grow in the future. The relationship between sustainability and that of service life planning and durability has already been addressed in several DBMC conferences. The major aim of this paper is to explore the research needs in the field of service life planning and durability of building materials as posed by innovation for sustainable construction. Despite the important social implications, the discussion here will be focused on the environmental and economic dimensions of sustainability.

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More precisely, innovation will be defined as the successful

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**1 INTRODUCTION**

Civil Engineers are increasingly working to achieve safe and sustainable development in a costeffective, environmentally protective and socially responsible manner. Civil engineers of the future need to be equipped to account for all aspects of construction given their broad roles from design to deconstruction of the built environment. Worldwide there is an increasing move to reform traditional engineering education programmes to incorporate the concepts of sustainability in undergraduate curricula. To acknowledge the shift in the societal expectations of the engineering profession it is essential that such programmes provide engineers with a sustainable vision of the world and provide the skills to allow engineer to evolve and meet the challenges that graduates will face when they enter the workforce (Augusti, 2007; Desha et al., 2009; Lopez et al., 2011). Therefore, the education of future civil engineering professionals demands the implementation of a holistic approach, enhancing sustainability through new approaches, methods, and information technology (Levitt, 2007; Augsburger, 2009).

Nowadays, “innovation” becomes a key word of modern economy but it seems to be the new global obsession also in engineering. Contemporarily as well as in the past construction innovations are hot spots in engineering science. The subject matter does not lose its validity but even brings about some new problems due to several reasons. An attempt has been made to define the paradigm of civil engineering development and to depict a wider view of knowledge-based construction engineering. Innovation means the successful exploitation of new ideas. More precisely, innovation will be defined as the successful introduction of new technologies or procedures into industry. In such cases, Research and Development (R&D) will be understood as the process that is undertaken to introduce innovation into industry. Continuous innovation is vital for sustainable development of the construction industry. Creative ideas and innovative solutions are recognized as important levers to effect growth and efficiency, especially in today’s dynamic world. The conviction that ideas should and did outrun innovation has been demonstrated in publication. The aim of this study is to underline the scientific background of construction innovation. Construction innovation occupies a special position amongst engineering innovation due to the scope of its impact, and responsibility related to construction and use of building structures. For this purpose, the definition of construction innovation needs to be formulated together with its specific challenges, limitations and possibilities.

1.1. Conditioning of construction innovation

1.1.1. Construction innovation versus fundamental requirements (CPR-EU 305/2011).

Innovation means each change. There exists product, process, organization and marketing innovations. Just “doing something” but only something related to construction could be extremely bad to the construction itself and even for its surroundings. Innovations are endless on the side of positive results, but on the negative side a catastrophe, understood as the fall of the continuum, is the obvious barrier in the material and conceptual senses. A building breakdown or even collapse could also be the source of innovative solution. It is an example of a smart use of unfortunate or even catastrophic events as a lesson to learn for the future. It is most painful and costly but generally a very effective source of innovation. Due to the safety and responsibility aspects, building construction activity has always come under so-called fundamental requirements.

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(1750 BC) and later of Marcus Vitruvius, author of De archi-

tectura (50 BC). Presently, construction fundamental require-

ments are described in the European Basic Requirements for

Construction Works, CPR-EU 305/2011

innovative solutions are recognized as important levers to effect

growth and efficiency, especially in today’s dynamic world.

The conviction that ideas should and did outrun innovation has

been demonstrated in publication [4]. The aim of this study is to

underline the scientific background of construction innovation.

Construction innovation occupies a special position amongst

engineering innovation due to the scope of its impact, and re-

sponsibility related to construction and use of building struc-

tures. For this purpose, the definition of construction innovation

needs to be formulated together with its specific challenges,

limitations and possibilities.

2. Conditioning of construction innovation

2.1. Construction innovation versus fundamental require-

ments (CPR-EU 305/2011). Innovation means each change.

There exist product, process, organization and marketing inno-

vations. Just “doing something” but only something related to

construction could be extremely bad to the construction itself

and even for its surroundings.

