



Case Report

Sustainable Built Environment in Mid Sweden: Case study based models for sustainable building and construction processes

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Abstract: A large proportion of the earth's resource turnover is caused by building and construction activities. There are also many health and safety problems related to the built environment. All these effects are contained in the concept of sustainability. In order to reduce the impact of the built environment it is important to plan for higher ecological, social, economic and cultural sustainability in all stages of the building and construction planning process. A problem is that these processes are complex with many actors involved in different stages. The complexity can be handled with an integrated planning model that is based on continuous dialogue during the process between the actors involved. Case studies of construction projects show that such models for continuous experience feedback can work in practice. The purpose of this paper is to study and analyze sustainable construction processes with regard to clear goal formulation and continuous follow-up of the sustainability parameters. It is also to develop a general model for managing sustainable construction and housing processes regarding ecological, economic, social and cultural dimensions. The model is the result of action research-oriented case studies carried out within the framework of the EU-project *Sustainable Built Environment in Mid Sweden* (SBEMS).

Keywords: sustainable built environment, sustainable building, construction processes, health and safety, leadership, work environment.

1. Introduction

1.1. Background

This article is based on the results presented in the final report for the EU project *Sustainable Built Environment in Mid Sweden* (SBEMS) [1] that was implemented 2016–2019. That goes especially for the parts of the report for which the authors of this article are responsible.

Mid Sweden is a collective name for the two regions, Västernorrland and Jämtland / Härjedalen, which are geographically located in the middle of Sweden. The area makes up just over fifteen percent of Sweden's area but is relatively sparsely populated with four percent of the country's inhabitants. The areal nutrients, especially forestry, still dominate, which characterizes the built environment. The Mid Sweden area was the leading region in Sweden and Europe in the early forest industry development at the end of the 19th century. A large proportion of the area still consists of forests and the forest industry is still a very important industry in the two regions. The buildings are concentrated in lanes along rivers, lakes and the Baltic Sea. The two largest cities are Sundsvall on the Baltic Sea coast and Östersund in the inland by the big lake Storsjön near the mountains. These two cities also constitute campus locations for Mid Sweden University.

Regarding the building culture in Mid Sweden, it is considered to be representative of Sweden as a whole and in many respects also representative from an international perspective. The three largest Swedish construction companies, Skanska, NCC and Peab, which have participated in the project, are also active in the international arena and apply largely the same concept and organizational principles in Sweden as internationally. Possibly it can be argued that the requirements for sustainability are particularly high in Sweden in comparison with other countries. This applies in particular to the work environment as Swedish work environment legislation places particularly high demands on health and safety and systematic work environment processes.

The SBEMS project was founded on the regional development strategies for the two regions Jämtland / Härjedalen and Västernorrland. These strategies emphasize the need for smart sustainable growth and that economic, ecological and social development should form the basis for the development of an attractive and sustainable built environment with regard to health and well-being in Mid Sweden. In order to build collaboration around these issues that are so important for the regions related to smart sustainable growth, the researchers at Mid Sweden University in the SBEMS project together with actors in the construction and real estate sector have identified and developed knowledge concerning issues with development potential and interconnection. Several municipalities and municipal real estate companies in the two regions have participated in the work of shaping and implementing the project. That also goes for companies in the construction and real estate sector.

1.2. Model for four sustainability dimensions

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 Persson (2009) and Sutton (2020) has thoroughly analyzed and explained how sustainability can be defined [2–4]. When it comes to ecological as well as social sustainability, experience shows that it is often difficult to implement the initial ambitions in construction projects. This is due to lack

of competence but also because sustainability criteria 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 develop a model for sustainable building and planning through action research by including economic, ecological, social and cultural sustainability. Health and well-being are very important aspects of sustainable built environment. Special mention can be made here of the indoor environment where people spend over eighty percent of their time, and the work environment both during the construction process itself and in the work environments that are created in the built environment.

