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A REVIEW OF THE SUSTAINABILITY CONCEPT IN MANUFACTURING ENGINEERING AND CIVIL ENGINEERING

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Abstract: *The paper will present a review of the importance of the impact on the environment in the case of the manufacturing process and the same point in case of civil engineering sites. Traditionally, the industrial sector has been linked to a negative ecological impact. In recent decades, the deterioration of the natural environment has become a global concern due to population growth, which has led to increased resource consumption, economic expansion, and the consequent intensification of industrial operations. As a result, manufacturers are now confronted with mounting pressure from various stakeholders and more stringent regulations to mitigate the environmental consequences of their operations. The field of sustainability research, particularly sustainable production, is experiencing rapid growth and transcending disciplinary boundaries.*
Keywords: *sustainability, manufacturing engineering, civil engineering.*

1. INTRODUCTION

Sustainability is a concept that has become increasingly important in both manufacturing engineering and civil engineering. In both fields, the goal is to create products and infrastructure that are designed to minimize their impact on the environment and promote long-term economic and social viability.

In manufacturing engineering, sustainability is often associated with the concept of "green manufacturing." This involves using environmentally friendly processes and materials, minimizing waste and emissions, and optimizing energy use. Green manufacturing can help reduce the environmental impact of the manufacturing process, while also improving efficiency and reducing costs.

Another key aspect of sustainability in manufacturing engineering is the concept of product lifecycle management. This entails considering the complete life cycle of a product, encompassing its design and production stages, as well as its utilization and eventual disposal or recycling. By designing products with sustainability in mind, manufacturers can create products that are more durable, efficient, and environmentally friendly while also reducing waste and increasing profitability.

In civil engineering, sustainability is often associated with the concept of "green infrastructure." This involves designing and building infrastructure that is designed to promote environmental sustainability, such as green roofs, rain gardens, and other forms of green infrastructure that can help reduce the environmental impact of urban development.

Sustainable civil engineering also involves the concept of "resilient infrastructure," which refers to infrastructure designed to withstand and recover from natural disasters and other extreme events. By designing resilient infrastructure, civil engineers can help protect communities from the devastating impacts of natural disasters while also promoting long-term sustainability and economic viability [1,2,3].

In general, the concept of sustainability is becoming increasingly important in both manufacturing engineering and civil engineering. By designing products and infrastructure with sustainability in mind, engineers can help reduce the environmental impact of these fields, while also promoting long-term economic and social viability.

There are several key principles that guide sustainability in manufacturing engineering, including:

1.Waste reduction: This involves minimizing waste generation during the manufacturing process by using materials efficiently and recycling waste products whenever possible.

2. Energy efficiency refers to the utilization of energy-efficient technologies and processes to minimize energy consumption during the manufacturing process.

3. Lifecycle thinking encompasses the holistic assessment of a product's entire life cycle, from its initial design and production phases to its usage and ultimate disposal. The goal is to minimize the environmental impact of the product at each stage, ensuring sustainability throughout its life cycle.

4.Sustainable sourcing: This involves sourcing materials from sustainable sources that minimize environmental impact and ensure social responsibility.

5.Environmental management: This involves the implementation of effective environmental management systems to minimize the environmental impact of manufacturing operations.

Manufacturing companies can implement sustainable practices in various ways, such as using renewable energy sources, reducing water use, using recycled materials, and designing products for reuse or recycling. By incorporating sustainability principles into their operations, manufacturers can reduce their environmental impact, increase efficiency, and improve their reputation among customers who are increasingly concerned about sustainability.

Civil engineers play a critical role in promoting sustainability by designing and constructing infrastructure that minimizes environmental impact, uses resources efficiently, and supports social and economic development. This requires careful consideration of the life cycle of infrastructure, from design and construction to operation and maintenance [4,5].

To achieve sustainability in civil engineering, engineers must consider several key factors:

1. Environmental impact: Civil engineers must strive to minimize the impact of infrastructure on the environment. Achieving this objective can be accomplished by utilizing sustainable materials, implementing energy-efficient design practices, and integrating green spaces into the environment.

