Management of Sustainability in Construction Works

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Abstract

The present global environmental condition is a consequence of the increasing consumption of natural resources whose depletion exceeds what is physically possible to sustain in the long term. The construction sector is a considerable contributor to this resource depletion and sustainability is adopted in the form of the theory of ecological modernization. The implementation depends to varying extents on sustainability demands at the global, national, regional, local, corporate and individual levels. In addition, there appears to be a lack of new knowledge transfer from the international research community to local construction project managers, particularly in the process of construction works in line with the objective of sustainability. According to environmental legislation, it is the client who is the responsibility party, performing activities as owner and administrator of construction works.

The aim of the research is, first, to define what sustainability in construction works is. The understanding and meaning of sustainability can vary considerably through the perspective of a client and a construction project manager, within corporate organizations and through sporadic knowledge transfer. A critical review of the use of the terminology of sustainable construction and sustainable building is carried out and a model for enabling a client to manage sustainability matters in relation to construction works and then validate this model within a defined context is established.

The construction sector is complex and fragmented and has, therefore, a tendency to resist changes leading towards sustainability. Clients and project managers are facing barriers to the implementation of sustainability, e.g. lack of pro-active sustainable measures, conflicts in real and perceived costs and inadequate implementation expertise. A common misunderstanding is that sustainability in construction works is more expensive in terms of investment costs compared to 'normal' mainstream buildings. It is critical to transfer knowledge from the research community to mainstream practitioners efficiently to help facilitate the implementation of corporate sustainability without delay or confusion of methodology.

By adopting the standard ISO 15392: “Sustainability in building construction – General principles”, it is possible to interpret sustainability for construction works accordingly, despite the different backgrounds of stakeholders. Therefore, different and confusing interpretations of sustainable building, sustainable construction or green building can be avoided.

To meet the holistic conditions of sustainability according to the standard above, it is crucial to implement a platform of multiple corporate management systems such as those focused on quality-, environment-, work safety-, stakeholders-, and knowledge into an integrated system of sustainability. By utilizing the STEPS (Start-up, Take-off, Expansion, Progressive, Sustainability) maturity roadmap, it is possible to achieve continual improvement in knowledge management in a ‘many-small-steps’ approach on the corporate level. It is also crucial to transfer knowledge horizontally, to formulate a sustainability policy regarding sustainability, to translate corporate activities into adequate key figures/ indicators in order to fulfil the commitment of continual improvement, and meet the community′s sustainability objectives. This information should be placed within the property instead of being held by the owner. A framework of assessment is necessary, objective-led, taking into account site-specific, corporate-specific and service-life issues.

The STURE (Stakeholder-Urban Evaluation) model is a product of the research and represents an approach that optimizes the sustainability demands and abilities of a client, stakeholders and authorities relevant to a single or multiple construction works. Five cases of construction works were used as input to validate the STURE model in line with the principles of the ISO 15932 standard. The cases studies were drawn from different phases in the life-cycle of construction works and in different stages of construction process. Furthermore, the cases represented buildings with different functions. The result of the validation implies the possibility to use the STURE model with some minor adjustments, to assess construction work or works in order to determine whether or not it is heading towards a sustainable, a partly sustainable or non-sustainable development.

The proposed STURE model connects to the STEPS maturity roadmap on the corporate level and the combinations of ISO standards are a way of structuring stakeholder demands or outcomes of expectancy with regard to sustainability objectives, optimized from national, regional, local and corporate levels together with technical and functional demands. Use of these methods also promotes continual improvement in project performance and basic organizational activities. This is, as noted earlier, a ‘many-small-steps’ approach and depends on the client’s ability, level of knowledge and inclination. The aim is not to be a world leader, but rather to recognize that improvement comes through successive small steps and, thus, creates a means for measuring improvement along the path of sustainability in the field of construction works.

Progress towards sustainability in construction works is rather slow, in spite of the short timescale before potential irreversible damage occurs from climate change. In the long run it is not enough to sustain on the level of present environmental depletion; it has to be a regenerative development. By these means, it is time for action by transferring current and new knowledge from the research community into an adaptive and practical framework for implementation. This knowledge must be complete with clearly defined economic incentives, and the gap between researchers and practitioners must be bridged with arguments of economic value. It is also important to bridge the gap of knowledge transfer in both directions between industrialized and developing countries, as local decisions and solutions affecting the built environment have both local and global impact. Last, it is the client/owner/developer, as the responsible performer of activities concerning construction works, who has the main responsibility concerning construction works and the obligation to commit sustainability. At the same time, there is an opportunity and a challenge to make the built environment more sustainable and begin regenerative development in the earnest.

Sammanfattning

Tillståndet på vår globala miljö är en konsekvens av den ökande konsumtionen av befintliga resurser vars förbrukning överstiger det som är fysiskt möjligt att bibehålla på lång sikt. Byggsektorn har en betydande andel till denna resursförbrukning och har därför anammat hållbarhetsbegreppet utifrån teorin om ekologisk modernisering. Införlivandet beror på varierande omfattning av hållbarhetsvillkor utifrån global-, nationell-, regional-, lokal-, bolags- och individuell nivå. Det verkar dock saknas ny kunskapsöverföring från internationell forskningsmiljö till lokala byggprojektledare, speciellt gällande den process av fastighetsföretagandet som har hållbarhet som målsättning. I enlighet med miljölagstiftning, är det byggherren som är den ansvarige parten, genom utövandet av verksamheten som ägare och förvaltare av fastigheter.

Syftet med denna forskning är, för det första, att definiera hållbarhetsbegreppet för fastighetsföretagande är. Förståelsen och betydelsen av hållbarhetsbegreppet kan variera betydligt utifrån ett byggherre- och byggprojektledarperspektiv, inom företagsorganisationer och vid sporadisk kunskapsöverföring. En kritisk granskning av begreppen hållbart byggande och hållbar byggnad har genomförts och en modell för att möjliggöra för en byggherre att styra hållbarhetsfrågor i förhållande till fastighetsföretagandet har upprättats samt validerats i ett väldefinierat sammanhang.

Byggsektorn är till sin natur komplex och fragmenterad och har därför en tendens att motstå förändringar som leder till ökad hållbarhet. Byggherrar och projektledare sätter upp murar när det gäller införande av hållbarhet, t.ex. saknad av förslag för hållbara åtgärder, konflikt mellan verkliga och förväntade kostnader och bristfällig tillgänglig expertis. En vanlig missuppfattning är att hållbara åtgärder i fastighetsföretagande är dyrare i investeringskostnad gentemot traditionellt förfarande. Det är angeläget att överföra kunskap från forskarhåll till vanliga utförare effektivt och att främja införandet av företagshållbarhet utan dröjsmål och förvirrande metodik.

Genom att införliva standarden ISO 15392: "Sustainability in building construction – General principles", är det möjligt att tolka hållbarhet i fastighetsföretagandet samstämmigt, trots olika bakgrund för olika intressenter. Följaktligen borde olika och förvirrande tolkningar av begreppen hållbar byggnad, hållbart byggande eller grön byggnad kunna undvikas.

För att möta denna standards holistiska villkor, så är det mycket viktigt att tillämpa ett ramverk av företagsinriktade ledningssystem inom kvalitet-, miljö-, arbetsmiljö-, intressent- och kunskapsledning till ett integrerat ledningssystem i hållbarhet. Användandet av STEPS (Start-up, Take-off, Expansion, Progressive, Sustainability) mognadsvägledning gör det möjligt att uppnå ständig förbättring gällande kunskapsöverföring genom ett på företagsnivå "många små steg" förfarande. Det är också mycket viktigt att överföra kunskap horisontellt, att formulera en hållbarhetspolicy på företagsnivå, att översätta företagets verksamhet till adekvata nyckeltal/indikatorer för att infria sitt åtagande om ständig förbättring och möta samhällets målsättning om hållbarhet. Denna information bör knytas till själva fastigheten istället för till byggherren. Ett ramverk för bedömning är nödvändigt, målstyrt, med hänsynstagande till plats-, företags- och underhållsberoende frågor.

STURE (Stakeholder-Urban Evaluation) modellen är ett resultat av forskningen och representerar ett tillvägagångssätt som optimerar hållbarhetsvillkor och förmåga hos en byggherre, intressenter och myndigheter relevant för en enskild fastighet eller för fastighetsföretagande verksamhet. Fem fallstudier från fastighetsföretagandet användes som indata för att validera STURE modellen med villkoren i ISO 15932. Fallstudierna var tagna från olika skeden från fastigheters livscykel och från olika etapper i byggprocessen. Fallstudierna representerade även byggnader med olika slutfunktioner. Resultatet från valideringen innebär att det finns en möjlighet att använda STURE modellen, med smärre förändringar, att bedöma om ett byggnadsverk eller en fastighetsföretagande verksamhet kan anses gå mot en hållbar, delvis hållbar, eller ohållbar utveckling.

Den föreslagna STURE modellen anknyter till STEPS mognadsvägledning på företagsnivå samt med kombinationen av ISO-standarder är det ett sätt att strukturera intressenters villkor eller förväntningar när det gäller hållbara målsättningar som är optimerade utifrån nationell-, regional-, lokal- och företagsnivå tillsammans med tekniska och funktionella villkor. Att använda dessa metoder främjar även ständig förbättring i projektsammanhang samt i organisationers basverksamhet. Men detta är, som framhållits tidigare, en "många små steg" tillämpning baserat på byggherrens förmåga, kunskapsnivå och benägenhet. Syftet är inte att bli världsledande, utan snarare att inse att förbättringar uppnås genom successiva små steg och, följaktligen får förmåga att mäta förbättringar längs vägen till hållbarhet för fastighetsföretagande.

