



INTERGRATION OF SUSTAINABLE DESIGN AND CIRCULAR ECONOMY
CONCEPTS IN CIVIL ENGINEERING CURRICULA

O5: GUIDELINES AND POLICY BRIEFING FOR RAISING AWARENESS

**D1: GUIDELINES FOR SYSTEMIC
TRANSFORMATION OF THE HIGHER EDUCATION
CIVIL ENGINEERING CURRICULA TOWARDS
SUSTAINABLE DESIGN & CIRCULAR ECONOMY**



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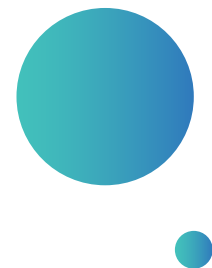


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1. Introduction

In the face of mounting environmental challenges and the urgent need for sustainable solutions, the field of civil engineering is embracing a transformative shift towards sustainable development and circular economy principles. As we confront the consequences of climate change, resource depletion, and waste generation, it becomes imperative for civil engineering curricula to equip future professionals with the knowledge and skills necessary to tackle these complex issues.

Sustainable development refers to the concept of meeting present needs without compromising the ability of future generations to meet their own needs (Barth 2015). It recognizes the interdependence of environmental, social, and economic factors and seeks to strike a balance among them. The circular economy, on the other hand, is an innovative approach that aims to decouple economic growth from resource consumption by designing out waste and promoting the continual use of resources within a closed-loop system. It emphasizes the principles of reduce, reuse, and recycle, thereby minimizing the extraction of raw materials and the generation of waste (Charef et al., 2021).

As the world transitions towards a more sustainable future, civil engineers are increasingly being called upon to design and construct infrastructure that aligns with these principles. From eco-friendly building materials and energy-efficient structures to resilient transportation systems and water management strategies, the role of civil engineers in shaping a sustainable built environment is paramount.

Recognizing this evolving landscape, the integration of sustainable development and circular economy concepts into civil engineering curricula has become essential (ABET, 2010; ENAEE, 2008). By equipping aspiring engineers with a strong foundation in these principles, educational institutions play a vital role in nurturing a new generation of professionals who are not only technically competent but also equipped with a holistic understanding of sustainability.

The importance of incorporating sustainable development and circular economy principles into civil engineering curricula extends beyond environmental considerations.

Emphasizing these concepts provides students with the opportunity to develop critical thinking skills, enhance their problem-solving abilities, and foster a deep sense of social responsibility. Furthermore, exposure to sustainable engineering practices instils an appreciation for the long-term impacts of engineering decisions and encourages innovative thinking to address complex challenges. By embracing sustainability and circularity in their curricula, civil engineering programs can equip students with the knowledge and tools to design and construct infrastructure that minimizes environmental impact, optimizes resource utilization, and enhances societal well-being. Such education ensures that future engineers are prepared to navigate the demands of a rapidly changing world, contribute to sustainable development goals, and actively participate in the transition towards a more circular and resilient future (Leifler and Dahlin, 2019).

This report is prepared as part of the SUSTAIN-CE project and aims to set guidelines to assist higher education institutions (HEIs) in achieving systemic transformation in the civil engineering curricula by embedding sustainable development (SD) and circular economy (CE) concepts.

2. Identifying the Barriers and Mitigating Measures in Academia to Systemic Transformation of Higher Education Civil Engineer Curricula towards SD/CE

To identify the barriers and the mitigating measures and solutions to these barriers, understanding the perspectives of both academia and government towards the implementation of SD and CE principles in HE civil engineering curricula was of crucial importance. Consequently, interviews with both academic and governmental and non-governmental representatives were conducted in Turkey, Greece and Portugal, and the results are discussed in the following subsections.

2.1. Interviews with Academia

Prior setting the guidelines on how to achieve systematic transformation of civil engineering curricula towards SD/CE, it was important to understand the level of familiarity with the concepts of SD and CE; relevant university's departments that should and could offer courses in SD and CE; the barriers that universities are facing to embed SD and CE curricula and modules, as well as to understand the possible mitigating measure, and the support that is needed to overcome them, therefore. In total 12 interviews were conducted, and Table 1 summarises the interview questions.