2. Resource efficiency: The efficient use of resources, such as water and energy, is crucial to achieving sustainability in civil engineering. Engineers must design infrastructure that uses resources efficiently, reduces waste, and conserves natural resources.

3. Social responsibility: Civil engineers have the responsibility to design infrastructure that benefits society as a whole. This can be achieved through the incorporation of community input, the provision of safe and accessible infrastructure, and the promotion of economic development [6].

4. Life cycle cost: Civil engineers must consider the full life cycle cost of infrastructure, including design, construction, operation, maintenance, and disposal. This requires the use of sustainable materials and design practices that minimize long-term costs and maximize the useful life of the infrastructure.

Overall, sustainability is a key concept in civil engineering that requires careful consideration of environmental, social, and economic factors. By designing and constructing infrastructure that supports sustainability, civil engineers can create a better future for all.

Civil engineering plays a significant role in sustainable development. The focus of the field on designing, constructing, and maintaining infrastructure makes it a crucial element of society's ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. Some of the sustainability issues raised in civil engineering are:

1. Environmental Impact: Construction and operation of infrastructure can have significant environmental impacts. The use of non-renewable resources and the production of waste and pollution can contribute to climate change, air, water, and soil pollution, and biodiversity loss.

Example: The construction of the Three Gorges Dam in China caused significant ecological and environmental damage, including the loss of fertile farmland, wildlife habitats, and the relocation of more than a million people.

2. Energy Efficiency: Civil engineering assumes a vital role in diminishing energy consumption and enhancing energy efficiency within buildings, transportation systems, and infrastructure.

2. EXAMPLES IN CIVIL ENGINEERING

Example: By incorporating sustainable building design elements such as green roofs, solar panels, and energy-efficient lighting and HVAC systems, it is possible to decrease energy consumption and mitigate greenhouse gas emissions.

3.Water Management: Civil engineering plays a critical role in water management, including the treatment, distribution, and storage of water resources.

Example: The Thames Water Ring Main in London is a water management system that recycles wastewater and pumps it back into the system, reducing the need for additional water resources and reducing wastewater discharge.

4.Social Impact: Civil engineering projects can have significant social impacts, including displacement of communities, loss of cultural heritage, and impacts on human health and safety.

Example: Construction of the Bujagali Dam in Uganda displaced thousands of people and disrupted the local fishing industry, causing economic and social challenges for affected communities.

5. Material Selection: Civil engineering projects require large amounts of materials, and the selection of these materials can have significant sustainability implications.

Example: The use of sustainable materials such as recycled steel, bamboo, and wood in construction projects can reduce the environmental impact of the construction industry and promote sustainable development.

In general, civil engineering plays a critical role in sustainable development. By addressing these sustainability issues and incorporating sustainable design and construction practices, civil engineers can help promote a more sustainable future.

Sustainability in civil engineering involves designing, constructing, and managing infrastructure projects with the aim of minimizing their impact on the environment and maximizing their benefits to society. Here is a case study on how sustainability was achieved in the construction of the Bullitt Center in Seattle, Washington.

3. EXAMPLES IN INDUSTRIAL ENGINEERING

Overall, implementing sustainability practices in industrial engineering requires a commitment to continuous improvement and a willingness to invest in sustainable technologies and practices.

One case study that highlights solutions for sustainability in industrial engineering is the Ford Motor Company's Rouge Center in Dearborn, Michigan.

The Rouge Centre is an industrial complex that produces automobiles using a variety of sustainable practices. Some of the key sustainability initiatives implemented at the Rouge Centre include the following.

1. Energy Efficiency: The Rouge Centre has implemented several energy-efficient technologies, such as a heat recovery system that captures waste heat from the production process and uses it to heat the facility.
2. Water Conservation: The Rouge Centre has implemented several water conservations measures, such as a rainwater harvesting system that collects rainwater from the roof of the facility and uses it to irrigate nearby green spaces.
3. Waste Reduction: The Rouge Centre has implemented several waste reduction initiatives, such as a comprehensive recycling program that recycles a variety of materials, including scrap metal, plastics, and paper.
4. Sustainable Materials: The Rouge Centre has implemented several initiatives for sustainable materials, such as using recycled materials in the production process and incorporating sustainable materials, such as soy-based foam, into vehicles produced at the facility.