Framsteg gällande hållbarhet för fastighetsföretagande verksamhet utvecklas ganska långsamt trots den korta tidsaspekten innan enorma skador inträffar p.g.a. klimatförändringen. På lång sikt är det inte tillräckligt att försöka bibehålla den nuvarande nivån på miljöpåverkan, det måste bli en regenerativ utveckling. Det är verkligen på tiden att agera för att föra över befintlig och ny kunskap från forskningssamhället till ett tillämpat och praktiskt ramverk för genomförande. Denna kunskapsöverföring måste vara komplett med tydligt definierade ekonomiska incitament och gapet mellan forskare och praktiker måste överbryggas med argument innehållande ekonomiska värderingar. Det är också väldigt viktigt att överbrygga gapet av kunskapsöverföring i båda riktningar mellan industrialiserade länder och utvecklingsländer, eftersom lokala beslut och lösningar rörande den byggda smiljön har både lokal och global påverkan. Slutligen är det byggherren/fastighetsägaren/fastighetsutvecklaren, som den ansvarige utövaren av fastighetsföretagande verksamhet, har huvudansvaret när det gäller skyldigheten att åta sig hållbart fastighetsföretagande. På samma gång är detta också en möjlighet och utmaning att göra den byggda miljön mer hållbar och börja med en regenerativ utveckling på allvar.

Acknowledgement

At last, after a long journey, this work has come to the very end. It began for more than fifteen years ago when I got the opportunity to begin to research in environmental management in construction works by the Mid Sweden University. But, because of lack of financiers and some other opportunities that occurred, my family and I did move to the south of Sweden and I began once again to work commercially as a consultant on a consultant company. This time with barely solely assignments regarding environmentally, and later on, also sustainability issues of construction works. The time went by and after a couple of years I began with my own business of consulting. During this period I also began to teach sporadically for the department of Construction Management at Lund University. This led, with some help from a business client, to a completed licentiate thesis in 2001, a half-time PhD. I then thought that my research effort was enough and I continued with my business. In the late 2005 I was asked for a half-time assignment at the department of Construction Management for teaching. This half-time was soon turned to full-time and about two years ago I got the opportunity to continue the research work.

This document is the final contribution and verification of the work I have done and I am proud to present the people that have been a part to and/or support of it. First of all, I would thank the division of Construction Management for supporting the time I have spent without being productive with teaching. Another stakeholder of finance was a real estate company which has closed down by a shift in ownership. I am very grateful for those contributions.

At the division of Construction Management, people have been very supporting and I thank them all, Bengt, Mats, Stefan, Kalle, Christina, Sofia, Martin and no name forgotten. But I would especially thank Radhlina, who had scrutinized a couple of times all the written pieces, both the written English, thesis structure and the content and always suggested (a lot of) improvements. Brian, who have been forced to read foreign (Sw)English, but still have been able to suggest as well minor as major alterations in content, structure and language. And, of course, Anne, who supported, supervised and coached all the way “into the tile” as a former Swedish national football coach said.

Of course, I am also thanking my family, Gerd, Simon and Olivia, for all the support and questioning “really, what are you doing anyway”? And finally, a warm acknowledgment to our two fur coated barking creatures, who always, with absolute happiness, not hesitated to invite me to unplanned brakes...

The greenhouse, late September 2009

Urban Persson
(Born in a sparsely populated area in the North, but now urbanized to Lund in the south of Sweden)

Table of content

0 Definitions and terms

A selection of key definitions presented in the text is shown in Table 0.1. A majority of the definitions are based on ISO standards, but a few are based on literature reviews.

Table 0.1 Key definitions.

Term	**Definition**	**Reference(s)**
Aspect	Aspect of construction works, part of works, processes or services related to their life cycle that can cause a change, especially with respect to economic, environmental and social (quality of life) matters	ISO 15392: 2008
Significant aspect	An aspect that has or can have an important impact	ISO 14001:2004
Construction work	Activities in forming construction works	ISO 15392: 2008

Term	Definition	Reference(s)
Construction works	Everything that is constructed or results from construction operations	ISO 15392: 2008
Building construction works	Construction works to provide shelter to occupants and/or their property as one of its main purposes; usually partially or totally enclosed and designed to stand permanently in one place	ISO 15392: 2008
Continual improvement	Encompasses the improvement of all aspects of sustainability related to the built environment including the buildings and other construction works over time. It also includes the performance of construction works as well as processes, and addresses means of assessment, verification, monitoring and communication	ISO 15392: 2008
Decoupling	Cutting the link between economic growth and environmental degradation	Naess (2006)

Term	Definition	Reference(s)
Dematerialization	A (more or less strong) contribution to decoupling of economic growth from resource consumption and negative environmental impacts through increased eco-efficiency and/or substitution	Naess (2006)
Eco-efficiency	The production of commodities of unchanged or better quality while reducing the resource consumption and negative environmental impacts associated with the production and products	Naess (2006)
Environment	Surroundings, within and to the global system, in which an organization operates including air, water, land, natural resources, flora, fauna, humans, and their interrelations	ISO 14001: 2004
Impact	Any change that may be adverse or beneficial	ISO 15392: 2008
Indicator	Quantitative, qualitative or descriptive measures	ISO/TS 21929-1: 2006

Term	**Definition**	**Reference(s)**
Life-cycle	Consecutive and interlinked stages of the object of consideration	ISO 15392: 2008
Performance	Ability to fulfil required functions under intended use conditions or behaviour in use	ISO 15392: 2008
Precautionary principle	Where there are threats of serious or irreversible damages, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation	Rio Summit (1992)
Stakeholder	Individuals and organizations who are actively involved in e.g. a project, or whose interests may be affected by the execution. A stakeholder could be any individual or group with the power to be a threat or a benefit to the project. Internal stakeholders are those who actively are involved or provide finance and external stakeholders are those who are affected significantly.	Gibson (2000); Winch and Bonke (2002); Olander (2006)

Term	Definition	Reference(s)
Substitution	Change in the pattern of consumption from environmental harmful to less environmental harmful forms of consumption	Naess (2006)
Sustainability	State in which components of the ecosystem and their functions are maintained for the present and future generations	ISO 15392: 2008
Sustainable development	Development which meets the needs of the present without compromising the ability of future generations to meet their own needs	Brundtland Report (1987)
Triple bottom-line	Interpretations of sustainability which involve issues of balancing economy and social development with ecological considerations	Pope et al. (2004); O'Connor (2006); Hacking and Guthrie (2008)

1 Introduction

The present global environmental condition is a consequence of the increasing consumption of natural resources whose depletion exceeds what is physically possible to sustain in the long term. The effects are resulting in degradation of eco-systems and conditions for human life. The future assumed (or presumed) growth of this consumption is, more likely than not, going to increase this impact. An example is the evidence of a more rapidly increasing content of carbon dioxide in the atmosphere than expected just a few years ago (Raupach et al, 2007). A major threat today is a consequence of this pressure, namely climate change which leads to serious consequences for present day living conditions that are more or less taken for granted (IPCC, 2007; Rummukainen and Källén, 2009). This situation is especially disturbing for densely populated coastal urban regions from a rise in sea level, and for other regions as a result of flooding, heavy rainfall, drought, fresh water shortage, increased extreme events, higher average temperatures and severe economic, social and health impacts (Roper, 2008). The situation is already at the tipping point for these consequences and there is a very limited timeframe in which to act to minimize huge negative impacts to our living conditions (Rees, 2008; Rummukainen and Källén, 2009).

The concept of sustainable development originated in the early 1980s and set guidance measures for the correction of market failures, ensuring regenerative capacity of renewable resources, avoidance of cumulative pollutions, steering product processes towards greater eco-efficiency including the substitution of renewable resources and a precautionary approach to development (Turner, 2006). The term sustainable development itself has many interpretations (Barrow, 1997; Lutzkendorf and Lorenz, 2005). The most common and famous definition is defined by the Brundtland Report (1987, p. 24) as:

“Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs”.

In the Rio Summit in 1992, a more in-depth formulation of sustainable development was drawn up with the global programme for the 21st century, henceforth known as Agenda 21. The Summit also defined the principle of precaution in Principle 15 (Rio Summit, 1992):

"In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damages, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

This principle is a very important part of how to handle sustainability in practice when scientific proof is interpreted differently or does not cover the actual issue. In Sweden the principle was enshrined in the Swedish Environmental Code (2000).

1.1 Problem statement

The construction sector is a considerable contributor to global resource depletion (e.g. Rees, 1999; Lorenz et al, 2008). Furthermore, it is clear that it has taken a long time for industrialized countries to adapt to the concept of sustainability in construction works. This has been achieved by introducing concepts and terms such as green building, sustainable building and sustainable construction. The research community of construction sustainability has, over a similar timescale, slowly shifted its focus from solely environmental issues and assessment methods, through questions such as energy savings and material productivity, to a more holistic view of sustainability including aspects of environmental, economic and social development, the triple bottom-line (discussed further in chapter 3).

By reviewing the subjects discussed during sustainable building conferences held during the past ten to eleven years, will give a better insight how the construction industry evolve and adopt the concept of sustainability.

Eleven years ago, in Vancouver 1998, assessment and design tools were in focus. These were about to minimize energy demand during construction and operation, to integrate energy use with renewable energy and with concern of living and working quality for occupants, e.g. Boonstra et al (1998) tested different assessment tools on the same building and found the output data was too differentiated to be comparable between the methods and an optimization of data was not a goal for most of the tools. The international GBC98 Tool, later named as GBTool, (Cole and Larsson 1998) was introduced, developed to assess different buildings in different countries with the same tool and has since then been used as a main equalizer between assessed objects in different countries. The discussion was about to recognize differences between the tools and the sites of assessments and differences between local and global conditions. Most of the methods and the contributions in Vancouver were about green buildings and environmental issues, only a very few regarded the construction process or the whole triple bottom-line of sustainability. The assessment tools have then evolved to commercial tools, e.g LEED, BREEAM. CASBEE, or NABERS (see chapter 4 for more details) each covering mostly environmental issues adapted to the actual country or region where in use.

Six years ago, in Oslo, Norway, the focus was shifted to mainly environmental issues as reducing carbon dioxide (CO2) emissions, to reduce environmental loads, about eco-efficiency through Factor 4 and Factor 10 (see chapter 3 for further details). These issues were replenished with issues of energy savings during the next couple of years, e.g SB05 in Tokyo. During these years the mainstream contributions to sustainable building conferences were focused on environmental issues as energy savings and material productivity. But some awareness of the rest of the triple bottom line of sustainability was addressed. Two agendas of sustainability in the construction sector were published, one general by CIB´s Agenda 21 of Sustainable Construction (see chapter 3) and one concerning the developing countries in Developing Countries Agenda 21 (du Plessis 2002). The latter stated a definition of sustainable construction including the triple bottom-line and the necessity of a holistic view. Countries as Brazil and South Africa began to contribute with thoughts about more socio-economic and management focus. There were also a couple of construction process oriented contributions in Oslo from Australia, Finland and South Africa. Discussions of indicators of sustainable construction was made e.g. by the CRISP project (Häkkinen et al 2002) Still, the mainstream research community was focused on solely environmental issues.

