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Analysis of the impact of individual phases in the building process cycle on the environment with respect to the principles of sustainable development

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Abstract. Construction is one of the most dynamically developing sectors. Continuous population growth entails urbanization processes which from all areas of human activities consume more and more natural resources. Development of the construction sector is a process that must not be stopped. However, the principles of sustainable development should be respected while the remaining natural resources should be adequately managed. Application of the sustainable development principles into this sector of the economy can greatly improve the condition of the natural environment throughout the world. All definitions of sustainable development agree on the need for proper management of natural resources.

The paper analyses the phases of the building cycle from the standpoint of the negative impact on the natural environment. Based on the interrelationship diagram (the tool for the quality management system), the study emphasizes the major causes of problems and discusses them in detail. The facilitations to each key stage were proposed in order to reduce the harmful impact of the factors of the building process on the environment. The paper analysed the advantages and drawbacks of the proposed solutions.

1. Introduction

Humans and the actions they take to improve their quality of life lead to the disturbance of the processes occurring in the natural environment. These processes should not be stopped while the solution should be found to help humans coexist with nature. The first action plans to protect the Earth and its natural resources were discussed during the World Conference in Stockholm in 1972 ("Only one Earth"). Another meeting, with representatives of 172 governments present, was organized in Rio de Janeiro 20 years later. The 1992 conference put forward the documents that defined the basic principles of environmental protection. This conference inspired other similar conferences that discussed the problem of depletion of natural resources. Conferences of the United Nations Framework Convention on Climate Change are held every year in various countries: 1995 – Germany, 1996 – Switzerland, 1997 – Japan, 1998 – Argentina, 1999 – Germany, 2000 – the Netherlands, 2001 – Morocco, 2002 – India, 2003 – Italy, 2004 – Argentina, 2005 – Canada, 2006 – Kenya, 2007 – Indonesia, 2008 – Poland, 2009 – Denmark, 2010 – Mexico, 2011 – South Africa, 2012 – Qatar, 2012 – Rio de Janeiro, 2013 – Poland, 2014 – Climate Summit, the USA (New York), 2015 – France. In 2015 in Paris, 195 countries adopted the climate agreement named the Paris Agreement. This was the first agreement to oblige all the states to take measures towards protecting climate. The major problems



discussed during climate conferences is reduction in greenhouse gas emissions and, more recently, promotion of the role of forests in consumption of carbon dioxide. The Paris Agreement will be in force from 2020. In the conference in 2016, Poland also promoted "forest coal farms". The program aims to capture more CO₂ through adequate forest management.

The ecological and social problems and the resulting threats have become an inspiration for the development of the concept of sustainable development. It is well known that industrial development causes environmental pollution. Environmental problems cause the production of castings, steel, construction materials, food products and more [1, 2]. The term "sustainable development" was first used in the Brundtland Report (1987) developed by the UN World Commission on Environment and Development [3]. The principles of sustainable development are aimed to secure natural resources for the generations to come, which, with the development of the urban complexes and the infrastructure, are being substantially depleted. The idea of sustainable development consists in the use of the methods to ensure development that meets our current needs so that the needs of the generations to come are also met [4].

Three major aspects of sustainable development are mentioned [5]:

- economic (e.g. through reduction in energy consumption),
- social (e.g. through ensuring healthy and safe environment for living and working),
- ecological (e.g. through efficient land management).

The purpose of the paper was to distinguish the phases of life of the building process and analyze them in terms of the negative impact on the environment. To achieve this goal, a tool, that is not typical for the issues related to building processes e.g. interrelationship diagram, was proposed.

Another goal of the paper was to propose actions to reduce indicated negative impact on the environment. In this case Ishikawa diagram was used.

2. The role of sustainable construction in sustainable development

Sustainable development has led to the necessity to implement changes towards balancing all areas of human activity, including the construction sector, which, according to the statistical data, is responsible for:

- 42% of the final energy consumption in the EU (construction and using the buildings),
- 35% of greenhouse gas emissions to the atmosphere,
- 30% of water consumption,
- 50% of all natural resources used,
- 33% of all waste produced, with particular environmental threat caused by waste after demolishing of building structures [6].