Table 1 – Interview Questions with Academic Representatives

- Q1** Are you familiar with the Sustainability and Circular Economy Concepts?
 - Q2** Do you believe these concepts will give added value to your University/School/Department?
 - Q3** Which are the schools and relevant departments that you would see involved in offering a Sustainability and Circular Economy Module in your university?
 - Q4** Which are the barriers to introduce this new Module?
 - Q5** What are the solutions that you see to the barriers indicated above?
 - Q6** If you are a faculty member: What are kinds of support you would need at an academic level to enable the integration of such a module in the curriculum?
 - Q7** If you are dean/rector: What are the kinds of support you would need from national and regional authorities to enable the integration of such a module in the curriculum?
 - Q8** General proposals/recommendations
-

All interviewed respondents gave a positive response to the question if they are familiar with the concepts of SD and CE, as well as all respondents stated that they believe these concepts would provide an added value to their institutions. Considering the relevant departments that could offer Sustainability and Circular Economy modules in their institutions, one responded did not provide any response to the question, one responded stated that all departments should provide such modules, however, economics and engineering departments should provide such modules more intensively. All respondents stated that they believe providing a module on SD and CE is important not only in the civil engineering department, but also in mechanical engineering, architectural, environmental engineering, food engineering, energy systems engineering departments, school of spatial planning, as well as construction departments.

2.2. Existing Barriers and Solutions

As it can be observed in Table 2, the main barrier to introducing new modules that occurs across most of the interviewed representatives from different universities was the fact that the academic organisations require structural changes to achieve this, followed by the resistance to change, as well as lack of teaching personnel with deep and spherical knowledge of the topic, which can be considered as an important barrier, as having such personnel is of crucial importance for delivering the course.

Table 2 – Barriers to Introducing SD and CE Modules

Barriers	Number of Respondents
Resistance to change	9
Lack of teaching personnel with deep and spherical knowledge of the topic	6
Time consuming	5
Lack of ability to attract an external expert and pay them	1
Structural changes in the academic organisation needed	10
Lack of interest from the students	3
Lack of connection with relevant markets that can give input and train students providing hands-on experience	4
Lack of interest	2
Needless to provide this kind of knowledge to students due to lack of market	1

Following the barriers, the respondents proposed some solutions that might be effective in resolving and overcoming the existing barriers. One such solution that was mentioned by most of the respondents was that more dissemination and seminars from professionals that are working on such projects (SD and CE) should be provided both to academic staff, as well as students in order to explain the importance of introducing such modules and courses is important in the civil engineering curricula, as well as why it is important for students to obtain such skills and knowledge.



On top of this, some respondents agreed that it is important to have a higher collaboration between industry and academia to promote and support the concepts and principles of SD and CE. Nevertheless, some respondents stated that a possible solution to the barriers would be a top-down approach, where the initiative to include such modules and courses is directed by the deans or heads of departments, or involving an expert that would be in charge to deliver such modules:

R5 *"To increase initiatives at the level of the dean and rectorate and to ensure that the requirements to adopt the concepts are demanded from above"*

R10 *"The proposed changes should be directed by the heads of departments. Faculty members could be individually persuaded. Other solution is to bring an expert for the topic to be covered from outside the university"*

Lastly, one responded raised the issue of the minimum ECTS requirements that also imposes a barrier on introducing a new course, since it is difficult to fit a whole new course on sustainability and CE in the 240 ECTS:

R9 *"240 ECTS. There are min requirements here. Some are requirements of MUDEK. And University's strategic goals. So, we have 240 ECTS for these. Sustainability is embedded in the strategic plan. However, the 240 ECTS is the problem. Some of these ECTS are required courses from central board. There is very limited space in this 240 for sustainability topics. In departmental view, the weak education in high school requires us to enforce simple courses like analytical thinking, etc. so most probably the solution is to include these in departmental courses. And these should be embodied in must take course. The graduation project course could be the place to embed these topics."*

2.3. Needed Support to Integrate SD and CE Modules

As a last part of the interview, the respondents were asked what kind of support they would need from national and regional authorities to enable the integration of the new module. As it can be observed from Table 3 (which summarises the responses), most of the respondents stated that they would prefer if existing learning materials and teaching notes are available, as it would be very helpful. However, some respondents also stated that further funding support is also important, as well as having appropriate policies, and administrative and faculty support.