Compared with economic and ecological sustainability, social and cultural sustainability are relatively new phenomena in the construction and real estate sector. Admittedly, architecture, various functions and services in the local environment can be regarded as examples of social sustainability. Cultural sustainability means, among other things, learning from and relating to the traditional building culture with regard to construction and housing.

Figure 1 illustrates the model for four dimensions of sustainability. The dimensions should not be regarded in isolation from each other but as overlapping and interdependent.

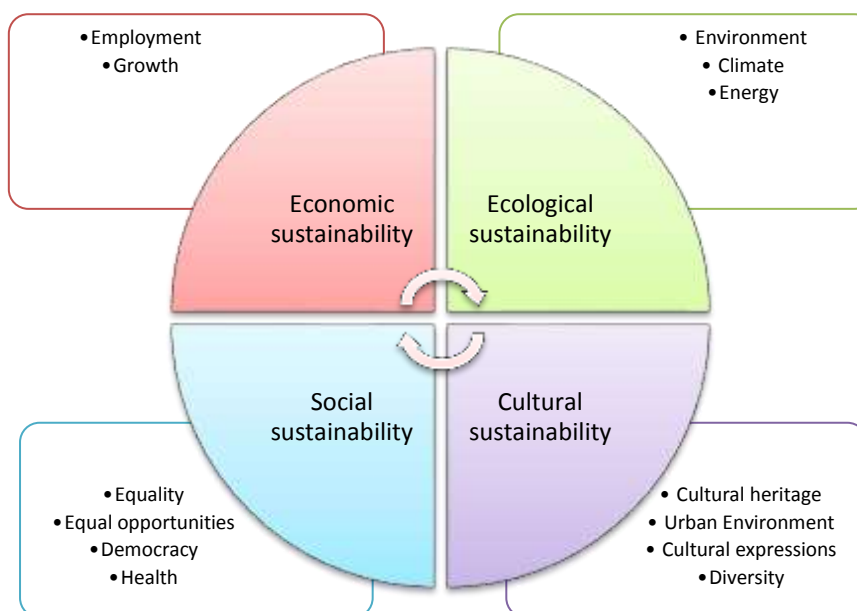


Figure 1. Model for four sustainability dimensions [1].

1.3. Model for sustainable building production

Work organization in the Swedish construction industry gives traditionally relatively good opportunities for workers to plan their own work. The self-governed team organization that is typical of the building industry is an example of an organic organizational model (Burns & Stalker, 1994; Mikaelsson, 1989), which has deep roots [5,6]. There are many experiences to get from that traditional model when forming a modern work organization with high degree of participation.

In the Swedish industry and the public sector, as consequence of the Codetermination Act, there has been developed forms of organization with a high degree of employee participation. The positive

results achieved are improved safety, greater satisfaction and low absenteeism and high productivity [6,7].

In the years 1985–1988 the project “Integrated planning” was carried out by Lund University in cooperation with the building industry and the trade unions [8].

Integrated planning is based directly on the traditional organic team organization which traditionally have formed the work organization in the Swedish building and construction industry. However, this is not a sufficient condition for workers' experiences and views to be included in the planning. To enable this, the team organization must be integrated with the mechanistic construction project management organization [5,6].



Figure 2. Model for Sustainable Building Production (SBP) [9].

According to Mikaelsson & Larsson (2016), the IP model can be refined towards a Sustainable Building Production model (SBP). The refined model emphasizes developing understanding of four critical factors: strengthening *leadership* (especially healthy and effective, relation-oriented behaviors); increasing the focus on *health and safety (work environment)*, especially worker self-estimates of health; basing a subjective quality perspective around modern *quality* management; and continually analyzing the impact of an organization upon its surrounding physical *environment* [9].

The starting point is the work environment on the construction site and how this can be improved with better production planning, work organization and leadership. The construction process is considered here in terms of sustainability with the aim to study how efficient construction with high quality can be combined with a good environment, health and safety. Important conditions to achieve this is a dialogue between the actors in the construction process in its various stages. The developer's wishes and expectations must be clearly spelled out in the program, drawings and descriptions as an adequate basis for the production. The schedule must be adapted to the available resources. This creates

the conditions for a rational production with good work environment. The factors included in a sustainable building production model are usually being handled and integrated in Swedish building and construction companies in a concept called KMA (Kvalitets-, Miljö-, och Arbetsmiljöstyrning; *Quality-, Environment-, and Work environment management*) [9].