The idea of the problems analysed were well described by Wierzbicki: *the concept of sustainable building is aimed to create and manage a healthy build-up area based on the principle of effective and ecological utilization of renewable resources. It takes into consideration the environmental aspect and quality of life as well as problems of culture and social justice and economic limitations* [7].

The main principles of sustainable building include [8];

- efficient utilization of renewable energy sources and energy efficiency (e.g. through the design of south exposure of buildings' façades),
- the use of environmentally-friendly resources renewable resources, preventing air pollution, water and soil,
- integration with natural environment and social environment and efficient land use.

Construction is the domain which depends on many entities [9 ÷ 10], as shown in Figure 1. Degree of sustainability of the building depends on how individual entities perceive the principles of sustainable development.

The effectiveness of sustainable building depends on many entities which also have to be involved in initiatives towards ensuring sustainable development, such as:

State - refunds to support sustainable building, promotion of green solutions.

Users - utilization of the building while respecting the principles of ecology.

Investors - investors should be convinced that higher costs connected with ecological solutions can be returned over the period of use.

Material producers: following the regulations and standards, production of green building materials made of renewable resources, biopolymers, innovative reinforcement fibres and hybrid organic and non-organic composites [11].

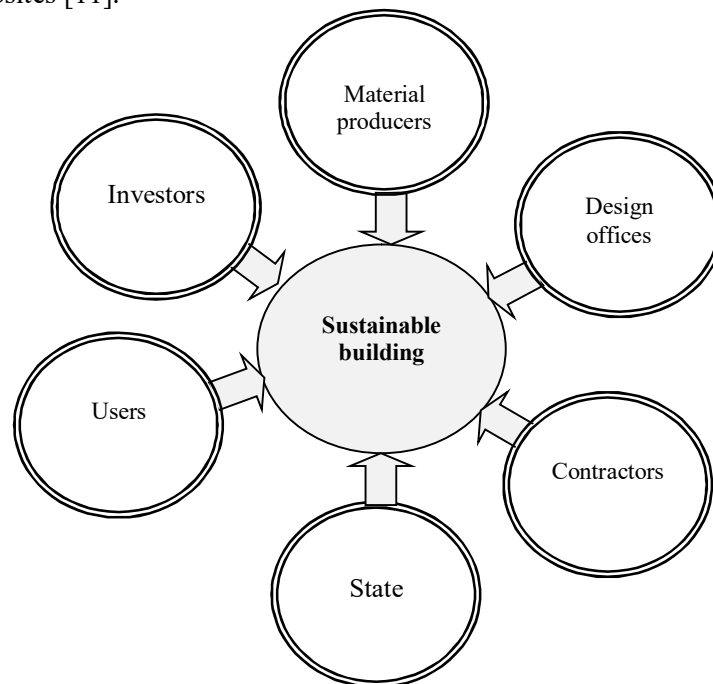


Figure 1. Entities that affect the level of sustainable building [own study].

Design offices - analysis of land development within the project and natural insolation.

Contractors: care for minimizing interventions in the nature, the use of machines and tools with low exhaust gas emissions levels and reduced noise level.

3. Building life cycle in consideration of the negative effect of each phase on the natural environment

While searching improved methods to process raw materials, manufacture materials and use them, it is essential that life cycle is used and each life cycle stage is thoroughly analysed. The problem related to sustainable development should be effectively managed as early as possible in the design process [12]. LCA at the early stage of design gives information to the designers about the impact of their components on the environment [12a]. The analysis should be made in terms of selection of the methods that are characterized by minimal impact on the environment. [14-15] Wg Bogenstätter U 2000 operation costs over the life-cycle of a building are a multiple of the initial construction costs. Decisions in the programming stage (briefing) and design process influence life-cycle costs in terms of space, the quantity of structural elements, technical/mechanical service equipment and the choice of materials[16]. The analysis of the life cycle in the building process was also proposed by Addis B., Talbot R 2001. In their work they proved that this is a basic activity identifying non-ecological environmental impacts in every phase of a building's life [17]. In the article quality management tools to analyze the negative impact on the environment of each phase of the life cycle of a building were used. Figure 2 presents a life cycle of a building from extraction of raw materials, processing and use through to recycling. Furthermore, the stages were analysed from the standpoint of a negative effect

