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Jonas Jonasson (Researcher and lecturer; Dep. of Ecotechnology and Sustainable Building, Mid Sweden University, Östersund)
Lars-Åke Mikaelsson (Senior lecturer; Dep. of Ecotechnology and Sustainable Building, Mid Sweden University, Östersund))
Urban Persson (PhD and lecturer; Dep. of Construction Management, Lund University, Lund)

Abstract

As the building construction industry accounts for a large part of the ecological burden, sustainable construction processes are very important for achieving sustainable communities. Construction is often a linear process, where different actors act at different stages of the process. In this process there are critical borderlines where the information is to be transferred from one actor to another. Over the years, the construction industry has developed a well-functioning and standardized arrangement for how this happens. However, this has proven to be problematic when sustainability is to be introduced in construction projects. Sustainability goals can often be perceived as diffuse and difficult to interpret. Different actors with different values and knowledge level regarding sustainability also interpret the goals differently. A common way is to set environmental goals as checklists with criteria to be met. In this process, it is common for certain aspects to be sub-optimized while other important aspects fall outside the scope. It is therefore very important to simplify the sustainability parameters without sacrificing complexity. The goals must be clearly formulated initially and followed up continuously throughout the process. The purpose of this paper is to study and analyze good examples of sustainable construction processes with regard to clear goal formulation and continuous follow-up. The result end up in a proposal for a model for knowledge management of sustainable construction processes.

Introduction

Background

A large proportion of the earth's resource turnover is linked to buildings and construction. This means a complex relationship to take into account in the realization of construction projects since economic and social aspects also affect the individual. In order to gain a holistic perspective on this relationship, during the construction process, one solution is to adapt the concept of sustainable development to the construction sector and to direct the construction process in this direction. [1]

Sustainable construction is an overall term used to describe a building that is environmentally adapted in all respects. There is no clear internationally accepted definition of what is meant by the term, but researcher Urban Persson has thoroughly analyzed and explained how it can be used and defined. [1] [2]. According to Persson, sustainable construction is largely

synonymous with sustainable building in terms of the product and sustainable construction in the process. These concepts are based on sustainable development, which includes ecological, social and economic sustainability. A now widely accepted model for describing sustainable development is the triple-bottom-line inscribed in the UN's 17th SDG (UN Sustainable Development Goals, 2020) with the ecological goals as a framework (Figure 1). This also means that, for example, soft factors such as mental well-being, social relationships, work environment issues and cost-effectiveness are important components of a sustainable construction (SDG nr 3,5,8, 10 och 11). [3]

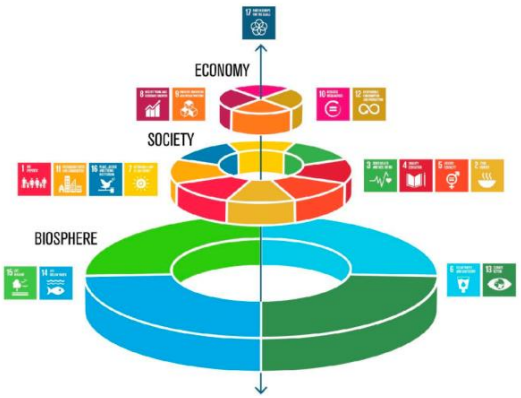

Figure 1: Triple-bottom-line of sustainable development and UN SDG:s [3]

In terms of social sustainability, experience shows that it is often difficult to implement and carry through the initial ambitions of construction projects. This is due to a lack of competence but also because sustainability aspects can be difficult to reconcile with short-term financial interests. One way to deal with this problem and at the same time increase competitiveness in the construction and real estate sector is to further develop models for sustainable construction production by including economic, ecological, social and cultural sustainability.

Construction processes are generally complex, with many actors involved at various stages. The information about what is to be built must be transferred from one actor to another is often done in a linear process during a limited period, in connection with procurement and contract writing. These processes when the information is transferred can be referred to as critical borderlines. Important borderlines are from programs to design then to production when architects and designers submit documents to construction companies and subcontractors who are to do what the projectors described. Communication and appropriate information systems are consistently critical factors for knowledge transfer throughout the construction process and many errors and mistakes in the process can be attributed to deficiencies in knowledge and information transfer. In the intersection of two phases in the construction process, the sociotechnical system can be completely replaced with communication and information problems as a result. This tends to take place mainly between the programming and planning stages and the implementation stage.
This problem can be overcome by having exponents of the original visions participate in all stages of the process from the early idea and program stage to the finished building. In order to make this possible, the contractual legal aspects of the process must be taken into account.

Sustainability adds even more complexity to a project, not least because the meaning of the word sustainability varies between different actors. New building techniques or materials may be needed, as well as specialized expertise from other areas. It is common for ambition levels to be gradually lowered between critical borderlines during the process. Here, many good intentions and high ambitions in terms of sustainability from the early program work risk being changed or lost. Initially high standards of sustainability, changes in favor of traditional solutions.

