SUSTAINABLE DESIGN AND CONSTRUCTION:

"New approaches towards sustainable manufacturing"

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Abstract. Ecological and environmental issues are playing an important and larger role in corporate and manufacturing strategies. For complete creative design process, buildings require both for construction and manufacturing, due to their comparatively long life cycle for maintenance, significant raw material and energy resources. Thinking in terms of product life cycles is one of the challenges facing manufacturers today. "Life Cycle Management" (LCM) considers the product life cycle as a whole and optimizes the interaction of product design, construction, manufacturing and life cycle activities. The goal of this approach is to protect resources and maximize the effectiveness during usage by means of Life Cycle Assessment, Product Data Management, Technical Support and last but not least by Life Cycle Costing. In this paper the environmental consciousness issues pertaining to design, construction, manufacturing and operations management are presented through computer intelligent technologies of this 21century. So, this paper shows the existing approaches of LCM and discusses their visions and further development.

1. Introduction

Sustainability can be thought of as representing a balance that accommodates current human needs without diminishing the health and productivity of natural systems, and without diminishing the ability of future generations to accommodate their own needs (Luke, A., Nicholson, P.,E., 2004). With the population of the world continuing to increase, and with the corresponding over taxation of the world's natural resources, the building design and construction industry are uniquely situated to continue to improve efficiency and make a positive difference in the world. The demand for sustainable buildings has grown dramatically in recent years. Sustainable design and constructability are both concepts concerned with the efficient use of resources in projects although they are usually addressed separately.

It is imperative that we continue to improve the efficiency of the building design and construction process if the building construction industry is to remain vibrant and successful in the world. The shift away from traditional design and construction toward sustainable design and green building is a strong start. In practice, designers have traditionally relied on past experiences and their intuition, in making decisions on new project design configurations. This is because of a lack of integrated structured methodology and techniques for sustainability appraisal as part of infrastructure delivery (especially during design and construction). Such decisions are often predicated on their mental models of past projects, some of which may have been designed with very little or no consideration to sustainability issues.

Typically, sustainable design is associated with a first cost premium because of the higher priced (recycled) materials and more expensive, but more efficient energy saving technologies. These costs are often offset by significant operational and energy savings over the life of the project. Constructability can also achieve notable savings for a project during the construction phase (Michael, P., Teresa, P., Michael, H., David, R., 2003). Therefore the main aim of this paper is to propose a methodology for study sustainable design and Construction from the vision of Life Cycle Management and sustainable manufacturing.

2. Architectural Response to Sustainability

Ecological thinking in architecture requires a multidisciplinary approach starting in early design stages. The feedback from diverse professionals in the AEC industry enables the incorporation of technologies and ecological friendly innovations. Green practices can benefit from such integration when including environmental considerations in building design. The ecological principle ‘thinking globally while acting locally’ should guide building practices. Environmental inputs are to be used on a sustainable scale appropriate to each bioregional setting (Mark, A., Dino, M., Chimay, J., Patricia, M., Malik, M.K., Jacqueline, Glas, 2006).

There are two positions concerning ecological thinking in the architecture creative process: ecological and technological sustainability (Jorge, A., Vanegas, Jennifer, R., D., Annie, R., P., 2001). The first position perceives sustainability as the driver of the practice. The eco impact of the building is the most important aspect to consider. It argues that architecture should learn from the synergies of natural systems. Ecological sustainability considers the balance and integration of components of natural systems and processes to reduce the impact on the atmosphere. The second position involves the use of smart engineering systems and innovations. This perspective is related to the second industrial age. Human beings use natural resources in ways that are environmentally respectful and have awareness of the limitation of resources. Ecology and architecture make strange, but star crossed, bedfellows, (Guy, S., and Farmer, G., 2001). However, buildings can be designed, built and operated in ways that are environmentally responsible. The key aspect is to realize how creative practices of ecological architecture *construct and enable alternative forms of relationship and hybridization between people, place, material and Earth* (Edmundas K., Z., Arturas K., Nerija K., 2001). Initiatives encouraging green practices and sustainable practices themselves play a major role in achieving the sustainable vision of the future that society demands.