Innovations are endless on the side of positive results, but

on the negative side a catastrophe, understood as the fall of the

continuum, is the obvious barrier in the material and concep-

tual senses [5]. A building breakdown or even collapse could

also be the source of innovative solutions [6]. It is an example

of a smart use of unfortunate or even catastrophic events as

a lesson to learn for the future. It is most painful and costly but

generally a very effective source of innovation.

Due to the safety and responsibility aspects, building con-

struction activity has always come under so-called fundamental

requirements, ever since the times of the Hammurabi Code

(1750 BC) and later of Marcus Vitruvius, author of De archi-

tectura (50 BC). Presently, construction fundamental require-

ments are described in the European Basic Requirements for

Construction Works, CPR-EU 305/2011

**Course development**

In 2008 the Department of Construction and Civil Engineering undertook the process of renewing its well established ab-initio three-year National Framework of Qualifications (NQF) Level 7 BEng in Civil Engineering. The programme prepares graduates to find employment as civil engineering technicians in the civil engineering sector and/or prepares them to continue on to a cognate NQF Level 8 programme. The programme is well regarded within the construction/civil engineering industry with high graduate employability within Ireland and more recently abroad.

However, in a rapidly changing world the programme team recognised that the course could not rest on its laurels. Commencing the review process the team were mindful of the findings of Angelides and Loukogeorgaki (2005) who stated that ‘Any changes to civil engineering education should be addressed with a strategic approach that takes into consideration worldwide trends, the societal requirements’. The review focused on how the Department could supply a graduate that will meet the future needs nationally and internationally. Subsequently the programme team started to develop the BEng (Honours) in Sustainable Civil Engineering as a two-year add-on degree, principally for Level 7 graduates. Throughout the development of the programme the team were cognisant of EI, NQAI and HETAC requirements.

The question them arose ‘What to leave out?’ Drawing on the learning of the course board in terms of personal experiences (example external examiners), SWOT analysis, specific challenges, barriers, the team developed an overall programme objective.

3.1 Programme objective To provide an environment and robust educational path where students are encouraged to develop solutions to complex problems in a creative, sustainable manner and espouse an ethical ethos. Students will be guided to develop lifelong learning skills in technical and non technical fields. The graduate will be conscious of the vital influence that civil engineers will increasingly have on achieving the various sustainability targets at national, EU and international levels.

3.2 Course Outline The course is designed in a modular format to facilitate integration with other engineering and built environment courses. It is offered in the full-time mode but the modular structure enhances the flexibility in the methods by which the course can be delivered and taken. From an operations perspective the terminal examinations are normally taken at the end of each semester in December and May. Most modules are awarded 5 European Credit Transfer and Accumulation System (ECTS) credits, whilst strategic modules are more heavily weighed. One academic year corresponds to 60 ECTS-credits.