The aim of the SBEMS project was to study how sustainability factors can be implemented, developed and maintained with regard to initially set goals and actual outcome. Construction projects can generally be described as relatively linear processes where different actors act in different phases. The information about what is to be built must be transferred from one player to another over a limited period of time. These occasions where the information is transmitted can be termed critical borderlines.

Construction processes are in fact very complex with many actors involved in different stages and this involves many critical borderlines where several and in some cases all actors are replaced. Important critical borderlines are from program to design then further to production when architects and designers hand over documents to building and construction companies and further to subcontractors who will carry out what the designers have described. Here, many good intentions and high ambitions when it comes to sustainability from the early program work risk being changed or lost. This can be bridged over by the bearers of the original visions participating in all stages of the process from the early idea and program stage to the finished building. To make this possible, the contractual legal aspects of the process must be taken into account. Communication and appropriate information systems are consistently critical factors. Errors and mistakes in the workplace can often be attributed to shortcomings in the information transfer. This applies to all levels according to Jonasson et.al. (2020) [10].

Sustainability adds even more complexity to a project, not least because the meaning of the word sustainability varies between different actors. New construction techniques or materials may be needed, as well as special expertise from other areas. When different actors negotiate with the goal of concluding an agreement, the ideal outcome is that the result is beneficial to all parties, even if the parties have partly conflicting interests. The result of a negotiation is usually a compromise, but even in projects that have a pronounced focus on sustainability. According to Svane et.al. (2011) the negotiations often lead to the environment getting the worst “deal” in favor of production economic factors [11]. It is therefore common that ambition levels of sustainability change between critical borderlines throughout the process so that initially high demands on sustainability are being changed in favor of traditional less sustainable solutions.

In the borderline between two stages in the construction process, the socio-technical system might be completely changed with communication and information problems as a result. This often happens between the program- and the production stage.

1.4. Purpose

The purpose of the SBEMS project was to actively and in collaboration with construction and real estate companies, users / residents and public organizations contribute to sustainable built environment in Mid Sweden by combining high demands on sustainability with efficient construction processes and collaboration between actors in the various stages of these processes. A specific purpose

was to develop a general model for sustainable built environment based on ecological, economic, social and cultural dimensions [1].

2. Methods

An action-oriented research approach has formed the basis for the entire project, where researchers and practitioners have collaborated within the framework of everyday activities. The researchers have contributed with scientifically based knowledge and expertise on issues of economic, ecological, social and cultural sustainability. The principle test-feedback-development creates open systems for knowledge production in collaboration with practitioners, which provides conditions for robust knowledge. Collaboration between different actors in the business community is often a prerequisite for innovative solutions, but equally important for this project is that municipalities and municipal real estate companies have been involved in the planning and implementation of the project. This applies to Sundsvall municipality (and the real estate company Mitthem), Östersund municipality (and the real estate company Östersundshem) and Ånge municipality (and the real estate company ÅFA). Via the industry council for Sustainable Construction at Mid Sweden University, there has been an established collaboration platform between the university and the construction industry and the municipalities for many years. This industry council has been the reference group for the project. The research has to a large extent been linked to case studies of a number of building and construction projects with the ambition of covering different stages of relevant construction and housing processes [1].

As the Storsjö Strand project had high ambitions regarding sustainability in the initial phases it was a particularly interesting project for a case study in order to study goal fulfillment from program to production [1].