The next couple of years through SB05 in Tokyo contained more practical issues as procurement procedures, valuating of assessment methods and social housing issues regarding all triple bottom-line values. More of management approach was assigned. New issues about ethics, the global aspect and city development were discussed. It was a broad spectrum of sustainability concerns regarding different economies and regions of the world, e.g. procurement procedures (Brophy and Lewis, 2005) as barriers to sustainable development and sustainable construction. They found the building projects within their study were procured, the scope of sustainability was lacking. The design teams in the study indicated that client commitment, design team commitment, motivation and expertise as the features that most contributed to the achievement of the project targets. Another example is about sustainable and affordable habitat for the rural poor in developing economies (Nair et al, 2005), and is depending on socio-cultural, economic, technologic and environmental factors including strategies and policies. A third example is arguments of sustainable construction contain environmental, economic and social values (Yin and Cheng, 2005) where local dimensions are significant. Sustainable construction is a long term objective. It should be in account of an early stage of a facility development with a management approach and with a focus on procurement methods. From SB05 the conclusion was that sustainability in construction in general was initiated and has become to gain acceptance but it is still a very long way to go.

During these years there have been attempts to demonstrate good examples of sustainable buildings and sustainable development of cities. Some good practice of green buildings in Scandinavia was demonstrated in SB07, Malmö Sweden, as progress in sustainability. The concept of Passive Houses and the importance of local sustainable development were highlighted plus the UK housing agenda – the Green Paper. Some lessons were learned, as S-house in Austria – a Factor 10 example. The arguments of sustainability contained mostly environmental issues and mainstream construction projects were still in the very beginning to adapt sustainability.

Adoption of sustainability to the construction sector depends to varying extents on sustainability demands at the global, national, regional, local, corporate and individual levels. It also depends on the cultural and social context of the society in question (Persson et al 2008a). Views on this concept of sustainability differ strongly according to the focus of content, from a regional/national level to the individual level and from different nations/regions to different social and cultural societies (Cole and Lorch 2003). Sustainability also depends on individual ideological preferences. All these differences have somehow the same meaning in the end because the concern is how current decisions are going to affect future well-being, i.e. changes in real asset values (Atkinson 2008). Yet, the impact on 'typical' construction projects and their stakeholders (e.g. the client, project management team and end users) remains unclear. It appears to be a lack of new knowledge transfer from the international research community to the local construction project management, particularly in the area of managing the process of construction works towards sustainability.

Referring to the view of Swedish environmental legislation, it is the part which performs an activity that is responsible for the environmental impact consequences (Environmental Code, 2000). Accordantly, it should be equivalent regarding sustainability impact consequences. Concerning construction works, it is no doubt that it is the client/owner/developer that is the responsibility part, performing activities as owner and administrator of construction works.

1.2 Research question

Wasley (2004) comments the importance of local cultural context in challenging and reforming the normative expectations of both construction professionals and end users. Curwell (2003) questions if humanity is able to change the ongoing processes, showing if sustainability is a believable direction of action. Alternatively, there is a further view, which is that of concentrating on first aid, i.e. address the worst examples of injustice and inequalities. According to Rees (2008), Foliente (2008), Lutzkendorf (2008) and Larsson (2008) in their introductory comments at the SB08 conference in Melbourne, they claimed that the irreversible damage has already reached the tipping point and it is probably too late to sustain the conditions of today for future generations: it is just a matter of minimizing the damage. The timeframe for action is very limited and the extent of necessary action is fast becoming extensive. Moreover, and with reference to the precautionary principle, playing a waiting game is no alternative.

Many industrial countries have already set national strategies for sustainable development in order to measure their national or regional share of global depletion of resources (Atkinson 2008). For the construction sector, these national strategies imply policies for sustainable buildings and sustainable construction. The policies and objectives as formulated are, from the public's perspective, directed towards the single client in the form of different kinds of incentives, e.g. taxation subsidies, direct investment subsidies, public procurement advantages and allowance of specific investment funds (Drouet 2003). It could also be a matter of sector agreements on common sustainability objectives and targets as in the case of Sweden's construction sector (Ecocycle Council 2003).

These incentives are intended to promote the activities of the client´s organization in acting positively in the form of corporate sustainability (see chapter 3). If the client's role is to manage and maintain facilities of different kinds, these incentives affect not only the organization but other stakeholders too, such as end users, financiers, authorities and the public. It also affects present and future projects, facility operation and maintenance and represents a top-down system when seen from the client´s perspective, see Figure 1.1.

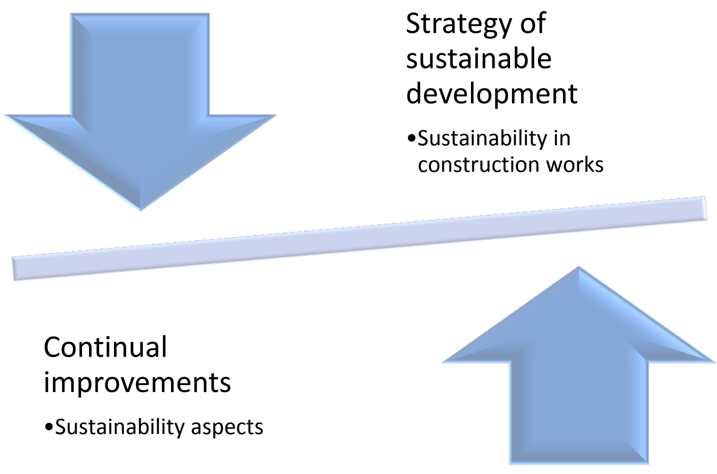


Figure 1.1 A client´s sustainability aspects matching with continual improvements and top-down demands.

To manage all the issues involved, the client has to utilise some kind of management system to structure all the information created for and by its activities and those of its stakeholders, e.g. business policy, accounting method, financial system, quality management system or environmental management system. In such systems, much of the incoming information has to be recorded. Records are then compiled and aggregated systematically into accounts held on a higher level over time. Eventually, this information appears in the annual accounts as key figures.

From the sustainability perspective, the more significant figures are evidence or verifications of continual improvements in the client´s environmental management system and further development of the environmental policy (ISO 14001). Nonetheless, key figures are also, with those aggregated from other clients, indicators of the national and regional strategy of sustainable development for a country (Figure 1.1).

The research questions are:

1. Is it possible to estimate whether a construction works development is heading towards sustainability or not?

2. Is it possible for a client to manage, verify and validate sustainability actions together with other important activities relating to construction works as part of a process of continual improvement within its organization?

These questions needs to be addressed in the context of top-down demands of national and regional strategies of sustainable development expressed by sustainability in construction works (Figure 1.1).

1.3 Aim, objectives and limitations

The aim of the research is to define sustainability in construction works, systematize aspects of sustainability and validate sustainability in construction works from a client and construction project manager perspective. The specific objectives of the research are to:

1. Define the basics of sustainability in construction works, corporate sustainability and the connection with knowledge transfer,

2. Critically review the use of the terms sustainable construction and sustainable building, and

3. Apply a model for enabling a client to deal with significant aspects (see chapter 0) of sustainability during construction works and validate this model with a well-defined context of sustainability in construction works, with input from real cases and from well-defined sustainability constraints.

The limitations of the research are:

- When using the term of construction works, it only concerns buildings,
- The focus of the recent development according construction sustainability is during the last eleven years,

- Legislation and governmental demands concerns the Swedish environmental legislation and governmental demands, unless otherwise stated,
- When activities of a client are in question; solely applying during the process of construction works, and
- The precautionary principle is applicable if different interpretations or contradictions in scientific sustainability knowledge occur.

1.4 Structure of the thesis

Chapter 2: Research methodology – describes the need of research methodology, different ways of approaching a research and the approach used in this research.

Chapter 3: Sustainability in construction works – aims to compile from recent literature knowledge of the increasing complexity of interactions and the requirements for knowledge transfer when sustainability is involved in construction works. First, a broad presentation is made concerning sustainability of general issues, including a definition of the triple bottom-line, and then special issues relating to construction works are described. The section ends with a definition of sustainability in construction works and its connection with the process and the product. The linkage between corporate sustainability (the organization) and knowledge transfer management are examined.

Chapter 4: Indicators and assessment of sustainability aspects – begins with a brief overview of different indicators that could be used and their relationship with construction and sustainability. The overview is presented from the perspective of a recently published ISO technical specification. The chapter continues with a summary of different types of sustainability assessments, the enablers of a stakeholder perspective assessment and, finally, the tools used for different assessment and evaluation methods are examined in the context of the triple bottom-line.

Chapter 5: Management systems – makes the connection between commonly used organizational management systems and the organizations ability and opportunity to achieve sustainability in its activities, especially those concerning construction projects.

Chapter 6: STURE – a model approach – presents a model to be used to manage the different aspects of sustainability on the corporate level, with particular respect to construction projects. The section ends with an example of a sustainability assessment method of a construction works site.

Chapter 7: Case studies – presents a couple of case studies, covering the life-cycle of construction works, for usage of a validation of the model described in chapter 6.

Chapter 8: Validation of sustainability management model – validates the model described in chapter 6 by the case studies presented in chapter 7 3 with a well-defined standard of sustainability constraints regarding construction works. Further on, it includes a discussion of the findings from the validation and whether these findings or other circumstances presented in this study could be generalized.

Chapter 9: Summary and final conclusions – summarizes the findings drawn from the study and its contribution to science and practice and, finally, recommendations for future work.