The following ideas, as provided by the Hannover Principles of Architecture should be seen as a means of improving the quality of life through environmentally friendly architecture. These points are constantly changing, so that they may adapt as our knowledge of the world evolves. We could list them in brief methodology:

1. Insist on rights of humanity and nature to co-exist in a healthy, supportive, diverse and sustainable condition.
2. Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.
3. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness.
4. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems and their right to co-exist.
5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creation of products, processes or standards.
6. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste.
7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.
8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled.
9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

3. Sustainable Construction

Sustainable construction is the creation and responsible management of a healthy built environment based on resource efficient and ecological principles (Du Plessis, C., 2005). Also, "sustainable construction" is a series of sustainable or 'best practice' decisions, which starts well before construction (in the planning and design stages) and continues long after the construction team have left the site: a process that takes in the design, construction and on-going maintenance of what is being referred to as a "green" building (Carolyn, S. H., Sarah, E. H., 2008). It includes the following principles:

- Minimizing non-renewable resource consumption
- Enhancing the natural environment
- Eliminating or minimizing the use of toxic materials

Such construction processes would thus bring environmental responsibility, social awareness, and economic profitability objectives to the fore in the built environment and facilities for the wider community. Construction has a significant effect on quality of life: its outputs alter the nature, function and appearance of the towns and countryside in which people live and work. The construction, use, repair, maintenance and demolition of such infrastructure consume resources and energy, and generate waste (Mark, A., Dino, M., Chimay, J., Patricia, M., Malik, M.K., Jacqueline, Glas, 2006). The construction industry is extremely conservative and subject to slow rates of change due to regulatory, liability, and limited technology transfer from other sectors of society. Sustainable buildings are assumed to merely represent differently configured technical structures, with particular pathways of technological innovation viewed as objectively preferable to others. The shift to sustainability can be seen as a new paradigm where sustainable objectives are within the building design and construction industry considered for decision making at all stages of the life cycle of the facility. Figure 1, outlines the evolution and challenges of the sustainable construction concept in a global context (Pekka, H., Lauri, K., 1998).

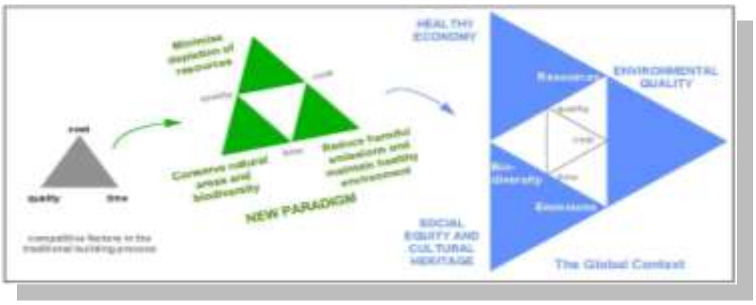

Figure 1. A simplified road map for sustainable construction, (Pekka, H., Lauri, K., 1998).

4. Sustainable Manufacturing

Manufacturing industries in buildings construction account for a significant part of the world’s consumption of resources and generation of waste. Worldwide, the energy consumption of manufacturing industries grew daily. Buildings manufacturing industries nevertheless have the potential to become a driving force for the creation of a sustainable society. They can design and implement integrated sustainable practices and develop products and services that contribute to better environmental performance. More recently, its efforts to improve environmental performance have moved towards thinking in terms of lifecycles, integrated environmental strategies, management systems, and companies have also begun to accept larger environmental responsibilities throughout their value chains.

Virtual production tools gain increasing popularity in industry because they facilitate work parallelization and concurrent engineering. This helps to reduce times to market for new products and the tools also enable development of sustainable and efficient production systems on a continuous basis, see figure 2.

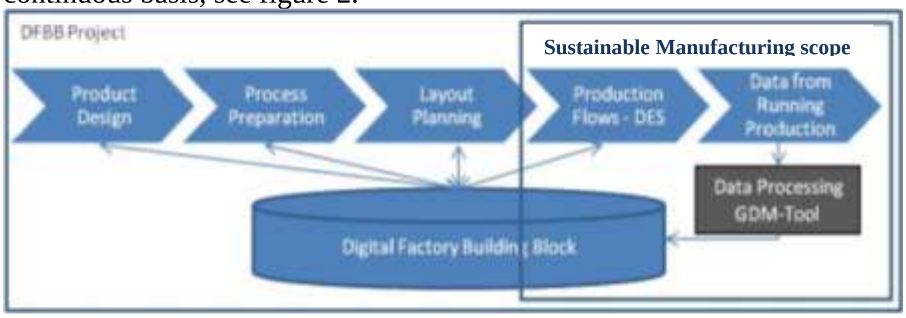

Figure 2: Framework of Digital Factory Building Blocks (DFBB) Project, (Boulonne, A., Aufenanger, M., Johansson, B.,Skoogh, A., 2010)