Supplementary studies of other construction projects have been carried out in order to study the implementation process. Special mention can be made here of the project Grönt Boende (detached single-family house in Sundsvall), the Hallstaborg project (rebuilding of a retirement home in Ånge municipality) and Remonthagen (rental housing in Östersund). Studies of sustainability processes have also been carried out in collaboration with the large national construction companies, NCC, Skanska, Peab and some smaller local construction companies. Studies of routines and activities related to the project's purpose and goals in these companies are included as an important part of the research project. The methods has been interviews with key actors, participation in planning meetings, study visits with own observations and studies of planning documents and other written documents. The research questions have been focused on communication and information problems that arise between the program and design phase and from design to the production phase and how these problems can be addressed with the help of integrated planning and better continuity in the construction process. The overall question is how the original visions of sustainability are processed through all stages from the early idea and program stage to the finished building [1].

3. Results

3.1. Bridging critical borderlines from program- to production stage

The critical borderline between program- and production stage has been studied in the case Storsjö Strand, a housing project in the center of Östersund by the big lake Storsjön. The goal for the area is to be an attractive and accessible addition to the city center with the following plans in terms of sustainability for the district formulated by the planning office: “The district will be supplied by renewable energy sources and show the way to future climate-smart buildings where a life cycle perspective is in focus” [12].

In the evaluation of how Östersund municipality's sustainability program turned out for the first stage of the Storsjö Strand project, the affected developers and administrators at Östersund municipality were interviewed. Initially, it was investigated how the sustainability program and the sustainability goals, and even the intentions behind these programs and goals were transferred across the critical borderline between developer and contractors. In order to meet the municipality's high ambitions regarding sustainability for the area, a design program for the entire area and an ecological sustainability program for the first stage were prepared. The design program was a common guideline for the municipality and the developers regarding design, construction, production and facility management of the buildings within the new district. The sustainability program describes how the work from the idea stage to facility management should be in order to fulfill sustainability requirements [12].

The studies of sustainability programs and life cycle analyzes showed that actors with practical building technical knowledge should have been involved early in the process. Experience from other project shows that such integrated planning creates not only higher sustainability but also a more cost-effective construction process with less conflicts and less problems later in the process as it provides conditions for not having to make changes and additional work during the project. The sustainability program has nevertheless permeated the entire process. The builders have been aware of the content of the documents and worked to meet the goals as much as possible. With revised and measurable goals, the sustainability program could be improved for future stages of the Storsjö Strand area. In order for sustainability programs to be fully implemented and the original intentions to be 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 [12].

In the master plan of Sundsvall and in the sustainable one the growth strategy highlights the need for attractive and varied accommodation with sustainable technical systems. Because of it - and an idea from architect Anders Nyquist to build villas in Sundsvall with the best available environmental technology - Sundsvall municipality created the project *Green living* (Grönt boende) in the years 2014–2016 [13].

To find families who wanted to build a new house in an environmentally friendly way the municipality, together with Mid Sweden University, created a series of seminars held during the period February-May 2015. It contained five seminars construction technology, construction economics, the construction process and sustainable lifestyle. The purpose of the seminar series was to give families knowledge in planning and carry out the construction process on a sustainable way. The evaluation

showed that the families increased their knowledge using the seminar series. Based on the seminar series, the families received information, inspiration, ideas and new knowledge to build their houses. The families had deepened their current knowledge through materials provided by the project and by themselves actively sought additional information online. With the received knowledge the four families created their own environmental program and described in which way they wanted to build their house [14].

3.2. Sustainable building production

As a complementary study two construction processes have been followed in order to further develop and test the model *Sustainable building production* (SBP) according to figure 2. [9].

A special study has analyzed how the work environment plan can form the basis for such a process. The processes were followed up by the researchers through parts of the design phase and the entire production phase until completion.

One case study was the Hallstaborg project, a rebuilding of an elderly care center in Ånge municipality. The commissioner was the municipality facility company (ÅFA) which is also was the building contractor. The starting point for the project was the work environment plan. It was set up by the architect in dialog with the site manager and the safety delegate. The site manager, who also was the work environment coordinator, set up lay out plan, time schedule and the other production plans with regards to the work environment plan. The current planning process during the construction phase was coordinated by the site manager in dialog with the safety delegate and by regular planning meeting once a month with all subcontractors and working teams. The planning meetings was an arena for current steering and coordination of the building process and building production. The planning process was carried through from a holistic perspective with integrated work environment-, quality-, environment management which requires a transformative leadership [9,15].