on the natural environment (Figure 3). For this purpose, a simple and efficient tool was employed: interrelationship diagram.

Interrelationship diagram means a diagram of mutual relations between causes. The diagram is a technique used to establish the correlations between the main problem and the interrelated factors [18 ÷ 21]. Unlike the Ishikawa diagram, apart from cause-and-effect relations, this diagram also illustrates the cause-cause relations [21 ÷ 22].

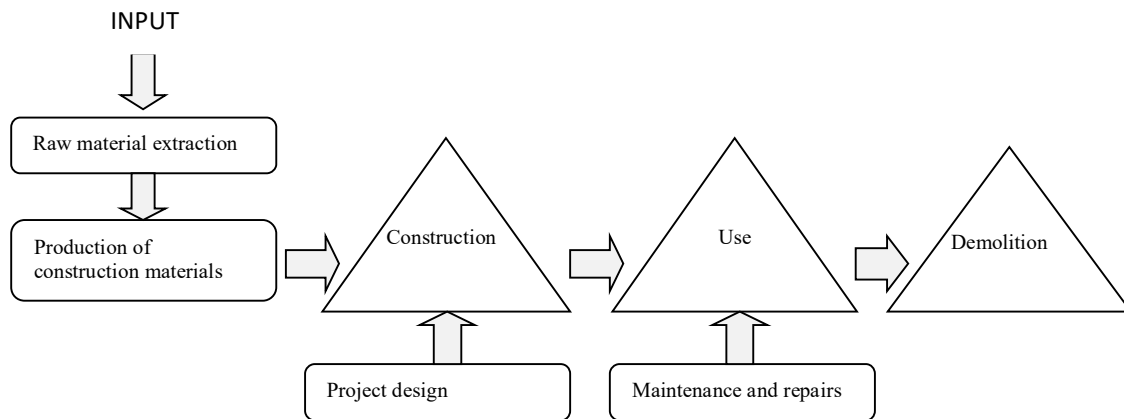


Figure 2. Building life cycle [elaboration based on 17].