In summary, the Rouge Center serves as a remarkable illustration of how industrial engineering can effectively foster sustainability and minimize the environmental repercussions of industrial operations. Through the adoption of sustainable practices like energy efficiency, water conservation, waste reduction, and the utilization of sustainable materials, industrial engineers contribute to advancing a more sustainable future for everyone [12].

4. METHODS

There are several methods used in determining sustainability in industrial engineering. Here are some of the most common ones:

1. LCA (Life Cycle Assessment) is an approach used to assess the environmental impact of a product or process throughout its entire life cycle, starting from the extraction of raw materials to its eventual disposal. This method considers various factors, including energy consumption, greenhouse gas emissions, and resource depletion, in order to provide a comprehensive evaluation.
2. Material Flow Analysis (MFA) is an analytical technique employed to measure and examine the movement of materials within a system, such as a manufacturing process or supply chain. The primary objective of MFA is to pinpoint areas within the system where material usage can be minimized, materials can be recycled, or materials can be reused. This method plays a crucial role in enhancing resource efficiency and identifying opportunities for sustainable material management. [7].
3. Ecological Foot printing (EF) is a technique utilized to quantify the ecological impact of human activities, considering the land and water resources required to support them. EF enables the identification of specific areas where resource utilization can be minimized or optimized, leading to more sustainable practices. By assessing the ecological footprint, it becomes possible to make informed decisions and implement strategies that promote efficient resource management and environmental conservation.
4. Sustainability Reporting: Sustainability reporting involves measuring and disclosing a company's social, environmental, and economic performance. This method helps track progress towards sustainability goals and identify areas where improvements can be made.
5. Design for Sustainability (DfS): DfS is an approach that integrates sustainability principles into the design process. This method involves considering the entire life cycle of a product or process and designing it in a way that minimizes environmental impact while maximizing economic and social benefits.
6. Lean Manufacturing: Lean manufacturing is an approach that focuses on reducing waste and increasing efficiency in the manufacturing process. This method helps reduce resource use and environmental impact while improving economic performance.
7. Green Supply Chain Management (GSCM): GSCM involves managing the entire supply chain in a way that minimizes environmental impact. This method includes selecting suppliers that prioritize sustainability, optimize transportation and logistics, and reduce waste throughout the supply chain.
8. Energy audits are conducted to analyze energy usage patterns and identify opportunities for improving energy efficiency. These audits encompass evaluating equipment and processes to identify potential areas for improvement. Additionally, energy audits may also consider the role of behavioral changes in optimizing energy consumption. By assessing equipment, processes, and behavior, energy audits provide valuable insights for implementing energy-efficient measures and achieving energy savings.
9. Sustainability scorecards: Sustainability scorecards are used to measure and track the sustainability performance of an organization. They can be used to identify areas where improvements can be made and to set goals for sustainability improvements.

10. Triple bottom line (TBL) analysis: The TBL analysis considers the economic, environmental, and social impacts of a product or process. It can be used to evaluate the overall sustainability of a system and identify opportunities for improvement.

5. OPPORTUNITY

Sustainability can be defined as the convergence of three fundamental components, and there are examples of features that exist at the intersection of any two of these components.

Sustainability indicators play a crucial role in measuring and assessing sustainability, as well as in guiding efforts to improve it. These indicators provide valuable insights into the current state of a system, the progress made towards achieving sustainability goals, and the challenges and issues that need to be addressed.

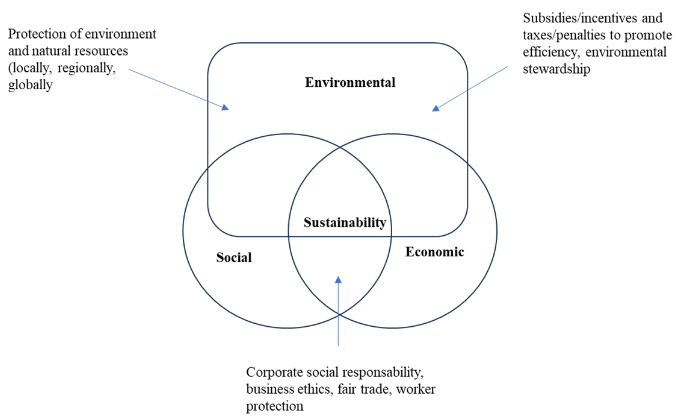

Fig.1 Interaction between environment, social and economic field in case of sustainability

They also serve as a basis for identifying appropriate measures and actions to tackle these challenges and ensure progress towards sustainability objectives.