Figure 1 and Figure 2 illustrate the programme overview for the level 7 BEng in Civil Engineering and level 8 BEng (Hons) in Sustainable Civil Engineering. Modules are broadly grouped into mathematics/science, structures/engineering design, technology, management & economics, research/projects, industrial placement, hydraulic/hydrology and sustainable/energy sub-categories. A number of modules are shared with students from other disciplines, usually within the School of Engineering. A breakdown of the Continuous Assessment/Final Exam marking scheme is also shown. It is clear from the programme overview that not all subject areas are included. A strategic decision was taken to exclude many subject areas including highway and transport engineering, geology and specific environmental engineering topics.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **STAGE 1** |  |  | **STAGE 1** |  |  | **STAGE 2** | |  |  | **STAGE 2** | |  |  |  | **STAGE 3** | |  |  | **STAGE 3** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **SEMESTER 1** |  |  | **SEMESTER 2** |  |  | **SEMESTER 3** | |  |  | **SEMESTER 4** | |  |  |  | **SEMESTER 5** | |  |  | **SEMESTER 6** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Surveying 1** |  |  | **Surveying 2** |  |  | **Soil Mechanics** | |  |  | **Surveying 3** | |  |  |  | **Surveying 4** | |  |  | **Energy Performance of** |  |
|  | CA:50% EX:50% |  |  | CA:50% EX:50% |  |  | SM-P (CME2) | |  |  | CA:50% EX:50% | |  |  |  | CA:100% | |  |  | **Buildings** | |
|  |  |  |  |  |  |  | CA:40% EX:60% | |  |  |  |  |  |  |  |  |  |  |  | CA:30% EX:70% | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Civil & Structural** | |  | **Civil Engineering BIM** |  |  | **Civil Engineering** | |  |  | **Civil & Structural** | |  |  |  | **Research Skills** | |  |  | **Project** |  |
|  | **Graphics** |  |  | CA:100% |  |  | **BIM 2** | |  |  | **Draughting** | |  |  |  | CA:100% | |  |  | CA:100% |  |
|  | CA:100% |  |  |  |  |  | CA:100% | |  |  | CA:100% | |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  | |  |  | |
|  | **Civil Engineering** |  |  | **Civil Engineering** |  |  | **Civil Engineering** | |  |  | **Fluid Mechanics** | |  |  |  | **Civil Engineering** | |  |  | **Civil Engineering** |  |
|  | **Mathematics 1** |  |  | **Mathematics 2** |  |  | **Mathematics 3** | |  |  | CA:30% EX:70% | |  |  |  | **Mathematics 4** | |  |  | **Mathematics 5** |  |
|  | PR-STAGE2 |  |  | PR-STAGE2 |  |  | PR-STAGE3 | |  |  |  |  |  |  |  | CA:15% EX:85% | |  |  | CA:15% EX:85% |  |
|  | CA:50% EX:50% |  |  | CA:50% EX:50% |  |  | CA:15% EX:85% | |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Statics & Dynamics** |  |  | **Structural Mechanics** |  |  | **Design of Structures 1** | |  |  | **Design of Structures 2** | |  |  |  | **Design of Structures 3** | |  |  | **Structural Analysis 1** |  |
|  | PR-STAGE2 |  |  | PR-STAGE2 |  |  | PR-STAGE3 | |  |  | PR-STAGE3 | |  |  |  | CA:30% EX:70% | |  |  | CA:30% EX:70% |  |
|  | CA:50% EX:50% |  |  | CA:50% EX:50% |  |  | CA:30% EX:70% | |  |  | CA:30% EX:70% | |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Civil Engineering** |  |  | **Materials Technology** |  |  | **Management for Civil** | |  |  | **Construction Health &** | |  |  |  | **Site Management** | |  |  | **Civil Engineering** |  |
|  | **Technology** |  |  | **1** |  |  | **Engineers** | |  |  | **Safety** |  |  |  |  | **Practice** | |  |  | **Technology** |  |
|  | CA:30% EX:70% |  |  | CA:30% EX:70% |  |  | CA:30% EX 70% | |  |  | CA:30% EX:70% | |  |  |  | CA:30% EX:70% | |  |  | CA:30% EX:70% |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Communications &** |  |  | **Engineering Science** |  |  | **ELECTIVE** (SM-F)**:** |  |  |  | **ELECTIVE** (SM-F)**:** | |  |  |  | **ELECTIVE** (SM-F)**:** | |  |  | **Environmental** |  |
|  | **Study Skills** |  |  | CA:30% EX:70% |  |  | - Intercultural |  |  |  | - Cultural Diversity |  |  |  |  | - Entrepreneurship |  |  |  | **Engineering 1** |  |
|  | CA:100% |  |  |  |  |  | Communications | |  |  | ….Management | |  |  |  | - Spanish B1.1 | |  |  | CA:30% EX:70% |  |
|  |  |  |  |  |  |  | - Spanish A1 | |  |  | - Spanish A2 | |  |  |  | - French B2.1 | |  |  |  |  |
|  |  |  |  |  |  |  | - French B1.3 | |  |  | - French B1.4 | |  |  |  | - Int’l English 3 | |  |  |  |  |
|  |  |  |  |  |  |  | - Int’l English 1 | |  |  | - Int’l English 2 | |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **6 modules @ 5 credits** |  |  | **6 modules @ 5 credits** |  |  | **6 modules @ 5 credits** | |  |  | **6 modules @ 5 credits** | |  |  |  | **6 modules @ 5 credits** | |  |  | **6 modules @ 5 credits** |  |
|  | **each = 30 Credits** |  |  | **each =30 Credits** |  |  | **each = 30 Credits** | |  |  | **each = 30 Credits** | |  |  |  | **each =30 Credits** | |  |  | **each =30 Credits** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