Table 3 – Needed Support to Integrate SD and CE modules

R1 *“Appropriate learning material. Further funding and support when needed.”*

R2 *“Policies, funding and collaboration”*

R3 *“Funding support, establishing guidelines”*

R4 *“Administrative and faculty support”*

R5 *“We need lecture notes containing this kind of information”*

R6 *“We would need course material”*

R7 *“To have a course material ready would be of a great help”*

R8 *“A ready-made module will make things a lot easier”*

R9 *“Course conduct will be easier with ready course modules. We don't need any help from national authorities. We can do everything by ourselves”*

R10 *“Course notes would be helpful. Once the administration decides to change the curriculum, this would be enough”*

R11 *“Case studies from industry”*

R12 *“Interest at the department and scientific area level”*

2.4. Interviews with Governmental and Non-Governmental Organisations

The interviews with academic representatives were followed by interviews with representatives from governmental and non-governmental organisations in the same three countries (Turkey, Greece and Portugal), that aimed to identify whether primarily these countries have set in place policies and initiatives that promote SD and CE in the construction and infrastructure sectors, as well as whether there are any policies and initiatives that promote embedding SD and CE modules in HE and VET curricula. Lastly, the participants were asked about their perspective on the importance of digital transformation of HE, as well as if there are any existing policies regarding that matter (the interview questions are presented in Table 4).

Table 4 – Interview Questions with GOs and NGOs

Q1 What is the level of Sustainability/Circular Economy embeddedness in the territory you are operating (national/regional/local level): relevant policies; initiatives/projects/experiences?

Q2 Are there any existing policies at a national/regional/local level that promote embedding Sustainability and Circular Economy Modules in HEIs and VET curricula?

Q3 Have you implemented any European policies that promote embedding Sustainability and Circular Economy Modules in HEIs and VET curricula at a national/regional/local level?

Q4 Are there any initiatives for promoting Sustainability and Circular Economy Modules in HEIs and VET curricula?

Q5 Do you think that policy makers play an important role when it comes to the integration of Sustainability and Circular Economy principles in HEIs and VET curricula?

Q6 In your view what can policy makers do to better support the integration of Sustainability and Circular Economy principles in HEIs and VET curricular?

Q7 Do you believe that digital transformation of higher education plays an important role in promoting the Sustainability and Circular Economy concepts in HEIs and VET curricula?

Q8 Are there any existing policies that promote digital transformation of higher education, accreditation harmonization and breaking the barriers to education through digital means?

2.4.1. Interview Results

In total 8 interviews were conducted with GO and NGO representatives in the three interviewed countries and the results showed that even though the implementation of policies and initiatives that promote SD and CE at a national, regional, and local level is still below the EU level, all three countries are setting into place such policies and initiatives. In terms of policies and initiatives that promote at a national, regional, and local level, all respondents from Greece and Portugal reported that there are such policies that are set in place, as well as in Turkey it was reported that such policies are in the process of being developed and set in place by the responsible institutions. On top of this Portugal reported that besides the existing requirements to embed SD and CE concepts in HE civil engineering curricula, universities, colleges, training centres, etc., are taking independent initiatives to include such modules in their curricula:

R1: *“The NQF (National Qualifications Framework) in Portugal provides a reference framework for the development of qualifications and promotes the inclusion of key competencies, including sustainability and circular economy, in educational programs, but these policies seem to have been implemented only on surface level. Beyond this, a number of universities, colleges, and training centres in Portugal have taken independent initiatives to embed sustainability and circular economy modules in their programs. Associated with HEIs, the foundation for Science and Technology has also been promoting a research and innovation agenda for circular economy recommending lines of research, as well as strategic priorities and enablers that complement R&I activities. In a similar manner, the fund for Innovation, Technology and Circular Economy supports policies that aim to enhance scientific and technological knowledge, consequently encouraging cooperation between HEIs, technological interfaces centres and the industry sector.”*