2 Research methodology

2.1 Introduction

Research is to contribute to a special field of issues with something unknown, unpredictable, generalized and/or interdependent to the main body of knowledge. To achieve this contribution in a systematic way it is essential to approach the performance of the research with appropriate and scientifically approved methods as explained by Atkin and Wing (2007; p 1):

“Knowing which path to follow, which tools and techniques to apply, and how to make sense of findings are the fundamental prerequisites of good research and, likewise, good researchers.”

To perform a decent research Robson (2002) identifies five inter-related phases to design a research:

1. Purpose – what is the achievement,

2. Theory – the theory which the study is based on including the design of research and the analysis of findings,

3. Research questions – what is the statement of possible findings and what the expectation of these findings is,

4. Methods – how to collect, analyse and validate the findings and how to show its reliability , and

5. Sampling strategy – how, where and when the input data should be collected and how the sample should be justified.

A similar division of phases is done by Andersson and Borgbrant (1998), where research questions, methods, sampling of data and findings are interacting with each other during the main moment of research performance; research design, performance and reporting. This interaction, with different peaks of emphasis, is in progress during the whole process of performance. Atkin and Wing (2007) points out that research is an interactive and continuously process during the performance. It is also a learning process but with sufficient efforts to plan and design the research, especially with research questions and method approaches, it is more likely to reach adequate and scientific proved findings of the research.

2.2 Research design

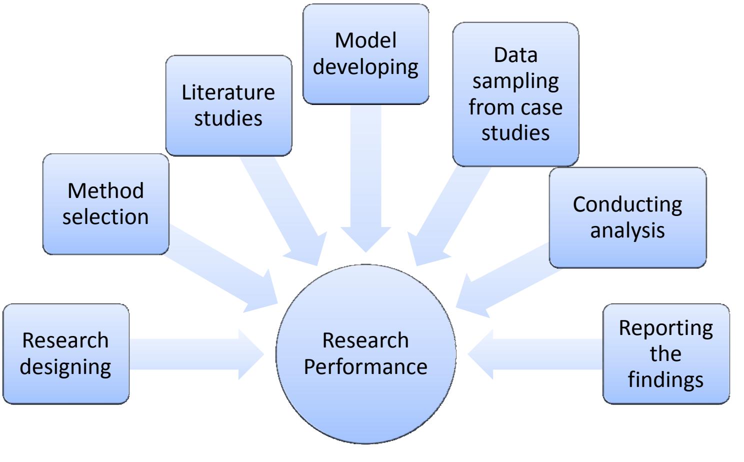


Figure 2.1 Input in this research' performance.

With reference to Robson's (2002) five phases of designing a research, this research's performance was divided in research designing, method selection, literature studies, model developing, sampling data from case studies, conducting analysis and reporting the findings, sees Figure 2.1.

The input according Figure 2.1 were used in the research process interactively and continuously to the very end of the performance because of their internal dependency of each other; when a small adjustment was done within one phase an overhaul and adjustment of dependent matters of the others were needed. According to Andersson and Borgbrant (1998), the peaks of emphasis of the phases have been at different times but in progress continuously and interactive during the process of research performance. The research performance described in terms of the Figure 2.1 input is structured in this thesis as follows:

- Research designing with background, purpose, aim and statement of the research questions in chapter 1,
- Method selection in this chapter (chapter 2),
- Literature studies including theory of sustainable development, assessment techniques and management systems in chapter 3, 4 and 5,
- Model developing of a model how to handle sustainability in management of construction work and works in chapter 6,
- Data sampling from case studies including descriptions of case studies in chapter 7 and data input from the case studies into the developed model in chapter 8, and
- Conducting analysis includes a validation of the model with a framework of sustainability principles of construction works and by a discussion if it is possible to generalize the outcome of the validation in chapter 8. Further on, it includes a summary, final conclusion of the findings, a statement contribution to the body of knowledge and, finally, a hint of possible future research in chapter 9.

The research development is conceptualized in Figure 2.2 as a model for the research design according to emphasis of the research phases by input and timing of knowledge transferring and research findings.

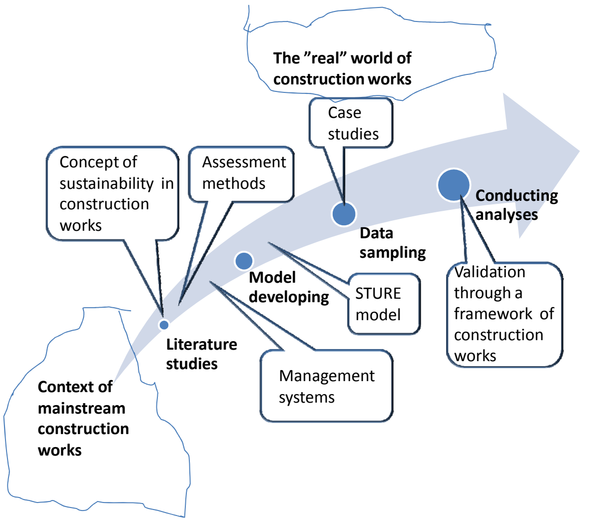


Figure 2.2 The research design according to input and timing of knowledge transferring and research findings.

2.3 Method approach

During the performance of this research, a combination of method approaches were adopted; literature reviews, development of assessment model and validation of assessment model with case studies from different stages of the life-cycle of construction works. This was done in a context of construction sustainability with client and project manager perspective.

2.3.1 Literature review

Literature studies has been undertaken covering definitions and concepts of sustainable development in general and sustainability in construction works in particular. Further on, an overview of useful indicators of sustainability for building construction, different assessment techniques and assessment tools adapted to buildings and its performance are made. Finally, an overview of some relevant management systems adapted to construction works is made.

The literature covers international peer-reviewed journals, scientific reports, conference proceedings from the Sustainable Building conference series, and books. The literature review has been used as input for validating an assessment model, which has been developed in the context of construction management systems in line with concept of sustainable development. The validation was performed by means of case studies encompassing different stages of construction works life-cycle. As visualized in Figure 2.3, sustainability in construction works is by this research defined as a result of blending the context of construction works, its associated management systems and the concept of sustainable development.

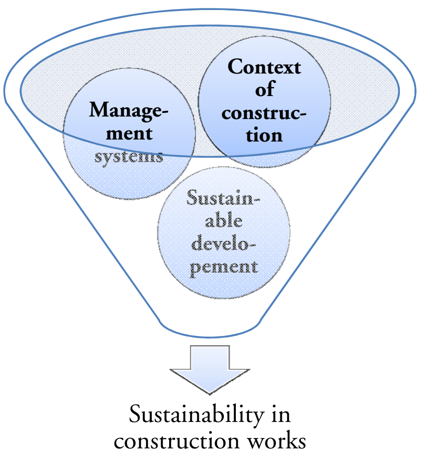


Figure 2.3 Blending concepts and context.

2.3.2 Model developing

During the phase of model developing, an assessment model approach was developed with respect to a client's desired level of sustainability during a project process. It has been developed with respect to present theories and practical usefulness. The development process included a conceptual model containing purely environmental aspects of construction work management (Persson, 2001) through a set of applications where additions such as sustainability construction works concept, stakeholder analysis, management systems and links to other facility developments or processes were added (Persson, 2002; Persson, 2003; Persson and Olander, 2004; Persson et al, 2005; Persson et al, 2008a; Persson et al, 2008b). The model is based on principles of environmental management systems, i.e. as the principles of ISO 14001.

The phase of model developing also contained a development of a simplified scheme (Persson, 2001) of how to assess site dependent sustainability aspects of a facility in accordance to a simplified version of standard environmental impact assessment, EIA, e.g. as described in The Swedish Environmental Code (2000). This scheme was intended as a compliment to the assessment model and was applied in Persson (2002), Persson (2003), Persson and Olander (2004) and Persson et al (2005).

2.3.3 Case studies

To apply the assessment technique in order to gather or predict relevant data, case studies were used. A case study could be defined as:

".. a unit of human activity embedded in the real world which can only be studied or understood in context which exists here and now that merge in its context so that precise boundaries are difficult to draw" (Gillham, 2000 p 1)

Case studies could involve single cases or multiple cases with multiple levels of analysis (Yin, 2003). A case study is often considered to be a qualitative study and should be the primary approach, but it often includes quantitative data (Eisenhardt, 1989; Gillham, 2000; Näslund, 2002). Quantitative case research often focuses of a small number of cases with suitable depth (Ellram, 1996) The data collected in case studies as evidence combines documents, records including personal notes, interviews, participant observation and physical artifacts, e.g. erected or dismantled buildings (Eisenhardt, 1989; Gillham, 2000; Yin, 2003). Case studies could be used to provide detailed description, test theory or generate theory (Eisenhartdt, 1989). The aim to use case studies in this research was using the evidences, mostly quantitative, by triangulation (Ellram, 1996) from each case to validate the developed assessment model. The input data or evidences are more predictable and reliable when using documented "real-world" cases instead of theoretically based predictions of input.

The criteria used to select the particular cases was made from the following requirements to cover as wide range of buildings and stages of construction works life-cycle as possible in order to be more acceptable to generalize possible findings:

- It have to be from different phases in a construction works life-cycle: exploitation, design, construction, operation, maintenance planning, refurbishing and dismantling,
- The type of construction works have to be limited to pure buildings, and
- The building functions have to be of different types.

It was inappropriate to formulate a hypothesis for the research because of avoiding specific relationships between variables and theories (Eisenhardt, 1989) and the complexity of the interactions among the many and different stakeholders. A further reason was likely to prove problematic to isolate individual variables so that they could be manipulated for similar reason (Atkin and Wing 2007) and because of the interdisciplinary nature of sustainability.

The approach is also explanatory, since it seeks an understanding of the complex relationships within the area of sustainability in construction works by means of a validated model. The matter of external validity is considered too, i.e. if it is possible to generalize the case studies' internal findings of significant aspects, as opposed to their effects. When using multiple case studies, results are more generalizable than using results from a single case study (Ellram, 1996; Yin, 2003). In other words, the intention is to examine, evaluate and validate significant aspects of sustainability in construction works from the client´s perspective that causes an impact on us and our environment, physical or psychological.