The Hallstaborg project in Ånge municipality is a good example of a rebuilding project implemented with a variant of sustainable building production with the work environment plan as the governing document. A work environment plan (AMP) for the entire construction process must be drawn up for each construction project in accordance with Swedish work environment legislation. In the Hallstaborg project AMP was used as a governing document for planning according to the SBP model. That illustrates that AMP is not only a statutory planning instrument for a building and construction projects. It can also be the starting point for SBP [9,15].

Another example is the Remonthagen project in Östersund. It was the building of seven multistore houses just outside the center of Östersund with Skanska as the main contractor.

Skanska has a general policy for work environment with a high-profile concerning health and safety. In the Remonthagen project there was a special focus on work preparations, a joint detail planning for building components or elements, in order to reduce incidents and accidents. The supervisor together with the workers made the planning that took advantage of the employees' skills and that made decisions firmly established in the whole group. Work preparations had the starting point in health, safety and work environment and it also provided an open and good working climate. Also, quality and other sustainability factors were regarded in the process [16].

At the Remonthagen project the aim was to surpass the general work environment policy for Skanska and the project have got an internal price for the best work environment in the region. The motivation was the active cooperation with all employers and work teams and the efforts for high degree of participation and awareness in the systematic work environment realization. Some success factors that were specially important were regular planning meetings for all employers with strong work environment focus where quality-, environmental-, and other important production matters were integrated [16].

The starting point for the planning process was the work environment plan according to the provisions [17,18]. The current systematic work environment realization at the site followed the descriptive diagram for systematic work environment management, and the production planning followed the principles of integrated planning (Figure 2) [16].

In both mentioned cases the planning process started with the work environment plan according to the provisions [15–20]. The current planning process to a certain extent follows the principles of integrated planning according to the SBP model (Figure 2) [10,15–20]. The two case studies in practice illustrate a concept for Integrated Work Environment Planning (IWEP). The results indicate that the work environment plan according to the provisions can be the starting point for implementing the concept SBP [15–20].

Studies of Skanska, Peab, NCC and other construction companies show that SBP is a model for continuous feedback of experience that can be rather easily implemented and function in practice. It is thus possible to implement SBP at an early stage with the help of the AMP. SBP is also a concept for coordination and communication of activities in a construction project. It is an informal model that can be applied more or less in all forms of procurement (partnering, own management, shared contract, general contract and turnkey contract). All actors in the process participate by virtue of their regular roles (users, clients, planners, site managers, supervisors, team bosses, contracting engineers, subcontractors and safety representatives). It is of course up to the developer to decide if and how the model is implemented in each project. The researchers' task here has been to present a proposal for a working model and to follow the process in all its stages with an action research approach [1].

SBP means planning with a high degree of involvement of the actors involved in situations characterized by variability and high demands on sustainability. Briefly, model can be described as follows. At the center of the model is in each construction project a planning group of formal leaders and representatives of the working teams and working groups. This planning group makes a proposal for planning which is discussed and agreed upon at a start-up meeting with all concerned. Throughout the process, a dialogue takes place between the planning group and the work team for continuous reconciliation and rolling planning. The socio-technical system that changes during the process can be handled in this way despite the fact that new actors and working groups are introduced while others leave the project. That means that the critical borderlines in the production stage can be bridged.

3.4. Knowledge generation and exchange of experience

This sub-project *Knowledge generation and exchange of experience* has run in parallel with other sub-projects in the SBEM project with the ambition of connecting these through dialogue seminars and sustainability summits for knowledge generation and exchange of experience in sustainable built

environment. On these occasions, researchers, primary and secondary stakeholders have participated. All stakeholders have been given access to current results and have been able to discuss these before the results are presented publicly. In addition to these special events this subproject has worked to raise debate about the areas of conflict that arise at the intersection of different sustainability dimensions and more general dissemination of information about the SBEMS project in the form of reports, articles, books, cell films and podcasts. In total, two anthologies, two reports, two articles and five podcasts has been produced. Each of the two anthologies consists of chapters written by researchers from the SBEM project, researchers from other universities and practitioners. The two articles have been presented at international scientific conferences. The five podcasts have been downloaded around 400 times each, which according to Mid Sweden University's communication department is a good number of listens compared to other similar podcasts at the university. Both researchers and practical professionals who have in some way been linked to the SBEMS project have contributed to disseminating results and information about the work that has been passed on to others. Furthermore, participants in the project have been part of the group that has built up a sustainability network at Mid Sweden University.