Reducing costs, improving quality, shortening the time-to-market, and at the same time act and think sustainable are major challenges for manufacturing industries, (Boulonne, A., Aufenanger, M., Johansson, B.,Skoogh, A., 2010). To strive towards these objectives, **discrete event simulation** (DES) has proven to be an effective tool for production system decision support.

As a result, the building blocks will improve interoperability and allow engineering applications, independent from major (Product Lifecycle Management) PLM systems, to communicate without expensive customized interfaces for data exchange.

5. Life Cycle Management (LCM)

A building life cycle consists of four closely interrelated stages: brief, design, construction and maintenance. A building life cycle may have a lot of alternative versions. These variants are based on the alternative brief, design, construction, maintenance and facilities management processes and their constituent parts. The above solutions and processes may be further considered in more detail. For instance, the alternative building variants may be developed by varying its three-dimensional planning, as well as structural

and engineering solutions. Thus, dozens of thousands of building life cycle alternative versions can be obtained. The diversity of solutions available contributes to more accurate evaluation of climatic conditions, risk exposure, maintenance services, as well as making the project cheaper and better satisfying a client's architectural, comfortability, technological and other requirements. This also leads to better satisfaction of the needs of all parties involved in the project design and realization (Edmundas K., Z., Arturas K., Nerija K., 2001).

Alternative definitions of sustainability abound, but for system design purposes the following definition is useful: A product, process, or service contributes to sustainability if it constrains environmental resource consumption and waste generation to an acceptable level (Robert, K., H., 1997), supports the satisfaction of important human needs, and provides enduring economic value to the business enterprise (Bakshi, B., Fiksel, J., 2003). Note that a product cannot be sustainable in an absolute sense; rather, it must be considered in the context of the supply chain, the market, and the natural environment. Therefore, the key practical challenge of sustainable design is to understand how products, processes, and services interact with these broader systems.

6. Sustainability, Building Design & Construction Industry: "Sustainable Manufacturing New Approach"

The current challenge for architectural practices is combining innovation with ecological respect. In the context of technological promises for a sustainable future it is important to question how such innovations could be applied as a means to achieve specific goals. The use of high engineering systems supported by adequate studies and on a case by case basis will give opportunities to achieve sustainability.

Life cycle considerations are particularly important with respect to the design, construction and manufacturing of built facilities because the life cycle of a facility involves more than just constructing and manufacturing the facility itself, see figure 3.

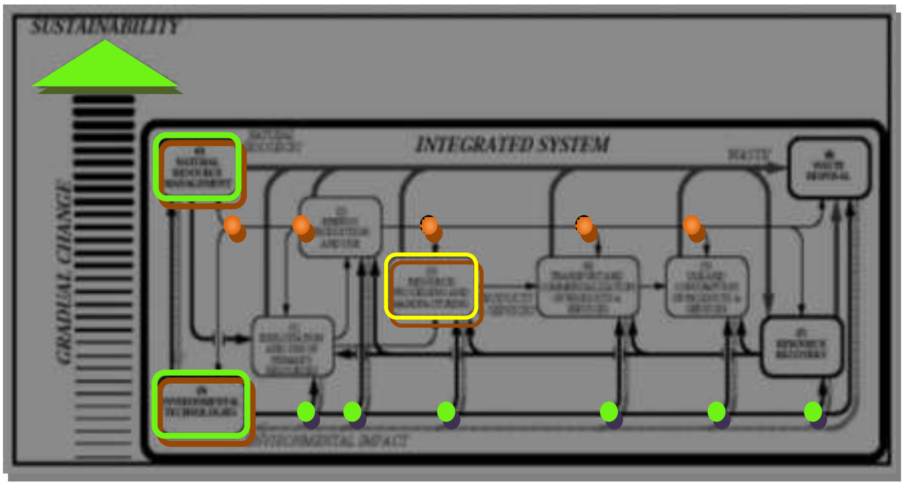

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Figure 3. Cyclic Sustainable Development Process (Jorge, A., Vanegas., 2003).

