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Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **83 (1999)**

PDF erstellt am: **28.06.2024**

Persistenter Link: https://doi.org/10.5169/seals-62811

Sustainability and Civil Engineering: From Concept to Action

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Abstract

Developed and developing nations have been facing problems such as widespread infrastructure deterioration, pollution, and urban sprawl; natural resource depletion and degradation, waste generation and accumulation, and environmental impact and degradation; and overpopulation, disease, and social, economic, and political conflicts. The complex interrelationship between the economic development needs and the environmental problems resulting from development efforts is compounding these problems, and also, is the source of increasing conflicts and growing concerns for many nations of the world today, affecting individuals, communities, businesses, industries, and private- and public-sector organisations. In response, scientists; engineers, architects, and urban planners; medical and other health professionals; members of the financial community; government, policy-making, and regulatory officials; members of non-governmental organisations and civic groups, are devoting significant efforts toward finding workable solutions to these problems. Sustainable development has emerged as a potential solution. In broad terms, sustainable development was defined by the Brundtland Commission as "...meeting the needs of the present without compromising the ability of future generations to meet their own needs."

For engineers, sustainable development and sustainable technology mean that sustainability goals, concepts, and principles must be integrated within all stages of the life cycle of the planning, design, production, delivery, and use of goods, products, and services. Specifically within the Architecture-Engineering-Construction (A/E/C) industry, to achieve sustainability either at a global Civil Infrastructure Systems (CIS) project or at a specific Structural Systems (SS) project levels, two fundamental changes are needed: (1) decision-makers must integrate sustainability goals, concepts, principles, and guidelines explicitly and systematically within their decision-making processes at all stages of the life cycle of a project, particularly the early funding allocation, planning and conceptual design phases; and (2) manufacturers, vendors, and suppliers must develop and offer a new generation of sustainable building technologies, systems, products and materials for CIS. These changes are not easy, and few of the discussions on sustainability have addressed directly or explicitly what it means at a global A/E/C industry, at a general CIS project, or at a specific SS perspectives. This paper is a direct response to this void. The paper discusses sustainable SS from the following points of view: (1) what is the intellectual foundation of sustainability, and what does it mean for engineers? and (2) what actions must civil engineers take to achieve sustainability at a global A/E/C industry level, at a CIS project level, and at the specific SS level?

The first part of the paper discusses sustainability from its multiple dimensions. These dimensions create a rich spectrum of complexity, and force any substantive discussion on sustainability necessarily to address issues as diverse and complex as environmental ethics, international justice and equity, bio-ethics, and conservation. In addition, meaningful discussions on some of these issues require that they be framed in either economic, ecological, or technological terms.

Furthermore, attempts to discuss sustainability from a social or political policy perspective require adding a temporal dimension and a spatial dimension to the discussions, which further complicates the discussions. Also, there is no consensus on a unified conception of sustainable development, nor on a unified framework for sustainability. Consequently, as a starting point for the creation of a common intellectual foundation of sustainability, this paper provides a discussion of several of the most prevalent conceptions and frameworks. In addition, to address what sustainability means for engineers, the paper presents two challenges: (1) specific requirements needed to achieve sustainability; and (2) a conceptual framework for the role of engineers within the context of sustainability. Finally, the paper concludes the first part with a description of specific possible responses that the next generation of engineers can provide as a response to these challenges.

The second part of the paper discusses a set of proposed specific actions that civil engineers must begin to take to achieve sustainability at a global A/E/C industry level, at a CIS project level, and at the specific SS level. These are:

- *significantly change the prevalent paradigm in the A/E/C industry towards the delivery and operation of CIS, to a paradigm of the A/E/C industry as a sustainable system.* The new paradigm strives to create a closed cyclical system for the industry, which is framed within a social/cultural, political, economic, technological, and ecological/environmental context, and gradually moves towards sustainability.

- *significantly change two additional prevalent paradigms in the A/E/C industry at a CIS project level: (1) the current relationship between the supply of building technologies, systems, products and materials for CIS, and the demand for them, which currently interact mainly at the commercialization and procurement phases respectively; and (2) the prevalent emphasis on cost, time, and quality as the principal parameters to evaluate CIS project performance.* A new framework is proposed, which views the life cycle processes for the development and supply of the technologies, systems, products, and materials used in CIS, and the life cycle processes for delivery, operation, and maintenance of CIS as an integrated system. In this system, these two life cycles come together more symbiotically, in a way that the problems, needs, and opportunities within each one, at each phase of their life cycle, provide both "push" and "pull" drivers towards finding tangible sustainable solutions to the problems, satisfaction of the needs, and realization of the opportunities. Also, both life cycles are framed within an expanded set of performance parameters that establish the constraints within which they are executed: physical and non-physical contextual compatibility and response; manufacturability, useability, and maintainability or constructability, procurability, operability, and maintainability performance; and short-term and long-term functional, formal/physical performance, risk, cost and schedule, safety and security, and quality, reliability, and sustainability performance.

- *significantly change the way that SS project definition packages are developed as the basis of planning and design, and the design process itself.* A new approach is proposed, which addressing sustainability is an explicit project attribute, an explicit project objective, and an explicit project scope parameter. In addition, the SS project must framed within an intra- and intergenerational, a complete resource supply chain, and a broader regional, national, and global contexts and perspectives. Furthermore, at every stage of the design process, there should be proactive input of constructability, procurability, operability, maintainability, and sustainability knowledge and experience. Also, as the design evolves through its different phases (i.e., conceptual, schematic, design development, and contract documents), there should be explicit and systematic short-term and long-term checks for functional, formal/physical, risk, cost and schedule, safety and security, and quality, reliability, and sustainability performance parameters. Finally, specific strategies, mechanisms, and tools to support sustainability need to applied throughout the planning, design, construction, and use of the SS.