The purpose of the dialogue seminars in the SBEMS project was to spread knowledge from the project to a wider target group and initiate discussions about this. The seminars have also made it possible for new development projects and further development of projects that already were initiated.

The dialogue seminars have started a long-term sustainable collaboration between various citizen groups, property owners and other private actors as well as public projects and institutions. The process has contributed to the joint design of visions and goals for urban development. The participants themselves proposed activities and organized themselves into different groupings to work with the implementation. The work has been carried out between the dialogue seminars and is reported at the seminars when new goals could be launched and new groups formed. This approach has been well received and is still continuing after the end of the project period.

4. Discussion

One of the goals of the project was to develop a model for sustainable built environment based on economic, ecological, social and cultural sustainability dimensions. In reality the economic dimension tended to grow larger than the other three dimensions quite early in the surveyed construction projects in order to expand further over time at the expense of the other dimensions. The reasons for that are:

External factors such as regulation can cause problems. These factors cannot be controlled by construction and real estate companies and affect the possibilities of acting from an ideal model.

Overoptimistic calculation and initially high ambitions are often stated in order to get permission to start construction projects at all. This means that renegotiations may need to be made later in the process and that ecological, social and cultural sustainability dimensions may be downgraded.

Time pressure means that projects are forced and sustainability efforts are downgraded.

There are industry-specific obstacles and cultural traditions in the construction and real estate sector that counteract multidimensional sustainable development.

A procurement where the contractor who has submitted the lowest price gets the job, may mean that there is less room for financial flexibility. This can lead to sustainability efforts are being downgraded for financial reasons.

The research group has also identified several development areas as follows:

Incentives are needed to stimulate new thinking in the construction and real estate industry before an ideal model can be introduced.

Cooperation between municipalities, construction and real estate companies and other actors is needed to establish a holistic approach to various sustainability dimensions.

The developer competence needs to be strengthened, especially with regard to sustainability aspects but also with regard to production economics aspects.

Alternative financing solutions need to be developed.

Business economics calculations need to be supplemented with socio-economic calculations. In connection with this, the business economic time horizon needs to be more long-term.

In summary, it can be stated that in the high-ambition projects examined, one or more sustainability dimensions might collide and that the economic dimension then tends to become controlling. This could indicate that it can be difficult to develop a balanced model for sustainable building and construction processes based on economic, ecological, social and cultural dimensions. This indicates that a model for sustainable built environment based on these dimensions needs to be supplemented with methods for overcoming critical borderlines.

5. Conclusions

Although there are many obstacles to formulate a general model for sustainable built environment, the results from the project SBEMS provide indications that a combination of different initiatives and models can be fruitful. The model for four sustainability dimensions according to figure 1 can advantageously be introduced very early in the process in the form of open dialogue seminars. It can advantageously be combined with the model for sustainable building production according to figure 2 already in the idea and program phase and then move on through all stages of the project.

6. Further research and development

A pilot study is underway in collaboration between Mid Sweden University and Jamtli, a regional museum for sustainable built environment, and other actors with ambitions to develop an arena for the sustainable built environment. The project is called Jamtli Living University (JLU) and the models from the SBEMS project will be implemented and tested in full scale building projects.

Through dialogue seminars a network is established between regional and national social stakeholders; academia, business, the cultural sector and the public. The device for the project is development of built environment from past to future. The JLU network is a tool for sustainable development that combines the best from traditional construction and housing with the sustainable built environment of the future.

Conflict of interest

The authors declare no conflict of interest.

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