Sustainability indicators differ from traditional indicators of economic, social, and environmental progress. They specifically focus on assessing and measuring the sustainability aspects of various systems and activities.

In the context of manufacturing, sustainable manufacturing involves the pursuit of improved environmental stewardship and sustainability without compromising profitability and productivity.

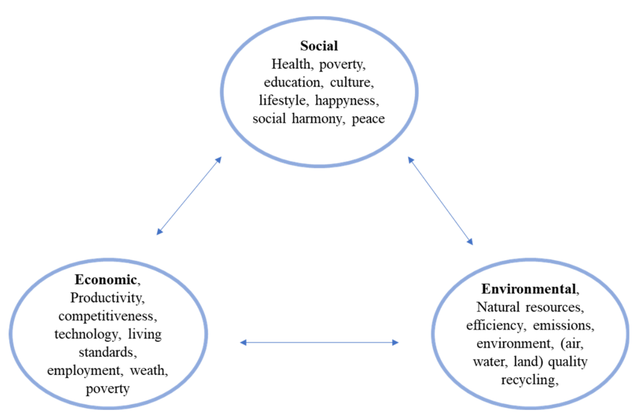

Fig.2 Relations between social, environmental, and economic parts of sustainability

It is increasingly recognized as a strategic objective for manufacturing companies. This shift in perspective acknowledges the importance of integrating sustainability into manufacturing processes and operations to achieve long-term success and mitigate the environmental impact of industrial activities.

Example of indicators: *American rating system LEED - Leadership in Energy and Environmental Design.*

- 40-49 points - project certified,
- 50 - 59 points - Silver level certification,
- 60 - 69 points - Gold level certification,
- 80 or more points - Platinum level certification.

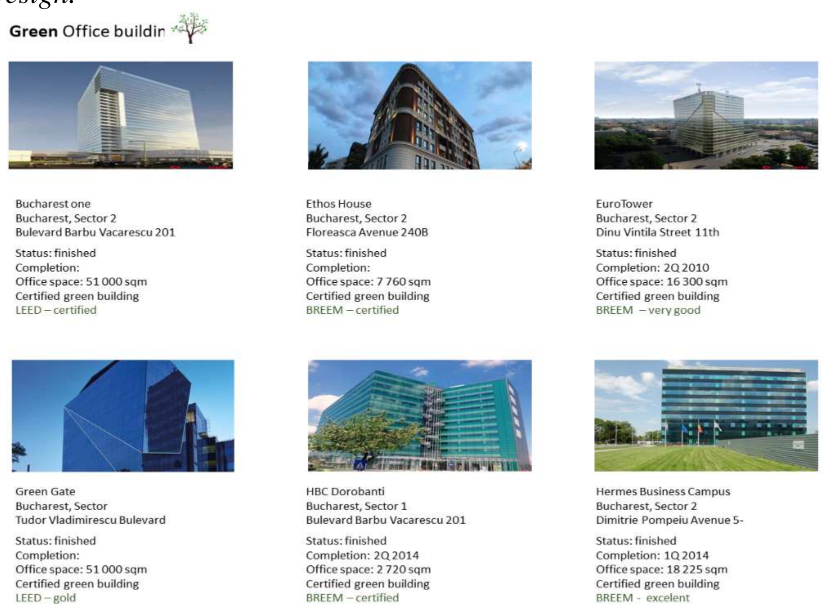

Fig.3. Example of certifications [11]

Several models have been devised to facilitate the implementation of sustainability principles in manufacturing, aiming to enhance overall manufacturing sustainability. [7].