**Figure 1 BEng in Civil Engineering Programme Overview**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Key:** | |  |  | **Management & Economics** | | |  |  | **Maths/Science** |  | **Research/Projects** | | |
|  |  | **Structures/ Eng. Design** | | |  |  | **Hydraulics/Hydrology Engineering** | | | | |  | **Sustainable/ Energy** |
|  |  |  |  |  |
|  |  | **Technology** | | |  |  | **Industrial Placement** | | |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**4. INTEGRATING SUSTAINABILITY, ETHICS AND SOCIAL RESPONSIBILITY**

As stated previously the course maintains the fundamental civil engineering curriculum, but focus is also placed on the overall understanding of the global ecosystem and limited natural resources. Lappalainen (2011) found that the key to sustainability is the inclusion of teaching social responsibility to engineers. At development stage it was recognised that teaching sustainability and ethics could not be mutually exclusive. Thus, there was a concerted effort from the outset of the course to make clear linkages between topics such as design and sustainability, ethics and sustainability by the inclusion of practical examples, problem solving and encouraging decision making. The importance of this was highlight by (Abbas El-Zein *et al.*, 2008) who found that ethics and sustainability overlap but do not coincide and thus need positive intervention to be effective. In addition to extending the traditional mathematics and structural design curriculum, new pertinent modules such as Clean Energy Technologies, Sustainable Energy, Construction Technology Systems, Innovative Technology, Building Energy Performance that include resource management, knowledge of environmental policies, law, and life cycle assessment were created.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **STAGE 4** |  |  | **STAGE 4** |  |  | **STAGE 5** |  |  | **STAGE 5** |  |
|  |  |  |  |  |  |  |  |
|  | **SEMESTER 7** |  |  | **SEMESTER 8** |  |  | **SEMESTER 9** |  |  | **SEMESTER 10** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Structural Analysis** |  |  | **Mathematical Modelling** |  |  | **Structural Analysis & Design** |  |  | **Structural Design** |  |
|  | PR-STAGE5 |  |  | CA: 100% |  |  | CA: 30% EX:70% |  |  | CA: 100% |  |
|  | CA: 30% EX:70% |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Civil Engineering Mathematics** |  |  | **Research Methods** |  |  | **Dissertation** |  |  |  |  |
|  | **6** |  |  | SM-F(CME3, QS3) |  |  | SM-P (CME4, QS4) |  |  |  |  |
|  | CA: 15% EX:85% |  |  | PR-STAGE5 |  |  | CA: 100% |  |  |  |  |
|  |  |  |  | CA: 100% |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Statistics for Scientists** |  |  | **Energy Performance of Buildings** |  |  | **Industrial Placement 2** |  |  | **Geotechincal Engineering 2** |  |
|  | SM-P (SCIENCE & SEE3) |  |  | CA: 100% |  |  | SM-F (CME4, QS4) |  |  | CA: 30% EX: 70% |  |
|  | CA: 30% EX:70% |  |  |  |  |  | CA: 100% |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Geotechincal Engineering 1** |  |  | **SCE Placement\*** |  |  | **Hydraulics** |  |  | **Hydrology for Sustainability** |  |
|  | PR-STAGE5 |  |  | PR-STAGE 5 |  |  | CA:30% EX:70% |  |  | CA: 30% EX:70% |  |
|  | CA: 30% EX: 70% |  |  | SM-P (CME3, QS3) |  |  |  |  |  |  |  |
|  |  |  |  | CA: 100% |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Construction Technology** |  |  |  |  |  | **Project & Corporate Management** |  |  | **Professional Practice** |  |
|  | **Systems** |  |  |  |  |  | SM-F (CME4, QS4) |  |  | SM-P (QS4) |  |
|  | SM-F (CME3) |  |  |  |  |  | CA: 30% EX 70% |  |  | CA: 30% EX:70% |  |
|  | CA: 30% EX:70% |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **Clean Energy Technologies** |  |  |  |  |  | **Sustainable Energy** |  |  | **Innovative Technologies** |  |
|  | CA: 30% EX:70% |  |  |  |  |  | CA: 50% EX:50% |  |  | SM-P (CME4) |  |
|  |  |  |  |  |  |  |  |  |  | CA: 30% EX:70% |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  | **6 modules @ 5 credits each =** |  |  | **Placement or Alternative\* @15 credits + 3** |  |  | **5 modules @ 5 credits each = 25** |  |  | **5 modules @ 5 credits each & 1 @10** |  |
|  | **30 Credits** |  |  | **modules @ 5 credits each =30 Credits** |  |  | **Credits** |  |  | **credits = 35 Credits** |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