The selection of the case studies was chosen non-probabilistic (Merriam, 1988) with the effort to contribute to development and validation of the emerging assessment model (Eisenhardt, 1989). The selected case studies were:

1. Residence buildings and student flats, a project in an very early stage during an exploitation project,

2. A new office building, a project during design and construction stage,

3. Residence and commercial buildings, a maintenance planning project for a real estate company,

4. Residence buildings, a maintenance and refurbishment project with construction work during tenants use, and

5. A project for dismantling a coal based power factory, dismantling equipments in a building that was indented to be used to another purpose. The case was about the project phase when to formulate documentation for procurement of a dismantling contractor.

Here, the number of cases covers circumstances characteristic of all main phases of construction works life-cycle; a selection of detailed knowledge from a limited set of circumstances in a small number of cases.

2.3.4 Conducting analysis

The analysis process is to validate the developed interdisciplinary process-orientated model with the ISO 15392 (2008) and the terms derived from the literature studies. The case studies' different significant data were aimed to validate the model with the ISO standard. The result of this validation is then put in a bigger context of sustainability of construction works, derived from the literature studies, to be discussed if the findings from the particular cases could be generalized to be valid to sustainability of construction works entire life-cycle. Further on, if the result of the generalization could lead to usability of the developed model to estimate range of sustainability of such construction works.

2.4 Conclusion

The research follows appropriate and scientifically approved methods as above and is conducted by literature studies, development of a management model focusing on sustainability in construction works suited to clients and project managers, validated by case studies and generalized to be used in projects covering construction works entire life-cycle.

The literature covered international peer-reviewed journals, scientific reports, conference proceedings from the Sustainable Building conference series, and books. An assessment model was developed with respect to a client's desired level of sustainability during a project process. It has been developed with respect to present theories and practical usefulness. To apply the assessment technique in order to gather or predict relevant data, case studies were used. The case study evidences, mostly quantitative, were by triangulation from each case, input for a validation between the developed assessment model and the sustainability principles according to ISO 15932. The result of this validation was then put in a bigger context of sustainability of construction works, derived from the literature studies, to be discussed if the findings from the particular cases could be generalized to be valid to sustainability of construction works entire life-cycle. Further on, if the result of the generalization could lead to usability of the developed model to estimate range of sustainability of such construction works. These matters fulfill the commitments of the chosen method approaches.

3 Sustainability in construction works

3.1 Introduction

This chapter compiles knowledge from recent literature about the increasing complexity of interactions and the requirements for knowledge transfer when sustainability is involved in construction works. First, a broad discussion concerning sustainability of general issues as strong and weak sustainability, ecological modernization and growth criticism. The definition of the triple bottom-line and its internal relationship is established. Then the chapter contains issues relating to construction works as its context, about expectations that end-users might have of a sustainable building and, finally, the basis for understanding the process leading to a sustainable construction works is considered. The chapter ends with a definition of sustainability in construction works and its connection with the process and the product. The linkage between corporate sustainability (the organization) and knowledge transfer management are also examined.

3.2 Sustainable development

To use the definition of sustainable development in chapter 1 uncritically is not recommended. Pearce (2005), for example, argues that there is a lack of consideration of the poor or wealth dimension which is given in the following lines of the Brundtland Report (1987: pp 24-25) and which is often overlooked:

"Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes."

Pearce continues by remarking on the attempt to interpret the definition as a win-win scenario (financial profit, no environmental damage and a contribution to community development by planning sufficiently enough) and the simplified interpretation of rising per capita standards of living through time which implies decreasing living standards for future generations.

On the other hand, du Plessis (2007) covers the wealth dimension by her interpretation of sustainable development as "managing the relationship between the needs of humans and their environment (biophysical and social) in such a way that critical environment limits are not exceeded and modern ideals of social equity and basic human rights (including the right to development) are not obstructed" (du Plessis, 2007 p. 70). This dimension is also included in her definition of sustainable construction (du Plessis et al, 2002). Atkinson (2008) suggests a capital approach, a matter of current wealth or capital (the sum of all assets in an economy) and the linkage with future well-being, i.e. changes in wealth today will have consequences in future well-being. Atkinson's definition of sustainable development is when the rate of well-being per capita is not in decline. Lützkendorf and Lorenz (2005, p 213) perceive a discrepancy between sustainable development and sustainability: "sustainable development can be seen as a journey towards a destination, sustainability" and they refer to four system conditions where sustainability could be measured:

1. The balance between extracted finite materials and the rate of redeposition in the Earth's crust,

2. The balance between the production of artificial materials and the ability to break it down by natural processes,

3. Maintenance of the eco-systems, where utilization of renewable recourses should not exceed the rate of replenishment, and

4. Dealing with human needs in an equitable and efficient manner.

The content of sustainable development with its triple bottom-line (see below) could then be divided into weak sustainability, strong sustainability (Turner, 2006;

Atkinson, 2008), ecological modernization (Mol and Spaagaren, 2000; Gibbs, 2003; Naess 2006) or growth criticism (Daly, 1993; Kovel, 2002; Nørgaard, 2006; Rees 2008). From the level of activities of organizations, there is the term corporate sustainability or corporate social responsibility, which means simultaneously addressing issues relating to the triple bottom-line with the consequences of shifting focus from shareholders to stakeholders (Robinson et al, 2006; Atkinson, 2008).

When using the capital theory approach (Turner, 2006; Atkinson, 2008) to sustainability it is assumed that physical man-made capital, social and natural capital, such as a capital stock, do not decline over time. This is a condition for the fairness across generations due to the sustainability definition given above. Weak sustainability occurs when man-made capital grows in parallel with the decline of natural capital, i.e. it is the whole sum that has to be consistent independently of whether the different parts are decreasing or increasing. Strong sustainability occurs when the natural capital is explicitly constant or rising over time (Jensen and Gram-Hanssen, 2008; Turner, 2006; Atkinson, 2008). Growth criticism considers the relationship between continuous economic growth and sustainability to be incompatible. The critics assume that economic growth cannot be decoupled from negative environmental consequences and thus, sustainability could not be achieved without a steady-state and zero growth economy (Nørgaard, 2006; Rees, 2008).

3.3 The triple bottom-line of sustainability

Deeper interpretations of sustainability using the Brundtland Report, Rio Summit and Agenda 21 as a basis have been generated and involve issues of balancing economy and social development with ecological considerations. This is called the 'triple bottom-line' and is an expression of these three complementary parts of sustainability (Pope et al, 2004; O'Connor, 2006; Hacking and Guthrie, 2008). These parts can be considered on an equal level as in Figure 3.1.

Figure 3.1 The triple bottom-line of sustainable development (adapted from Lützkendorf and Lorenz, 2005; CEM, 2008; ISO 15392:2008).

Otherwise, the model could also be viewed as the Russian doll model concept with the environment as the dominant part, as in Figure 3.2. The economic activity depends on social issues and both are constrained by environmental factors (Lützkendorf and Lorenz, 2005; CEM, 2008).

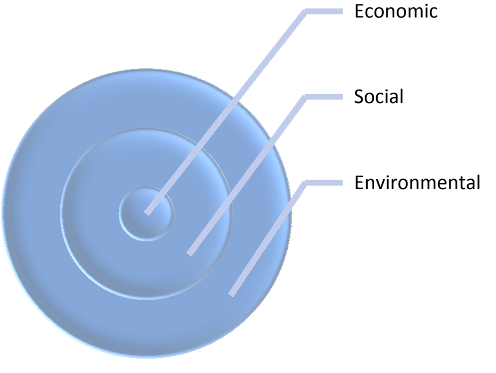


Figure 3.2 The Russian doll model of sustainability (adapted from Lützkendorf and Lorenz, 2005; CEM, 2008).

The five capitals model of sustainability (CEM, 2008) implies that five capital assets (includes in the economy part) are linked with the other parts in the triple bottom-line:

1. Financial capital – has no real value, but represents natural, human, social and manufactured capital, e.g. shares, bonds and banknotes,

2. Manufactured capital – commodities which contribute to the production process, e.g. tools, machines and buildings,

3. Social capital – institutions such as family, community, business and unions that help to maintain and develop human capital,

4. Human capital – health, knowledge, skills and motivation, and

5. Natural capital – resources (renewable and non-renewable), sinks (absorbs, neutralizes or recycles waste) and processes such as climate regulation.

O'Connor (2006) considers that the regulative factor is important for reaching sustainability and thus suggests regulative or governance functions of triple bottom-line systems. Other dimensions are also mentioned, e.g. moral, technical and political (Pawlowski, 2008). The implication is, according to Pawlowski, that the dimensions interact on different levels, with the moral dimension as the highest followed by the original triple bottom-lines on the next level and on the lowest level, the political, technical and legal dimensions. Yet, this interaction is not by means of actions between the dimensions; it is more a need to achieve solutions by holistic thinking, i.e. between the complex problems of interconnected and interdependent relationships which determine the interactions within and between the dimensions (du Plessis, 2007). Thus, if nothing else is apparent, references to the triple bottom-line in this thesis means that the three original dimensions are on an equal level as in Figure 3.1. This is the most common way to interpret the triple bottom-line in the construction sector, e.g. the standard of ISO 15392 which is described in the end of this chapter.

3.4 Ecological modernization

Ecological modernization is more a policy concept of the process towards sustainability than a matter of valuing the results of the process (Jensen and Gram-Hanssen, 2008). This concept can lead to either strong or weak sustainability depending on the actors and actual process. Ecological modernization is the theory that integrates technological innovations and improvements together with sociological, environmental and economic (the triple bottom-line) issues on to how to deal with the challenge of sustainability. It is assumed that several industrial and service sectors will partially go through a modernization process involving more ecologically-friendly production and consumption. With a growth economy, society will be able to learn and renew itself to reach a win-win situation and the environmental challenge will probably not act as a barrier. Some key concepts of ecological modernization are as follows (Naess, 2006):

- **Decoupling:** cutting the link between economic growth and environmental degradation,
- **Dematerialization:** a (more or less strong) contribution to the decoupling of economic growth from resource consumption and negative environmental impacts through increased eco-efficiency and/or substitution,
- Increasing **eco-efficiency:** the production of commodities of unchanged or better quality while reducing the resource consumption and negative environmental impacts associated with production and products, and
- **Substitution:** change in the pattern of consumption from environmentally harmful to less environmentally harmful forms of consumption.