Another respondent reported that universities and educational institutions have the autonomy to design, develop and elaborate on their teaching plans and curriculum, however there are both existing frameworks, as well as interests from the universities to contribute to the transition to SD and CE, although the level of inclusion of such modules in the teaching programs is still not certain:

R2: *"In Portugal, HEI's have teaching autonomy which means they have the capacity to elaborate their own study plans and curriculum. That been said, National Strategy for Education for Sustainable Development (ESD) do include guidelines and recommendations for integrating sustainability across all levels of education, including HEIs and VET. The Portuguese National Qualifications System also provides a framework for the recognition and certification of qualifications, including those related to sustainability and circular economy. It can also be noted that there is an interest to include education in the Pathway for circular economy as Knowledge is one of the levels of action in this transition. Although we can't talk with certainty about the implementation extend of this framework, there are some Portuguese universities that include circular economy in their study plans for civil engineering, for example University of Porto and University of Aveiro."*

Furthermore, all respondents reported that policy makers play an important role in the process of transitioning to SD and CE, as well as in integrating such modules in HE civil engineering curricula, and the means by which policy makers can support this better are:

- » Provide further training
- » Provide further information on the importance of the integration of the concepts in civil engineering curricula
- » Actively promoting sustainable development by supporting workshops, webinars, etc related to the topic
- » Establish more funding for students and researchers to support their own sustainable projects
- » Work in together with local industries and companies to better implement education at local level
- » Develop policy frameworks that push eco-innovation
- » Institutional drive and commitment
- » Enhance interaction between HEIS and VET and the stakeholders.

Lastly, the results showed that all respondents believe that digital transformation of higher education plays an important role in promoting sustainability and CE concepts in HE and VET civil engineering curricula, thus they reported that there are existing policies that for digital transformation of higher education:

R1: *"There are a number of frameworks in place. For instance, the Recovery and Resilience Plan elects Reform of Digital Education as one of the goals by the end of 2025. This includes redesign of digital education, including digital technologies and the way they're used in the knowledge acquisition process. That is also the aim of the Nation Digital Competences initiative 2030 which has the intention to enhance digital competencies in education, research, qualification and specialisation."*



More specific in the AEC sector, the Plan of Action for Circular Economy in Portugal also considers digital platforms and tools to support sharing of knowledge and information on the verification of quality, circularity and sustainability of constructions, thus acknowledging the importance of advocating for a twin transition (ecological and digital), in which the promotion of the reduction of environmental impacts and waste management is done along with the rise of the productivity and efficiency of the construction sector."

R2: *"Although not directly related to the AEC sector, Portugal does have in place an Action Plan for Digital Transition that elects capacity building and digital inclusion as one of the aims. This program sets to improve continuous learning quality, innovation and development of the educational system (including VET), as well as widening the training offer of higher education institutions and their needs in terms of digital skills. Also, in place is a National Program for Support Training in Digital Skills in Higher Education set in 2016 to promote digital skill in active population and, especially, to increase the number of Higher Education trainers. Teachers in higher education in particular require further digital and pedagogical training as digital skills were not developed as systematically as those in compulsory education. Nonetheless, this policy frameworks seems to be more directed to digital competence and digital usage, focusing on skills, concepts, approaches and professional application rather than innovation and creativity."*



3. Guidelines for Systemic Transformation of Higher Education and Sustainable Design/Circular Economy (SD/CE)

The results showed that both at the HE level, as well as at the policy level, although the integration of such concepts in civil engineering curricula is still at an average level, there is high interest for achieving this at a larger scale. Therefore, this section provides guidelines that aim to assist HEIs in the process of systemic transformation of their curricula in the context of embedding SD and CE modules in their teaching plans.