In the creation of built facilities, there are many opportunities to improve how design and construction are currently done to make them more sustainable, see figure 4. Three general objectives should shape the implementation of sustainable design and construction, while keeping in mind the three categories of sustainability issues discussed above (social, environmental, and economics). These objectives are:

- Minimizing consumption of matter and energy over the whole life cycle of consumption, while
- Satisfying human needs and aspirations with sensitivity to cultural context, and
- Avoiding negative environmental impact.

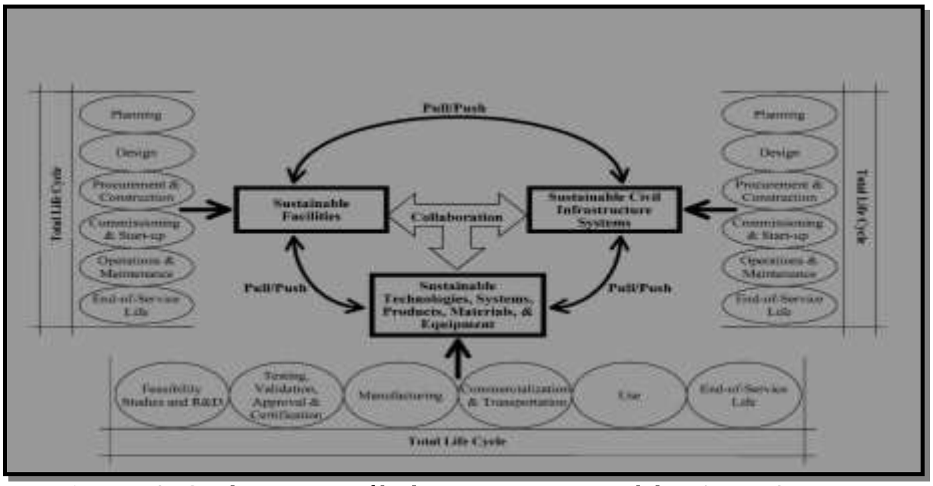

Figure 4. AEC industry vision of built environment sustainability..(Jorge, A., Vanegas, Jennifer, R., D., Annie, R., P.,2001)

6.1. COMPUTER AIDED SUSTAINABLE DESIGN (CASD)

CASD is being designed to suit the following aspects of building design: the iterative nature of the 'real-world' design process, the language of actors involved, and to supply results which can be interpreted by a multi-professional team. The originality of this software is that the inputs and the outputs are generated in a building actor's understandable language and it's not necessary that they have good computer skills, (Bennad ji, A., AHriz, H., Aalastair, P., 2004), see figure 5.

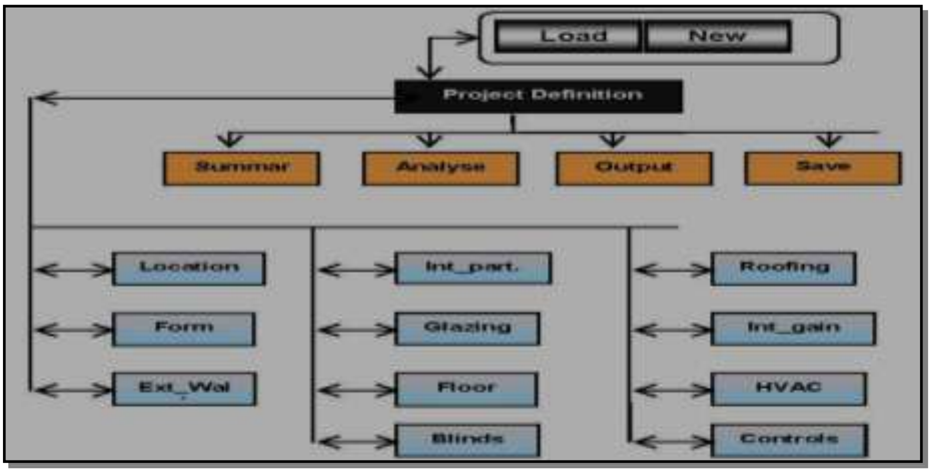

Figure 5. CASD's Interface, (Bennad ji, A., AHriz, H., Aalastair, P., 2004).