In its present form, the global economy is limited by nature's capacity to absorb the effects of economy growth and to supply the resource input. If the economy is to be sustainable, it is necessary to undergo a process of transformation. A key to this transformation is to decouple the economy from resource consumption and environmental loads (dematerialization). This leads to increasing need for eco-efficiency or material substitutions to maintain or decrease the level of environmental degradation.

It is not only the growth of the economy which is a factor of environmental impact. In the middle of the 1970s, there were thoughts of a connection between the global population growth, the consumption of commodities and environmental impacts from the production of these commodities (Holdren and Erlich, 1974).

This relationship could be expressed by the IPAT-formula (Holmberg et al, 1999; Kohler, 1999):

$$I = P \times A \times T$$

I = the environmental impact in relative terms

P = the population growth

A = level of affluence expressed by relative level of individual consumption

T = technology level expressed as eco-efficiency of consumed unit

Assume the level of environmental impact is, as a base of the present level, set as a relative amount of 1 and the size of the population and its level of affluence per capita also set to 1. Finally, assume the level of eco-efficiency of today is a relative amount of 1, the formula should express this relationship:

$$1 = 1 \times 1 \times 1$$

Assuming that the population will double over the next fifty years and that there will be equal proportions of affluence as today, the affluence growth will be at the same level as population growth. To sustain the same level of environmental impact produces this expression:

$$1 = 2 \times 2 \times X$$

Where X is the relative amount of eco-efficiency needed; here X = ¼, i.e. the need for four times more eco-efficiency technology. This is called Factor 4 and was originally formulated by the Wuppertal Institut, Germany (von Weizsäcker et al, 1997). Later a Factor 10 has been formulated, implying that half the environmental impact and assumption for the level of affluence is adjusted to meet the fairness distribution demand of sustainability as defined above.

Table 3.1 below shows the necessary dematerialization factors needed in the next 500 years (Naess, 2006) when the population growth is included in the affluence-factor by an annual production growth of 2.1%, i.e. doubling wealth while halving resource use. If the environmental quality 500 years from now is to be kept at the same level as today, and the volume of production grows by 2.1% annually, then an average dematerialization factor of 32500 will be necessary. In order to reduce to half environmental load, compared to the present level, factor 65000 will be required. This is the main argument, especially from the growth criticisms, of the ecological modernization theory; it is not possible in the long run to dematerialize the economic growth without doing anything about the economic growth itself. One suggestion by Daly (1993) is a requirement of a steady-state economy, i.e. zero growth, with measures such as governance regulations.

Table 3.1 Necessary dematerialization factors if the volume of grows by 2.1% and environmental load becomes one half of the present level (adapted from Naess 2006).

Number of years	Volume of production	Necessary dematerialization factor
33	2 times higher	4
100	8 times higher	16
200	64 times higher	128
500	32500 times higher	65000

Proponents of the ecological modernization defend the theory according to Mol and Spaargaren (2000):

"..all major fundamental alternatives to the present economic order have proved unfeasible according to various (economic, environmental and social) criteria" (p 23)

Barry and Paterson (2003) exemplify how concerns for traditional economic growth and competitiveness have gained precedence to environmental concerns in the practical policies within two policy fields, transport and genetically modified organisms. They also point to a connection between ecological modernization and a hypothesis which includes the assumption that growth in already affluent societies will contribute to improving rather than reducing environmental quality, because increased wealth implies that more money might be spent on the development of environmentally-friendly technologies. This is known as the Environmental Kuznets-curve hypothesis (von Weizsäcker, 2005).

3.5 Sustainability in building construction works

The contribution of the construction sector to sustainable development according to Pearce (2003) is the contribution by man-made (built), human (labour force), social (human well-being) and environmental capital to the capital stock and with technological (productivity, labour- and material productivity) change. As mentioned in chapter 1, the research community for the construction sector has slowly shifted its focus over the last ten years from solely environmental issues to a holistic view of sustainability including the triple bottom-line. This is confirmed by Lützkendorf and Lorenz (2005), who consider the construction sector to have been strongly focused on environmental considerations only. Kohler (2003) argues that the connection between sustainability and buildings as a category of products is that regional culture and sustainability are complementary components and the existing building stock is an essential part of regional and cultural diversity. Pearce (2006) maintains that it is because of the seductive nature of the value-loaded phrase of sustainability that different persons define the term differently according to their own view of society and how this view is accepted by others.

Common terms used in the construction sector considering sustainability are sustainable building, sustainable construction and green building. These are often interpreted differently by the stakeholders in a construction project depending on their education, age, cultural background etc (Cole and Lorch, 2003). There are, however, other obstacles that prevent international construction sustainability research from connecting meaningfully with local conditions (Wasley, 2004). Following sub-sections explains some of these obstacles.

3.5.1 The context

The construction sector is of a complex and fragmented nature and has, therefore, a tendency to resist changes leading to more sustainability, if there is, indeed, any tendency at all (Myers, 2005). In industrialized countries, construction has typically an economic importance of about 10% of the country's GDP (Costantino, 2006). In the EU, buildings are estimated to consume about 40% of the total available energy, responsible for roughly 30% of total CO2 emissions and generate about 40% of all man-made waste. The issue of sustainability occurs at all levels in the economy connected to the construction sector: macro, meso and micro (Bon and Hutchinson, 2000). On the macro (global) level, the construction sector declines as the country develops and, so far, sustainability has become more important in industrialized countries with a declining share of construction. This implies that, at the global level, the construction sector is a poor contributor to sustainability. In recent years, however, there has been a change and more developing countries are adopting sustainability issues in construction (Persson et al, 2008a). On the meso-economic level, the construction sector is composed of products and services supplied by many of other industrial sectors, so it is difficult to assure sustainability along the whole supply chain especially with emerging global market and international trade (Bon and Hutchinson, 2000). On the micro level, the single facility or building tends to be erected with a shorter time-horizon in mind because the client or investor is facing a more uncertain economic environment. The facility is likely to contain more mechanical, electrical and electronic equipment and is best suited as a short-to-medium-term economic asset on the part of owners.

The basic context for issues of environmental and sustainable concerns in Sweden is drawn in the Environmental Code (2000) including the precautionary principle. With regards to the construction sector, this could be described as a context of ecological modernization for a number of reasons. The shift in construction regulation from detailed 'how-to-do' to regulated objectives where the targets are then formulated by the developer (Jensen and Gram-Hansen, 2008) is one, and the shift to more sector agreements, e.g. the Environmental Programme 2010 (Ecocycle Council, 2003) for avoiding detailed legislation is another. In addition there has been a shift in standardization, i.e. norms and voluntary agreements, where eco-labeled construction materials are more frequently demanded by the end-users and even clients. The above mentioned Environmental Programme could also more or less be included in this standardization.

3.5.2 User expectations

There are four variables that correlate with the occupants´ comfort, satisfaction and productivity (Lützkendorf and Lorenz, 2005):

1. Personal control – the possibility for the occupants to control their environment,

2. Responsiveness – the facility's capability to rapidly respond to the needs of the users,

3. Breadth of the building – for optimal human performance the breadth of a building has to be about 12m, and

4. Workgroups – room size and organization of workgroups where productivity tends to decline with groups of more than four persons.

There is a widespread misconception that environmentally-friendly buildings have to be unattractive and odd in appearance, that they must be more expensive and that users have to change their lifestyle to fit the building (Curwell, 2003). User expectation is more about functionality and service (of the product) orientated and that is why there is an advantage in promoting issues of higher quality, higher level of performance and lower operation costs than conventional buildings.

It seems that the necessity of air-conditioning the indoor climate of today's buildings is based on an expectation of stable indoor conditions despite the weather, season or cultural behaviour (e.g. taking siesta, a rest during the warmest part of the day, and having the time to socialize). This is based on quantitative standards which equalize all persons to become an average male human being. Brager and de Dear (2003) call this thermal monotony, i.e. our ability to sense that a natural time or other natural concurrencies are becoming limited. Instead they suggest promoting thermal delight, a view of qualitative indoor conditions adapted together with the actual social, regional and cultural context.

3.5.3 The process of construction works

The management team of a sustainable construction work project should consider the entire process from an early design stage towards the final product, and the benefits and negative impacts regarding the triple bottom-lines of sustainability that are to be expected during the lifetime of the final product, i.e. the facility. The principle of triple bottom-lines applied to construction works is shown in Figure. 3.3.

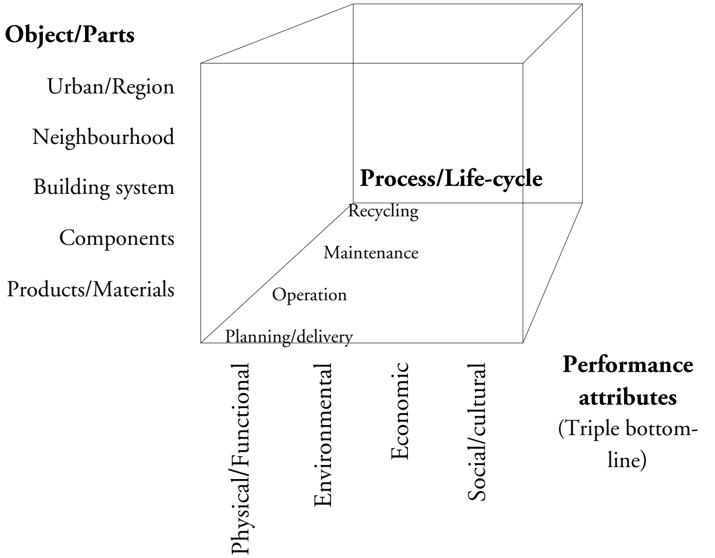


Figure 3.3 The triple bottom-lines applied on construction works (adapted from Foliente et al, 2007).

There are relatively few examples of good practice regarding sustainability in mainstream construction. It seems that clients and project managers are facing barriers to implementation. Williams and Dair (2005) found at least 12 barriers to implementation, the most common were being lack of pro-active of sustainable measures, conflicts in real and perceived costs and inadequate implementation expertise.