Even though the systemic transformation of curricula is a long process, there are some steps that HEIs can follow in order to achieve it. Prior establishing the curricula and the modules, it is important that in this process the HEIs clearly define their visions and goals on transforming the curricula, and to prioritize the incorporation of SD and CE principles, and to emphasize the need for a holistic and interdisciplinary approach, as well as an analysis should be performed on the existing curricula in the civil engineering departments in order to understand the existing gaps and the areas where SD and CE concepts should be integrated (Brandt et al., 2013; Lang et al., 2012). On top of this, the institutions should integrate the core concepts of sustainability and CE, such as life-cycle assessment, sustainable materials and construction practices, renewable energy systems, green infrastructure, and waste management throughout the curriculum, thus the learning outcomes should be reviewed and updated accordingly to reflect the integration of SD and CE concepts, as well as to ensure that these learning outcomes will help graduates to gain the necessary knowledge, skills and attitudes to address environmental and social issues in their professional practice (Leifler and Dahlin, 2019). However, in order to identify the proper concepts that should be incorporated in the curricula, it is of a great importance that a comprehensive needs assessment of the key stakeholders (employers, industry representatives and professionals, regulatory bodies and community representatives) is performed, to identify their perspectives on sustainability challenges, emerging trends, and the skills that are necessary for civil engineering graduates.

Moreover, it is evident from the interview responses that civil engineering departments should not be the only departments that provide such curricula and modules, thus various disciplines should offer such knowledge, therefore it is important that when integrating such concepts in the curricula, interdisciplinary collaboration should be encouraged between civil engineering departments, and other relevant disciplines (i.e., environmental science, architecture, urban planning, and social sciences), so as students will be provided with a holistic understanding of the challenges of sustainable development and the solutions to these challenges.

Similarly, HEIs should adapt the curricula in such a way that they would not provide only standard teaching methods, but rather to adopt an active learning method such as problem-based learning, case studies, that would help students to enhance their critical and problem-solving skills. However, it is important that the active learning methods are encompassing a global perspective, by providing international case studies, projects, and collaborations into the curriculum, so as students would be exposed to diverse cultural, economic, and environmental context to broaden their understanding on the sustainability challenges and solutions (Leifer and Dahlin, 2019). Besides global perspectives, it is important that HEIs incorporate digital technologies and innovation in the curriculum in order to explore how technologies such as Building Information Modelling (BIM), Internet of Things (IoT), and data analytics can contribute to sustainable infrastructure design, operation, and maintenance. Lastly, HEIs should embrace a culture of continuous improvement and adaptation in the curriculum, meaning that they should be well-informed about emerging trends, technologies, and best practices in SD and CE, as well as to make sure that the curriculum is reviewed and updated accordingly to the advancement in the field (Sisiopiku and Peters, 2015).

The interview responses also noted that the envisaged transformation should be initiated by the faculty management (deans, heads of departments), as well as that policies should be set in place in order to embed SD and CE concepts in curricula, meaning that having a top-down approach might be more effective to achieve such a transformation. Therefore, HEIs should ensure commitment and support from institutional leadership, such as the university administration, deans and department heads, and develop a shared understanding of the importance of sustainability and CE in civil engineering education, hence it is essential that sustainability goals are defined and integrated in the institution's strategic plans (Kelly, 2021). As it was also confirmed through the interview responses, universities could independently develop policies and initiatives at the institutional level that mandate the integration of SD and CE principles in civil engineering curricula (i.e., requirements for course offerings, faculty expertise, and collaboration with sustainability-focused research centres or institutes).

Furthermore, the curriculum review and approval processes should be regularly reviewed and updated, as to ensure that sustainability and CE considerations are incorporated, thus guidelines and criteria for evaluating the alignment of courses and programs with sustainability principles should be developed. However, in order to ensure an effective transformation monitoring and evaluation mechanisms should be established to evaluate the progress of the transformation, such mechanisms could be regular reporting on the integration of SD and CE concepts, assessment of learning outcomes, and soliciting feedback from stakeholders (Chau, 2007).