**Figure 2 BEng (Honours) in Sustainable Civil Engineering Programme Overview**

It was felt that a standalone ethics module would be somewhat removed from other modules thus, all of the modules have an ethical component. This decision is supported by in a paper by Flynn and Barry (2010) who suggest that stand alone ethics modules can be a ‘tick box’ approach and students would perceive ethics as not being core to the curriculum. However, modules such as professional practice and project and corporate management have a particular ethical emphasis.

**5 CAREER OPPORTUNITIES IN CIVIL ENGINEERING**

**Popular careers for Civil Engineer Bachelor’s graduates**

Civil Engineering, as a degree, covers a lot of ground when it comes to understanding our surroundings and how to work with it, but, in the future, you will have to settle on a specialisation and follow it. Some of the most popular careers that wait for you after you graduate are:

**1.** Construction managers

Construction managers are the bosses of the working sites. With knowledge on the most basic things, like weather, costs, team and time management, managers have to be the eyes and ears of the person who hired them, and have to see that everything works smoothly.

**2**. Geotechnical engineer

Geotechnicians have to be on the lookout for everything nature-related and know how to manage waste disposal, flood control, when and where to build a dam or a bridge, and so on. And, once you get the hang of it, then, dam, you will be the best.

3. Environmental engineer

Environmental engineers are the closest we have to superheroes, as they take care of the planet and allow us to keep living here (or simply living, which is nice). You will get to go and restore landscapes and nature from what other people ruin, you will get to explain to other people what a healthy indoor and outdoor environment is, and what to do in the future to stop wrecking our planet.



4. Public Health Engineer

Do you remember that scene in Tim Burton’s ‘Batman’, where there are penguins living in the sewer and even an evil lair? Technically, as a public health engineer, you will be responsible for that never to happen!

Controlling the water supply and sewage system, you take care of people in towns and villages, making sure the water is clean and villain-free.

**5.** Transportation Engineer

Do you think public transportation just happens? All those subways, trams, roads, highways, and such don’t just spring from nowhere: top transportation engineers are there, taking care of us to get home on time or not wait in the rain for your bus, like the most tragic figure from literature.

**Innovations in Civil Engineering Aimed at Improving Sustainability**

## Plastic Roads

As a response to massive local waste and plastic pollution within their country, India’s government began experimenting with plastic roads during the early 2000s, with waste plastic being used as a construction material. An early report by India’s Central Pollution Control Board discovered that even after four years of use, Jambulingam Street in Chennai—one of the first plastic roads—had not sustained much damage. The board cited that no potholes, rutting, raveling, or edge flaws were discovered during the evaluation. This level of performance attracted the interests of local governments, who were looking to rid the Tamil Nadu region’s urban environments of the discarded shopping bags, foam packaging, and other unrecyclable plastic products that litter the streets. As of 2015, any Indian city with a population of at least 500,000 is required to construct their roads using waste plastic as a core material, in efforts to promote greater pollution control and environmental sustainability for Indian communities.