A common misunderstanding is that sustainability in construction works is more expensive in terms of investment costs compared to ‘normal’ mainstream buildings. A survey conducted by the World Business Council for Sustainable Development (WBCSD, 2008) investigated the difference in investment cost between a ‘normal’ building and a certified sustainable building is about 17%. Other sources claimed this figure to be up to an additional of +15% (Lützkendorf, 2005). Yet, Balcomb and Curtner (2000) show that initial costs do not necessarily increase if energy consumption (one of the most significant factors in building sustainability) is reduced by about 50%. This can be brought about by means of conducting energy simulation tests at a very early stage of the designing process, thus cutting the costs of heating, ventilation and air-conditioning (HVAC) equipment. These costs are as much as about of 40% of the total construction costs and could be balanced with the improvement measures that make HVAC downsizing possible. Kats et al (2003), and Matheissen and Morris (2007) found that a 'green' building is cost effective, no additional cost compared to normal buildings is necessary and the total benefits over the life cycle are more than ten times the average initial investment required to design and construct a green building. It seems that the stakeholders in a construction project, i.e. clients and project team, are not well enough informed about the basic linkage between construction works and sustainability.

To promote work towards sustainability in the process of a construction project, some economic instruments can be used, especially by financial authorities, communities and government. These are mentioned by Drouet (2003) and are further discussed in chapter 4.

3.6 Terms of sustainability in construction works

Some key differences between green building and sustainable building are about social and cultural problems that are considered a limitation in the former (Kohler, 2003). In contrast, social, cultural and economic objectives are valued at the same level as ecological objectives when considering sustainable building. Where green building is focused on limitations and obstacles, sustainable building focuses on promoting synergy effects and optimization.

A seminar was held regarding sustainable building in the Netherlands and 35 experts on the subject from 14 different countries were gathered (Rovers, 2006). One question concerned the definition of sustainable building and the result showed that practically none of the participating countries could agree on one definition.

It seems to be necessary to clarify the concept of sustainability regarding buildings and construction, i.e. sustainable construction and sustainable building. While the former is about the whole process from the stages of pre-design and design, procurement, construction towards the final product and then the different stages over the product's lifetime; operation, maintenance, refurbishment, re-construction, demolition and recycling; the latter concerns only on the final product, the building.

3.6.1 Sustainable construction

Sustainable construction could be interpreted in many different ways. The term covers a broad and complex interaction between involved stakeholders, aesthetic, and functionality and material interactions. Construction itself could imply everything between site-specific activities to the creation of human settlement. Sustainability, on the other hand, should imply a holistic view, "*the whole is more than the sum of its parts*" with relationships and interactions between humans, society, the biosphere, economy and the state of technology (du Plessis, 2007).

CIB (International Council for Research and Innovation in Building and Construction) defined sustainability in construction through the Agenda 21 for Sustainable Construction (CIB, 1999) as about reaching sustainable development through environmental, socio-economic and cultural aspects. It is divided into three parts:

1. Management and organization,

2. Product and building issues, and

3. Resources consumption.

Management and organization is a key aspect of sustainable construction according to CIB (1999). This part contains technical aspects as well as those of social, legal, economic and political nature. It is a complex issue because of the interdependency of the above aspects and because of the number of different stakeholders involved in the construction process. The challenge involves the construction process, but also the environmental effects, human resources issues, innovation of new solutions of construction methods, knowledge transfer in the project, demands from stakeholders, common standards and relevant legislation.

Product and building issues concern optimization of the construction process according to local conditions such as climate, culture, building traditions and level of technology. They also include issues of material productivity, for example energy content, recycling ability and emission minimization for a healthy and productive indoor environment.

Resource consumption involves minimization of energy use and resource productivity, i.e. to use actual resources as effectively as possible. It also means making use of renewed and recycled material or construction parts.

Another definition of the process towards a sustainable building and during its life cycle is the definition of sustainable construction agreed on by CIB, United Nations Environment Programme, UNEP, and the research institutions CSIR and CIDB of South Africa in their Agenda 21 for Sustainable Construction in Developing Countries (UNEP et al, 2002; du Plessis, 2007):

"...principles of sustainable development are applied to the comprehensive construction cycle, from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and built environments, while creating settlements that affirm human dignity and encourage economic equity." (UNEP et al, 2002: p. 3)

This supports the triple bottom-line philosophy and the wealth dimension mentioned above, is applicable at a global, regional and local level, and supports the CIB definition.

3.6.2 Sustainable building

Sustainable buildings could be defined as "buildings that contribute to sustainable development" (Lützkendorf and Lorenz, 2005 p 214) or as described in Figure 3.4 (adapted from Kohler, 1999): where the right-hand column defines the performance objectives of a sustainable building regarding the principles of the triple bottom-line of sustainability; ecological, economic and social/cultural development, with equal importance (Pope et al, 2004).

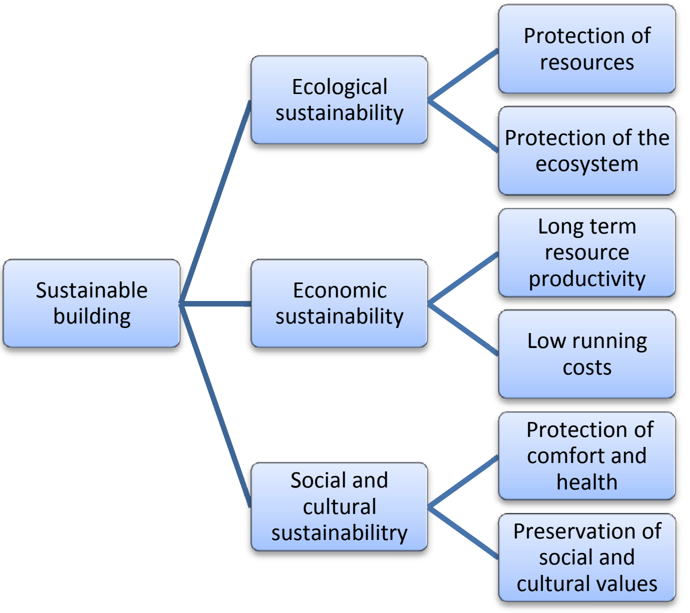


Figure 3.4 Sustainable building (adapted from Kohler, 1999).

The European research project Methodology Development towards a Label for Environmental, Social and Economic Building (LEnSE 2007) has extended the view of a sustainable building shown in Figure 3.4 based on the triple bottom-line content as:

- Environmental,
    - Climate change,
    - Biodiversity,
    - Resource use, and
    - Environmental management and geophysical risk.
- Economic,
    - Financing and management,
    - Whole life value, and
    - Externalities.

- Social,
    - Occupant well-being,
    - Accessibility,
    - Security, and
    - Social and cultural value.

Lützkendorf and Lorenz (2005) argue that the issue of satisfying users' needs is also an important requirement for a sustainable building, i.e. maximization of a building´s serviceability and functionality should be addressed with importance.

3.6.3 An ISO-standard of sustainability in building construction

These various interpretations have been adapted and are now defined in a new ISO standard applied to construction works: the international standard "Sustainability in building construction – General principles" (ISO 15392: 2008), containing most of the issues presented previously.

This standard is linked to ISO 14001 and to the coming standard of corporate responsibility ISO 26000. It refers to the concept of sustainable development defined in the Brundtland Report (1987) adapted to the triple bottom-line. The standard is applicable to one or more buildings' whole life-cycle from the very beginning to the end of their life including the related materials, products, services and processes. It is important to note that sustainability is the result of the activities related to the concept of sustainable development.

The internal relationship of the triple bottom-line is set to as being of equal importance, see Figure 3.1, and each of these should be addressed systematically and then prioritized as protection goals derived from the needs of the triple bottom-line.

According to ISO 15932, there are six objectives in the promotion of sustainable development when applied to construction works:

1. Improvement of the construction sector,
2. Reduction of adverse impacts while improving value,
3. Proactive approach,
4. Innovation,
5. Decoupling of economic growth from increasing adverse impacts, and
6. Reconciliation of contradictory interests between short-term and long-term decision making.

To meet these objectives there are nine principles to be fulfilled (without prioritization) (ISO 15392: 2008):

1. Continual improvement – improvement of all sustainability aspects over time adapted to construction works including performances and processes. It addresses methods or means of assessment, verifications, monitoring and communication,
2. Equity – includes the consideration of intergenerational, interregional and intra-societal ethics including the triple bottom-lines,
3. Global thinking and local action – when acting locally consider global consequences and when applying global strategies consider local implications,
4. Holistic approach – includes all aspects of sustainability when considering or assessing sustainability in construction works and regarding the whole life-cycle,
5. Involvement of interested parties – involvement of stakeholders in relation to their importance, responsibility and timing,

6. Long-term consideration – taking in account of short-, medium-, and long-term implications in decision making, including performance over time, life-cycle thinking and legacy impacts (the impacts as a result of a development),

7. Precaution and risk management – the precautionary principle adapted to construction works such as avoidance of risks through risk management, i.e. risk assessment, risk treatment, risk acceptance and risk communication,

8. Responsibility – comprises the moral responsibility for actions carried out, and

9. Transparency – information in an open, comprehensive and understandable way with traceable underlying data and verifiable credibility, e.g. information about products and decision-making processes.

3.7 Corporate sustainability and knowledge transfer

To introduce the concept of sustainability on the level of a single company or organization, there has to be a shift in governance and policy thinking by the management of these companies. This requires a shift towards simultaneously addressing issues relating to finance, human, environmental and social capital (Robinson et al, 2006). It implies also a shift from a shareholder to a general stakeholder perspective and is a business-related interpretation of sustainability, i.e. by what, how and by whom a product is produced and the implications for the company's stakeholders through carrying out this production. This way of managing a company with a sustainability perspective is called corporate social responsibility, CSR (Myers, 2005), or corporate sustainability (Robinson et al, 2006).

Atkinson (2008) exemplifies corporate sustainability as when a firm does not leave the environment in a worse state at the end of each accounting period than it was at the beginning. Lützkendorf and Lorenz (2005) defines it as when the company's contribution of products and services are assessed according to its ability to meet requirements of present and future as wells as the capability to keep present and future impacts, expenses and risks within defined limits. Sustainability is a fact when the assessment results are positive.