Purpose, boundaries and methods

The purpose of this paper is to study and analyze sustainable construction processes with regard to clear target formulation and continuous follow-up of the sustainability parameters. It is furthermore to develop a general model for the management of sustainable construction processes based on ecological, economic, social and cultural criteria, especially with regard to bridging the knowledge transfer between the critical borderlines of the construction process. The model is based on action research-oriented case studies conducted within the framework of the Structural Funds project "Hållbart Samhällsbyggande" (Sustainable Building and Planning; HåSa, 2016-2019) supplemented with previous research by Mikaelsson, Persson and other researchers. The paper is mainly based on case studies of construction projects followed by the researchers with participation, own observations, interviews, surveys and studies of planning documents.

Problem formulation and implementation

Model for four sustainability criteria

Building and Planning are key issues in municipal and regional development. In Sweden there are some areas where building and planning is increasing while in other parts it has more or less stagnated due to relocation and an aging population [4]. Recent years have also been characterized by extensive migration in some areas which has had impact on the need for building and planning activities. A difficulty for construction and real estate companies is, under such conditions, to obtain a sustainable economy in their construction projects. At the same time, the demands are growing that both new buildings and renovations must be ecologically sustainable and contribute to reduced exclusion through social sustainability. [4] In terms of ecological as well as social sustainability, experience shows that it is often difficult to implement and transfer the initial ambitions in construction projects through the whole process. This is due to lack of competence but also because sustainability criteria can be difficult to reconcile with short-term financial interests. This study addresses this problem by further developing a model for sustainable building production through an action research approach by including economic, ecological, social and cultural sustainability. [4]

Compared to economic and ecological sustainability, social and cultural sustainability are relatively new criteria in the construction industry. Architecture, building planning, service in the local environment and work environment can be seen as examples of social sustainability. Cultural heritage, diversity and cultural expression in the construction industry are examples of factors linked to cultural sustainability. Figure 2 [4] illustrates the various sustainability criteria and what factors they primarily concern. The four criteria should not be regarded as separate parts but as overlapping and interdependent.

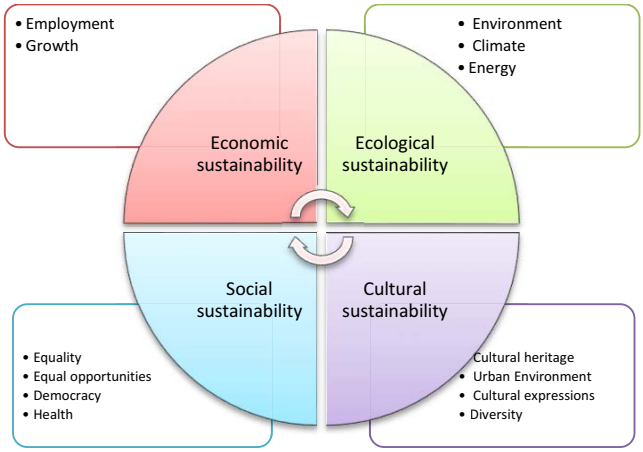

Figure 2: Model for four sustainability criteria. [4]

The researchers in the HåSa project, together with actors in the construction and real estate sector, have identified and developed knowledge about areas with development potential in Sustainable Building and Planning. Several regional construction real estate companies have been involved in shaping the project. The project has focused in particular how to develop and maintain sustainability factors with regard to initially set goals and actual outcomes through the implementation phase of the construction process. [4]

Storsjö Strand is an area in the town Östersund where the municipality, in collaboration with private real estate companies, intends to establish a unique and sustainable district. The Mid Sweden University researchers have been involved in the process in an early stage through a network with the aim to strengthen education, research and strategic development of the construction sector in the region. The Storsjö Strand project had good intentions regarding the various sustainability criteria in the initial phases and was therefore an interesting project to follow as a case study. At the same time, the competence possessed by Mid Sweden University researchers could be participating when these intentions were put into practice during the implementation phase. [4]

In order to illustrate this under different conditions, supplementary studies have been carried out by following other construction projects in the region. Important cooperation partners have been Sveriges Byggindustrier (the national organization for Construction Industries in Sweden), NCC, Skanska, Peab, INAB, Ånge Municipality and its real estate company ÅFA, Sundsvall Municipality, Kramfors Municipality and Örnsköldsvik Municipality. Studies of routines and activities linked to the purpose and objectives in these companies and municipalities are included as important parts of the project. There are also many links to and collaboration with other relevant projects and actors. In addition to follow-up research, the researchers have contributed to sustainability and life cycle analyzes to assess how ambition levels in terms of requirements and criteria have changed during the process. This has partly been done as project work in the building engineering program at Mid Sweden University. [4]

Strategic efforts to bridge critical borderlines

In a first step, the municipality of Östersund developed a sustainability program for the area Storsjö Strand. The sustainability goals in the program were mapped and analyzed during a

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planning of construction projects with the participation of all participating actors during the process. [5]

Figure 3: Model for sustainable building production. [5]