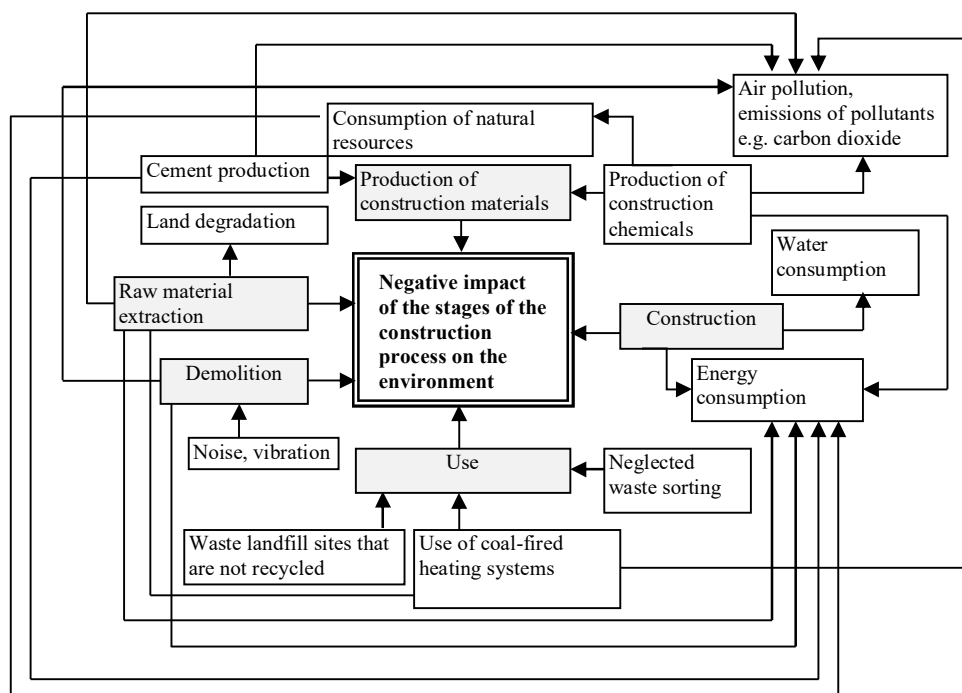


Figure 3. Interrelation diagram used to illustrate the relationships between individual causes of the negative impact on the environment over all the phases of building life cycle [own study].

Figure 3 shows that all stages are connected first of all with energy consumption and emissions of pollutants. The analysis of the figure shows that:

- Each of the analyzed phases of the life cycle of a building (cement production, production of construction chemicals, raw material extraction, use of coal-fired heating systems, demolition) directly or indirectly affects air pollution, emissions of pollutants e.g. carbon dioxide.
- High energy consumption is affected by: raw material extraction, demolition, cement production, consumption of natural resources, production of construction chemicals, construction.
- Processes affecting negatively on production of construction materials are: production of construction chemicals, cement production, consumption of natural resources.
- Raw material extraction influence on land degradation, air pollution, emissions of pollutants, energy consumption.

The purpose of the proposed actions which were supposed to reduce the negative impact on the environment of each phase which were necessary in the realization of building process was the Ishikawa diagram. All elements affecting the individual phases of the life cycle of a building object are grouped into five areas: Project, Materials, Machines and equipment, Man, Use. The diagram was used to organize the solutions whose implementation would significantly improve environmental protection. Twenty eight causes of inconsistencies were found. Furthermore, these stages were analysed in terms of improved utilization of the resources and application of the methods with minimal impact on the environment (Figure 4). Figure 4 illustrates the ideas for improvement of the current state.