Transitioning to the use of plastic roads will lead to more manageable plastic waste and potentially, safer roads, but there are still some concerns regarding hazards that accompany plastic roads as they age. As these roads gradually deteriorate due to heat and light, they may dissolve into micro-plastics that give off harmful pollutants, affecting the functionality and biodiversity of soil and water resources. Creative civil engineers play a significant role in ensuring that the science behind using waste plastic for roads is accurate, and that future iterations of this concept are carried out with consideration for environmental health and safety.

## Green Roof Systems

The Environmental Protection Agency defines a green roof as a “vegetative layer grown on a rooftop.” Today, green roof systems have become popular all over the world, not only for their beauty, but also for the benefits they provide toward environmental sustainability. Germany is currently leading the world in green roof technologies, and they have implemented green roofing systems on approximately 10% of German homes since the technology emerged in the early 1970s. Civil engineers are responsible for ensuring that the green roof’s supportive infrastructure—for instance, a comprehensive watering system—is engineered to consistently deliver an appropriate amount of resources, and the roof itself must be designed to effectively provide working improvements to environmental sustainability.

However, civil engineers still face some obstacles when planning the installation and maintenance of green roof systems, like high costs and harsh climates, but innovations in modern engineering techniques for green roofing systems have allowed the industry to consistently offer the following environmental benefits to urban communities:

* Enhanced Urban Biodiversity: Green roofs accommodate new flora, which may act as new habitats for different species of plants and animals.
* Cooling of Buildings: The vegetation on the roof acts as thermal insulation, storing excess heat and decreasing peak temperatures within the building. This means less energy must be consumed to heat the building, resulting in decreased energy costs and lower pollutant emissions.
* Reduced Runoff Quantity: On average, green roofs retain 40-60% of total rainfall. Storing this rainwater as it falls has been shown to result in runoff reduction of 34% between September and February, and 67% between March and August. By reducing runoff, civil engineers that design green roof systems can limit strain on sewage systems and mitigate the costs of roof damage.
* Pollution Control: Green roofs are composed of plants that absorb nitrogen, lead, zinc, and airborne pollutants like carbon dioxide. This absorption also reduces the negative effects of acid rain by raising the pH values of acid rainwater before it becomes runoff water

.

## Eco Floating Homes

Affordable housing and overcrowding in cities are putting pressure on urban populations to make changes. To combat these issues, civil engineers are designing floating homes—practical living spaces that sit upon the water. The homes are designed to resist floods by floating on top of water using a foundation of concrete and Styrofoam, which makes them virtually unsinkable. This approach means that homes can be built in spaces that were previously off-limits, like rivers, lakes and other bodies of water. Civil engineers predict that modern floating home technology will lower the costs of flood damage in urban cities, while also providing compact inner-city populations with more diverse housing options.

**Vertical Farming**

Using multistory high-rises to grow food is known as “vertical farming,” and The Association for Vertical Farming has found that, when compared with traditional agricultural methods, growing food indoors uses 98 percent less water and 70 percent less fertilizer on average. To generate the amount of light and water necessary to keep plants healthy, while remaining as cost-effective as possible, vertical farmers use a combination of energy efficient LED lights and hydroponic technology (plumbing, irrigation, filtration). By implementing modern automation techniques to regulate these systems, civil engineers can also limit the cost of labor required to maintain these farms. The costs associated with vertical farming are still quite high, but as science in this field advances, civil engineers will be able to provide the populations of un-farmable regions with opportunities to grow their own natural produce.

Many entrepreneurs and scientists are currently evaluating how growing food inside of buildings coincides with improving social and environmental sustainability. Vertical farms also have higher yields than traditional farms, allowing the production of more food, using far less urban space. Significant progress in the study of vertical farming could lead to improved food diversity, especially for residents of population-dense urban areas and in places that are normally unable to grow produce using traditional methods.

## Rainwater Harvesting

Harvesting rainwater is a climate adaptation strategy that has been used in many ancient and modern societies. The antiquated rainwater harvesting techniques of the past were attempts to cope with severe climate conditions by storing the water as it fell, allowing populations to drink the water or prevent oversaturation of the land during extreme precipitation. Modern rainwater harvesting is fundamentally the same in theory, but advancements in science and engineering have introduced sophisticated filtration and rain-capturing technologies that boost the efficiency of the process.