The interview results also showed that there is a strong need for providing further information and training on SD and CE challenges, hence a lack of skilled professionals that would be able to teach such modules, as well as a promotion of the compelling elements of these concepts, therefore, in this process professional development opportunities should be provided to faculty members to enhance their understanding of sustainability and CE concepts, as well as to prepare faculty members for delivering such modules (Dlouhá et al., 2017). On top of this, to raise public awareness about sustainable civil engineering practices, and the benefits of CE, HEIs should engage in outreach activities, as well as they could organise workshops, seminars, and public lectures to promote

Nevertheless, the respondents raised the issue that industry collaboration is also important and there is still a lack of such collaboration, therefore, another important aspect is the involvement of industry professionals, practitioners, and even alumni in the transformation process of the curricula, as these individuals could provide very useful inputs both on the required knowledge and skills in the field, as well as they could provide opportunities to further enhance the knowledge of both faculty member and students, by delivering guest lectures, offering internships, as well as collaborative projects (Homberg and Samuelsson, 2006). Besides offering professional development opportunities, HEIs should also develop recognition and incentive mechanisms (i.e., awards, grants, and promotion criteria that highlight and reward sustainability-focused teaching, research and service) to encourage faculty members and departments to actively engage in the transformation of the curriculum.

3.1. Digital Transformation in Achieving Systemic Transformation towards SD and CE in Civil Engineering Curricula

Digital transformation plays a very important role in promoting SD and CE in civil engineering curricula, as digital technologies are enablers of easy access to vast amounts of knowledge and resources related to sustainability and CE. The online platforms, open educational resources and digital libraries provides students and educators with a load of information, research papers, case studies, and best practices from around the world. As it was also identified through the conducted interviews, action plans for digital transformation are set in place, due to the fact that digital technologies enable the collections, analysis and visualization of data related to sustainability and CE, as well as students can learn how to use data analytics tools to assess the environmental impacts, monitor resource consumption and evaluate the effectiveness of sustainable practices (Castro Benavides et al., 2020). However, digital tools and platforms play an important role in promoting collaborative learning and networking, as students, educators and professional can collaborate through online discussion forums, video conferencing, and collaborative document editing, which enables sharing ideas, team work as well as connecting with experts and practitioners in the field (Fleaca, 2011).

Furthermore, online learning platforms and mobile applications enable students to access learning materials at their own pace and convenience, thus adaptive learning systems can tailor content and assessments to individual needs and preferences, enhancing engagement and learning outcomes.

Nevertheless, lifelong learning and continuous improvement in SD and CE knowledge and skills is also facilitated and ensured through digital transformation, due to the fact that online courses, webinars, and digital certifications enable students and professionals to upskill or reskill in these areas, by providing up-to-date materials and information regarding the advancements and the practices in the field (Faria and Novoa, 2020).

An important aspect of digital transformation in today's environment is that it promotes and supports sustainability by reducing the use of paper, travel requirements and energy consumption, as they minimise the need for physical infrastructure and can contribute to the reduction on environmental footprint of educational institutions. Last but not least, the results from the interview showed that the representatives of academic institutions would prefer to have ready teaching and course materials in order to implement SD and CE modules in their curricula, as it would be easier, therefore the use of digital technologies enables the dissemination of sustainability and CE knowledge beyond the boundaries of individual institutions, therefore, HEIs and VET providers can share their curriculum models, teaching resources, and research findings with a global audience, fostering collaboration and knowledge exchange (Tay and Low, 2017).

4. Conclusion

The transformation of HE civil engineering curricula towards SD and CE is a complex process that requires collaboration and support from academia, government, and non-governmental organizations. The interviews conducted in this study shed light on the barriers and potential solutions to this transformation. It is evident that there is a positive awareness of the importance of SD and CE among academia, and policies and initiatives are being implemented at various levels. However, there are challenges such as resistance to change, lack of teaching personnel, and structural barriers within academic organizations that need to be addressed. The guidelines provided in this paper serve as a roadmap for institutions seeking to achieve a systemic transformation of their curricula. By defining their visions and goals, involving interdisciplinary collaboration, adopting active learning methods, incorporating global perspectives and digital technologies, and embracing a culture of continuous improvement, institutions can effectively integrate SD and CE principles into their civil engineering curricula.

It is crucial for institutional leadership, including university administration, deans, and department heads, to demonstrate commitment and support for this transformation. Additionally, policy frameworks that promote SD and CE in curricula can provide a solid foundation for change. By following these guidelines and working together, HEIs can play a significant role in preparing civil engineering graduates who are equipped to address the environmental and social challenges of the future and contribute to sustainable development and circular economy principles.

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