Harland et al. [8] put forth a model called the Environmental Health and Safety Technology Engagement Model (Table 1), which outlines the potential for integrating sustainability objectives throughout the product or process development cycle. This model encompasses three key phases: research, development, and commercialization. The design of a new manufacturing product or process typically takes a significant amount of time, often spanning several years. Table 3 demonstrates that the feasibility of implementing sustainability objectives varies depending on the specific time frame and phase of development. It is essential for manufacturing engineers and designers to acknowledge this dependency and recognize the critical role it plays in effectively integrating sustainability into processes and products.

Table 1.

Model for potential for implementing sustainability in manufacturing.

Development phase	Potential for modification	Time before commercial manufacturing	Cost benefit of proper decision
Research	Low-medium	Long	Low
Development	Medium-High	Medium	Medium
Commercialization	Low-medium	Short	High

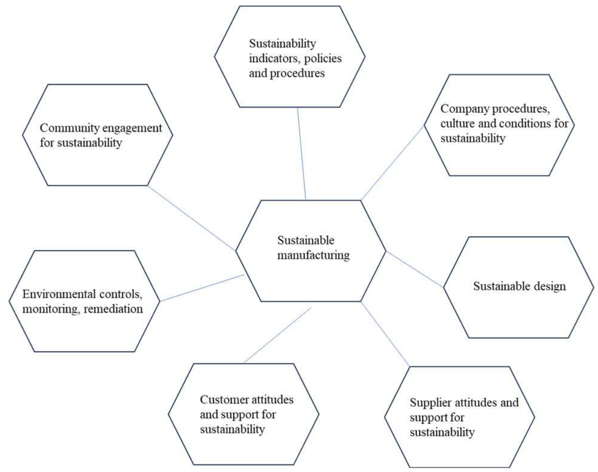

Fig.4 sustainable manufacturing.

The significance of integrating sustainability into manufacturing and design practices is emphasized, underlining the necessity of employing suitable tools like environmental design and life cycle assessment [10]. In addition to competitiveness, profitability, and productivity, environmental stewardship and sustainability are expected to gain growing significance for the manufacturing industry, shaping the primary priorities for advancing manufacturing operations and technologies.

Designing a smart manufacturing system at each iteration involves only one or a few metrics relevant to system intelligence, i.e., flexibility, visibility, sustainability, resilience and even some traditional metrics such as efficiency and agility, as well as one or a few corresponding digital triads (DT-II) or configuration in IoDTT.

The objective is to achieve economic sustainability within the manufacturing system by determining the optimal balance between the flow of parts among machines that are already equipped with the required modules and the endeavor to install the necessary modules on the machine where the part is currently located.

6. CONCLUSION

The sustainability concept is an important one in the fields of civil and industrial engineering, modelling the way we approach development and progress. This paper delves into the realm of sustainability by providing an insightful overview of case studies that demonstrate its application in both fields. In addition, it explores various methodologies that can be employed to embrace and embody the concept of sustainability.

In identifying sustainability, it becomes clear that environmental, social, and economic factors play a crucial role. These three interrelated dimensions have a significant impact on the viability and long-term success of sustainable practices. By considering the environmental impact of engineering projects, promoting social equity and inclusion, and encouraging economic stability, we can create a more holistic and sustainable future. By integrating these aspects, we can ensure a harmonious balance between human activities, nature and society, ultimately paving the way to a more sustainable world.

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O analiză a conceptului de durabilitate în ingineria fabricației și în ingineria civilă

Lucrarea prezintă o trecere în revistă a importanței impactului asupra mediului în cazul procesului de producție și a impactului asupra șantierelor de construcții civile. În mod obișnuit, industria a fost asociată cu un impact negativ asupra mediului: în ultimele decenii, degradarea mediului natural ca urmare a creșterii populației și a creșterii asociate a consumului de resurse (Holdren și Ehrlich, 1974), a creșterii economice și a intensificării asociate a activităților industriale (Meadows și Clubul de la Roma, 1974) a devenit o problemă globală incontestabilă (Comisia Mondială pentru Mediu și Dezvoltare, 1987). Producătorii se confruntă cu o presiune tot mai mare din partea părților interesate și cu reglementări mai stricte pentru a reduce impactul activităților lor asupra mediului. Cercetarea în domeniul sustenabilității în general și al producției durabile se dezvoltă rapid și transcende granițele disciplinare.

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