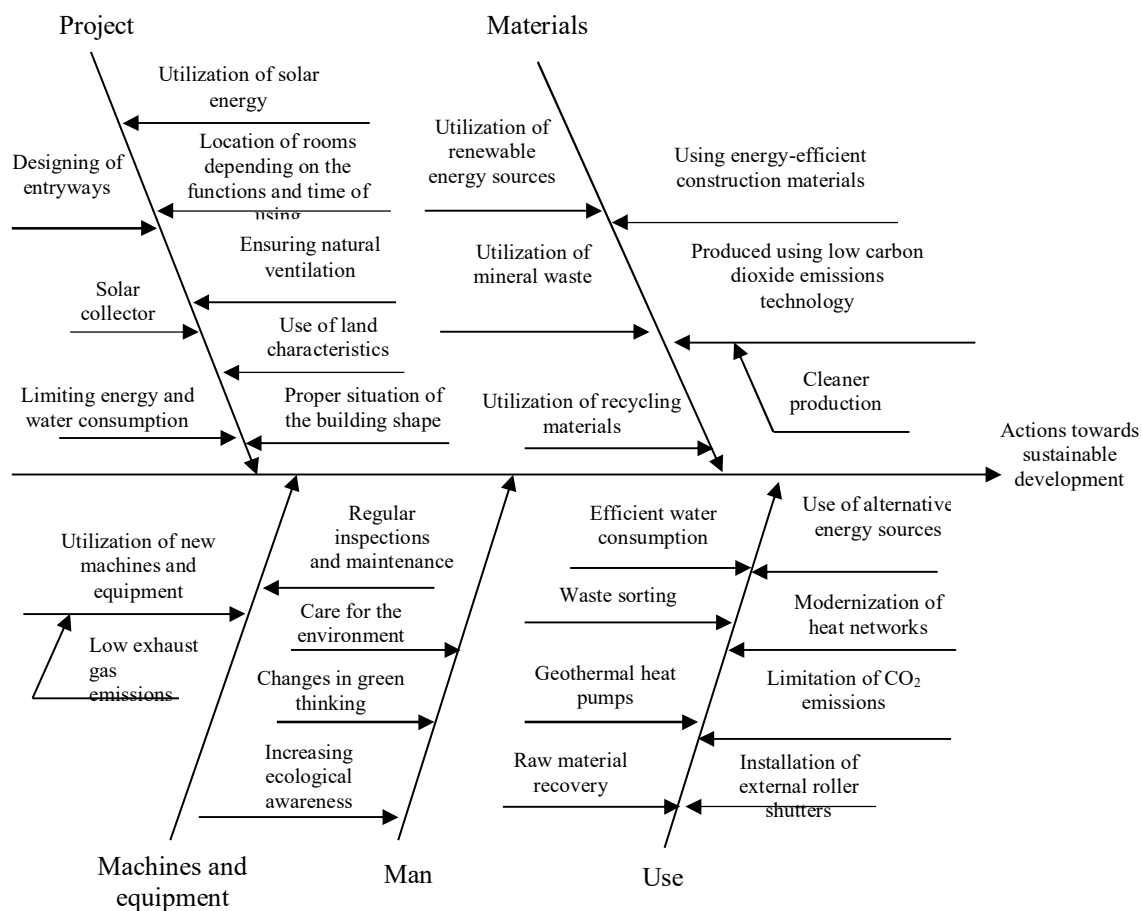


Figure 4. Organization of activities towards sustainable development in the building process [own study].

The signals of reducing natural resources have become a driver to search new sources of energy and gas. Measures for sustainable building construction should be taken into account at the design stage (project of the facility itself, design of implementation processes, technology, logistic processes, organization and assembly), as it has a huge impact on subsequent utilization. The sustainable development must be taken into account at this stage.

There are many solutions that were not once common in building construction, and whose use will reduce the negative impact on the environment, e.g. location of rooms depending on the functions and time of using, use of land characteristics, proper situation of the building shape, shape of the building (Figure 4). Also, the materials used may be more or less ecological. It is a man who influences the level of "environmentalism" of used building materials, modernity of used machines, regular inspections and maintenance. Actions for environmental protection are also proper exploitation, among others: raw material recovery, installation of external roller shutters, efficient water consumption (Figure 4).

4. Conclusion

In the paper the life cycle of the building process taking into account the negative impact on the environment of each of its elements was presented. Each phase of a building's life cycle causes a negative impact on the environment from the extraction of materials through construction, utilization up to demolition. The paper used the tools of quality management in order to demonstrate the effect of individual building life cycle on the natural environment. Identification of the causes which have negative impact on the environment at each stage will optimize the negative impact of the entire construction. The interrelation diagram in a clear and transparent manner showed the dependencies between the factors of each phase of the life cycle of the building and their impact on the natural environment. The most serious problem is substantial energy consumption and emissions of CO₂. Therefore, it seems necessary to departure from previous methods to generate energy since the increasing extraction of fossil fuels, their consumption and deforestation contribute substantially to higher concentration of greenhouse gases in the atmosphere.

The alternative methods to organize all the stages of the construction process should be proposed such that they do not have a negative impact on the environment and final users.

For this purpose, a very simple and efficient tool of quality management was employed: the Ishikawa diagram. According to the methodology required to prepare the Ishikawa diagram, five major areas involved in the building process were used: design, materials, machines and equipment, employees and use.

Humans have to be aware of the ecological aspects of many actions they take. The focus should be on the nature viewed as a "common good" that should be cared for rather than as "inexhaustible natural resources" as people used to think 50 years ago. Therefore, production of materials and construction techniques which comply with the principles of sustainable development should be promoted while recycling materials and new technologies of treatment and saving water should be implemented.

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