In the framework of the sub-project, special attention has been paid to how the work environment plan can form the basis for such a process for continuous experience feedback. The process has been followed up by the researchers during parts of the design phase and the entire production phase until completion. The ÅFA project, rebuilding of elderly housing under the guidance of the real estate company ÅFA, is a clear example of how a construction project can be managed with a variant of sustainable building production with the Work Environment Plan as a governing document. Generally, a Work Environment Plan (AMP) for a construction project must be made before the construction site is established. The commissioner of the construction project (BAS-P) has to ensure that this happens. The intention is that the (AMP) shall be used to control the work environment planning during the construction phase. The contractor (BAS-U) has to make sure that it is available at the joint workplace as soon as the construction site is established. He must also make the necessary adjustments to the plan. [4]

What is special about the ÅFA project regarding integrated work environment planning is that a work environment a plan was established at an early stage before any other planning was carried out in the production process. Initially, the work environment plan was firmly rooted in the intentions of the commissioner and the projector (BAS-P) had regular participation during construction meetings. The real estate company built under its own management, in the form of a general contractor where the developer served as both commissioner and general contractor with a consulting company (BAS-P) as projector. With this, the developer had complete control over the design and production process. Construction meetings were a legally binding arena for production control and at the same time a forum for production planning in which all involved actors have been invited to participate; for example, the commissioner (general contractor), the subcontractors, the projector as well as the user and his

process including Mid Sweden University, developers and different stakeholders from the municipality. This process was meant to assure that the intentions behind these goals were also transferred across the critical borderline between the municipality as commissioner of the building project and the developers. In order to meet the municipality's high ambition regarding sustainable urban construction for the area, a design program for the entire area and an ecological sustainability program for stage 1 was developed. The Sustainability Program describes how the work from idea stage to management must be carried out in order to achieve the sustainability requirements and be the central governing document for all planning and all sustainability perspectives on Storsjö Strand. In the evaluation of how Östersund Municipality's sustainability program has fallen out for the first two houses on Storsjö Strand, the relevant actors at the municipality of Östersund were interviewed (Rudeklint & Olsson, 2017 cited in [4]). An evaluation was carried out of the sustainability program, as well as a life cycle analysis for two of the neighborhoods in the Storsjö Strand area, block C / house C and block B / house B.
The level of requirements for sustainability work has been set on the basis that the project must comply with the national, regional and Östersund municipality's environmental objectives. [4]

The analysis shows that block B has the most goals that are fully met (approx. 30%), which means that almost a third of the requirements in the sustainability program are fully met. However, 21% of the targets are not met at all. Block C has more than 25% of the goals from the sustainability program fully met and just over 30% partially met. Block C has a smaller proportion of sustainability goals that are not met at all than Block B (11.6%), but since the proportion of unanswered questions is greater for Block C than for Block B. For Block C, 74.4% of the goals are met, to a large or partial extent, while for block B, 62.8% of the goals are fully, partially or partially met.

The studies of sustainability programs and the life cycle analyzes show that what is really realistic and feasible could be improved in future stages. Persons with practical building technical knowledge should be involved early in the process. Previous research by Mikaelsson and Larsson [5] shows that such integrated planning creates a more cost-effective construction process with less conflicts later in the process as it provides the conditions for not having to do alteration and add-on work during the project. The sustainability program has nevertheless permeated the whole process. The actors have been aware of the content of the documents and have worked to meet the goals as far as possible. Although the client did not have the means to control the sustainability parameters during the process, the goals were nevertheless met fairly well. With revised and more measurable goals, the sustainability program can be further improved to future stages of the Storsjö Strand area. In order for sustainability programs to be fully implemented and the original intentions maintained, the construction contractors should be involved at an early stage in the project, in order to increase their own competence but also to contribute knowledge. [4]

Knowledge and experience feedback from the implementation phase to the programming and planning phase

Supplementary studies of some other construction processes have been followed as comparative examples and in order to further develop and test the model "Sustainable Building Production" (see Figure 3) [5] which was formulated in the Structural Fund project "Sustainable Development Processes" and is based on many years of research on integrated

dialogue takes place between the planning team and work teams for continuous reconciliation and current planning. In this way, the socio-technical system can be managed despite the construction process is changing and new actors and working groups come at the same time as others are wound up and leave the project. [4] [5]

Regarding other sustainability criteria, there are already procedures for quality, environmental and work environment management (KMA) in the construction process. These routines can be integrated in the process.

It is important that there are user-friendly tools for everyone involved in a construction project. It should promote flexibility for employees in order to adapt their own work to ongoing planning.

Results and conclusions

Taken together, our study shows that the communication and information problems that arise between the programming and design stages and the production phase can be solved with the help of integrated planning and better continuity of the construction process. This can be bridged by having exponents of the original visions participate in all stages of the process from the early idea and program stage to the finished building. The Swedish Work Environment Plan is a statutory planning instrument for a construction project in Sweden and can be used as a starting point for planning in accordance with the model of Sustainable Building Production in Figure 3 [5]. According to the model, more focus is needed on organizational and social work environment and leadership that promotes flexibility for the employees in order to adapt their own work to ongoing planning.

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