Dutch engineers and researchers have observed that effective large-scale implementation of rainwater harvesting infrastructure can reduce stormwater runoff by 20 to 50 percent, mitigating the strain that excess storm precipitation usually places on sewers and drainage systems. This is made possible by mounting rainwater catchment devices on the roofs of buildings, then routing the rainwater that is collected by the catchment through a treatment system and into a storage tank. To ensure the effectiveness of these rainwater-harvesting systems, the contents of each storage tank must be depleted before significant rainfall events occur. Therefore, civil engineers must obtain the knowledge and experience necessary to analyze the precipitation patterns and water usage rates of a region before installing any rainwater harvesting systems. With cost-effective approaches to the catchment, storage, and filtration technology used in rainwater harvesting currently being implemented and improved, large-scale rainwater collection is poised to become a widely used, economically viable solution to urban potable water shortages and stormwater management.

**6. CHALLENGES**

While the Civil Engineering programme is in a strong position, there are significant challenges at present, including reduced student numbers, student abilities in Mathematics and English, a reduction in resources, the need for improved education in design and BIM software, increasing academic diversity.

*5.1 Reduced Student numbers*

With the severe downturn in the Irish economy, the domestic engineering and construction industry has been decimated and the education sector is facing into a period of significant change. These issues pose serious challenges for the Civil Engineering programme in the short-to-medium term in relation to student numbers. However, there is an upside; smaller student groups encourage a more open interactive learning space whereby students can express and discuss ideas and work together to solve problems.

*5.2 Reduction in Resources*

It is inevitable that there will be fewer resources in the short to medium term to deliver the Civil Engineering programme. This has been mitigated, to a certain extent, through the sharing of common modules with other programmes in the Department and School.

*5.3 Academic Diversity*

The traditional homogeneity of the student cohort studying Civil Engineering is now developing into a diverse group of learners. Seated side by side are students; from other disciplines and streams; whose first language may not be English; from broadly diverse cultures, economic backgrounds; of both genders;

highly advanced learners; and students of widely varying interests and preferred modes of learning who underachieve for a complex array of reasons; motivated and unmotivated; with some fitting two or three of these categories. This change in the student profile leaves Civil Engineering Lectures with the need to address learner variance. This will require adaptation of teaching and learning routines to address the broad range of learners' readiness levels, interests, and modes of learning. Currently we are modifying curricula, teaching methods, resources, learning activities and assessment. Addressing the diverse needs of individual students is a new challenge and one that will be embraced with innovative and appropriate pedagogical differentiation methodologies.

**7. CONCLUSION**

It is essential that civil engineers develop a sustainable vision for the world of the future, as throughout their careers they will play a leading role. Developing this programme course did not mean that all parties involved in the process agreed entirely with the outcome but consensus was achieved. It is recognised that social sustainability is difficult to teach as it requires a departure for conventional thinking and may not be suited to the traditional classroom.

Arciszewski and Harrison (2010) propose that the scientific paradigm in civil engineering today is insufficient and needs to practice creativity and proposes a conceptual outline of what needs to be done. The paper proposed a new civil engineering education paradigm, called “Successful Civil Engineering Education”. We believe that the new BEng (Hons) in Sustainable Civil Engineering has broken the old paradigm and offers a dynamic approach that meets the needs of future civil engineers.

It is clear that all facets of sustainability including ethics, technology, social sustainability are included in the sustainable civil engineering programme, but benchmarking of Sustainability in Engineering Education is imperative for future development.

The course boards will continue to develop the undergraduate course and develop towards achieving the recommendations identified in the recently published *‘Engineering Research in* *Irish Economic Development’* (IEA, 2010). This will require us to build on our existingpartnerships, collaborating with other institutions, interaction with future students through secondary school visits, modify and develop our education to reflect the current and future needs of the economy by fostering a more innovative and entrepreneurial culture. Future development will continue to increase student numbers by providing new industry specific courses.

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