CASD is a whole building energy prediction method and a program that allows users to enter a minimum amount of data to produce an energy analysis file. The analysis of this file is performed by a third party analytical program. It is intended to be used to compare the performance of different building's design that the building's actors can choose the best option regarding the thermal point of view.

CASD has been deigned to capture all the data needed by any thermal model, and as such can be plugged-in any software that uses thermal models to predict annual primary energy consumption as a function of:

- Local climatic conditions
- Orientation of façades
- Area and type of glazing.
- Obstructions due to adjacent buildings.
- Occupancy and vacation patterns.
- Lighting levels.
- Internal gains.

6.2. SUSTAINABILITY WITHIN SIMULATION DATA ARCHITECTURE

A computer-based building product model (BPM) developed that, together with a building management system (BMS), and other IT tools and technologies, creates an integrated environment allowing for the storage, measurement and control of certain performance-based sustainability criteria in relation to the buildings energy usage, see figure 6.

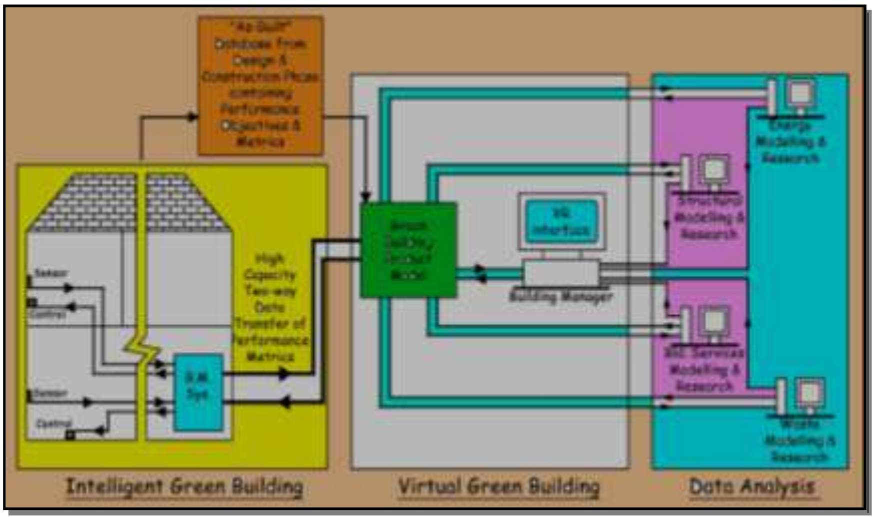

Fig. 6. Environmental Research Institute (ERI) project overview,(Sullivan, D., Keane M., Kelliher D, Hitchcock R., 2004).

The developed architecture was enhanced by the integration of sustainability data. Therefore, the developed environment supports storing of sustainability indicators – environmental and ergonomic – in the DES resource description. Designing reusable resource production blocks by the use of a resource information repository is a very efficient way to adapt existing and develop new manufacturing lines in a sustainable way.

Dynamic architecture provides a solution where each individual element plays a part in it. The Core Manufacturing Simulation Data (CMSD) XML document is designed to be the architectural binder, enabling interoperability and proper understanding between each element. Thus, building and parsing XML files and keeping to strict rules is the cornerstone of successful data exchange. Moreover, using a standardized interface for communication provides the possibility to separately develop each element without affecting the complete architecture.

7. Conclusion

The potential to improve the design sustainability and the constructability of a project is enhanced when these two initiatives are integrated and approached in a combined fashion through sustainable manufacturing and building lifecycle, within the intelligent use of computer giving technologies (such as DES models & CMSD XML document). Effective implementation and achievement of built environment sustainability begin with visions for sustainability at global, industry, and project levels and continue with a road map for implementation at strategic, tactical, and operational levels. However, to fully achieve built environment sustainability, what is required is the continuous application of specific sustainability principles, concepts, heuristics, strategies, guidelines, specifications, standards, processes, tools, best practices, lessons learned, or case studies within the various processes embedded in the visions. Taking into consideration building life cycle sustainably through design, construction and manufacturing.

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