Myers (2005) undertook a review of the annual reports of construction companies listed on the UK Stock Exchange and found that attitudes to corporate sustainability were only to be found in the very large companies and even then they had just begun to formulate acknowledgement of sustainability. A majority of the companies in the construction sector are small firms with 10 or less employees and very few have any records of corporate sustainability. The same trend exists at a European level according to Myers (2005).

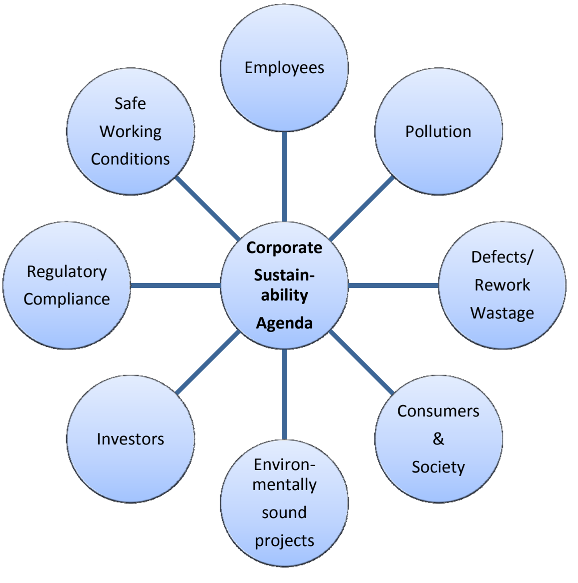


Figure 3.5 Issues of corporate sustainability of construction organizations (adapted from Robinson et al, 2006).

Robinson et al (2006) show in Figure 3.5 the issues related to corporate sustainability agenda for the construction sector to include the triple bottom-line. The benefits of this agenda are cost savings, gains from improved image from the perspective of the public, loyalty, brand value and improved market access.

Even if more and more companies in the construction sector acknowledge the above-mentioned sustainability agenda, there is no evidence in reality of more engagement or efficiency compared to other industrial sectors. This lack of evidence is more indicative of the contrary. Because of the fragmented and complex nature of the construction sector, especially in Europe, a rapid transition to engagement is more or less out of the question (Myers 2005).

Robinson et al (2006) argue that knowledge management, defined as "any process of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to enhance learning and performance in organizations", is a vital strategy if objectives of corporate sustainability are to be reached. Construction companies have to apply the concept of sustainability such as managing their knowledge assets, i.e. intellectual, structural and customer capital, to facilitate continual improvements in its performance. Intellectual capital is defined as economic value associated with organizational, customer and human factors. Structural capital is defined as organizational processes, hardware- and software and supply chains remaining after the employees have left for the day. Finally, customer capital is defined as products and customer relationship knowledge with consumers, society and other stakeholders. A standardized framework for corporate sustainability is being undertaken by ISO in the forthcoming standard ISO 26000, which addresses social responsibility aspects relative to organizations. More about knowledge management in the context of managing construction works and sustainability are discussed in chapter 5

3.8 Conclusions

Sustainability is adopted by the construction sector in the form of the theory of ecological modernization, but it is, in the long run, not possible to continue dematerialize the economic growth. It is a temporary direction.

By the international standard ISO 15392 it is possible to interpret sustainability for construction works accordantly, despite different backgrounds of stakeholders. Confusing interpretations of sustainable building, sustainable construction or green building have to be a closed chapter.

It is urgent to bridge the gap, to transfer knowledge from the research community to mainstream performers, especially to clients and project managers, and to implement corporate sustainability for making this knowledge transferring possible in the long run.

4 Indicators and assessment of sustainability aspects

4.1 Introduction

In order to verify that a building, i.e. the product, fulfils the demands of sustainability its performance has to be assessed by a practicable set of indicators. This chapter begins with an overview of indicators that could be used and their relationship with construction and sustainability. Different types of sustainability assessments and the enablers for such assessment from a stakeholder perspective are discussed. Finally, there is a review of tools for different assessment and evaluation methods in the face of one or more of the triple bottom-line requirements.

4.2 Indicators of sustainability

Technical specification ISO/TS 21929-1 (2006) set a framework and guidelines for sustainability indicators for construction works, where indicator is defined as quantitative, qualitative or descriptive measures. Sustainability indicators for buildings include aspects from the triple bottom-line of a building or a group of buildings. During the design stage in the construction process there may be predicted or simulated indicators and during the operational stage the indicators may be measurable. The choice of indicators should reflect the stakeholder interests and the goal or objective of the assessment.

The ISO/TS specification covers two types of indicators: direct or consequential indicators. Where the direct indicators address, ecological, economic or social impacts directly, the consequential address the consequences of such impacts and are useful in the case of building sustainability assessment. The latter could also address all triple bottom-line impacts. The use of the indicators should be set in a life-cycle perspective and accompanied by an explanation of how to obtain the value of the indicator

Ecological indicators address aspects such as loadings or impacts, for example the following consequential indicators:

- Building performance,
- Durability and service life of the building,
- Accessibility defined as ability of a space to be entered with ease, i.e. public transport,
- Location, and
- Building site

Economic indicators address monetary flows related to the life cycle economy of the actual building(s) exemplified as:

- Investment,
- Usage of buildings,
- Maintenance and repair,
- Deconstruction and waste treatment,
- Development of economic value of the building, and
- Revenue generated by the building and its service.

Social indicators should be used for describing the interaction between the building and sustainability issues at the community level such as the following examples:

- Quality of building as a workable and liveable place,
- Building related issues of health and safety,
- Access to services,
- User satisfaction,
- Cultural protection and architectural quality, and
- Possibility for social cohesion such as a mix of social and cultural groups or use of local labour.

Lützkendorf and Lorenz (2005) suggest similar key performance indicators, covering the triple bottom-line, to suit a building information system containing the information needed and from this base of information it should be easy to retrieve aggregated information depending on the purpose and kind of stakeholder.

There are difficulties with communicating sustainability indicators from a complex reality. Moffatt and Kohler (2008) mention two examples of attempts to quantify impacts of the natural capital; ecological footprint and The Natural Step. Ecological footprints convert flows into areas of productive ecosystems required to sustain the flows. The Natural Step compares material flows with global limits of regenerative and assimilative resource capacities.

Wealth account is also a possible indicator of sustainability on a national level, where measurements of man-made, human and natural capital are presented (Pearce, 2006). The account adds these assets and shows whether the national wealth is increasing or not. Value-adding indicates the contribution the construction sector makes to gross domestic product (GDP is the sum of all value-added across all sectors in the national economy). Pearce suggested such a national (UK) wealth account for the construction sector.

4.3 Environmental and sustainability assessment

Environmental impact assessment, EIA, of proposed projects has been used since the late 1960s and early 1970s and has now become a compulsory part in the development of greater facility projects (such as power plants and other infrastructure projects), as stipulated by the Swedish Environmental Code (2000). During recent years, there has been movement towards sustainability assessment (Pope et al, 2004). The aim of a sustainability assessment is to ensure an optimal contribution to sustainable development of assessed plans and activities. To assess sustainability there are three different approaches: EIA-driven integrated assessment, objectives-led integrated assessment and assessment for sustainability. The first approach, the EIA-driven assessment, originates from the traditional EIA at a project level complemented with triple bottom-line approach and with baseline conditions aimed at minimizing unwanted and adverse impacts. It points towards the direction for sustainability but the exact position is unknown – see Figure 4.1.

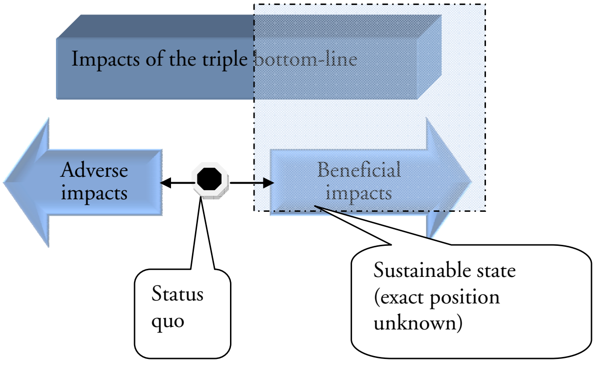


Figure 4.1 EIA-driven integrated assessments (adapted from Pope et al, 2004).

Secondly, the objective-led assessment was originated from the strategic environmental assessment (SEA) and is based on triple bottom-line visions or objectives, i.e. the assessment compares and maximizes the objectives with the assumed outcome of a project. This is a proactive and directional approach according to Pope et al (2004), but the exact position of the sustainable state of the project is unknown – see Figure 4.2.

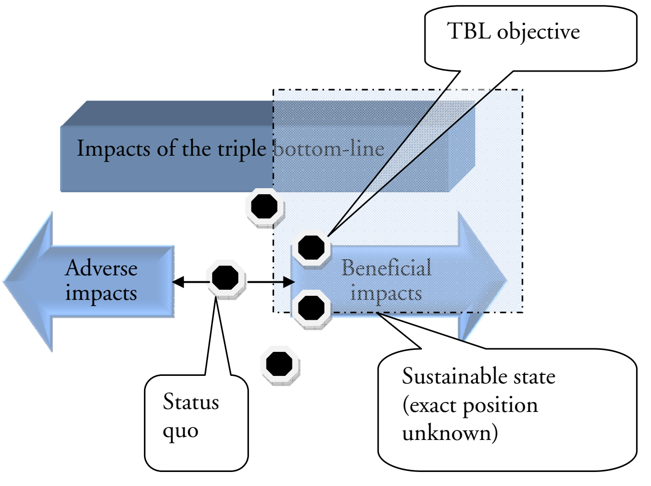


Figure 4.2 Objective-led integrated assessment (adapted from Pope et al, 2004) (TBL = triple bottom-line).

The third approach to sustainability assessment, suggested by Pope et al (2004) as Assessment for Sustainability, is a “process to determine whether or not a particular proposal, initiative or activity is, or is not, sustainable and therefore effectively becomes a yes/no question” (Pope et al 2004, p 607), simplified as the question “Are we there?” instead of assessing whether or not the project is heading in the right direction. This requires clearly defined criteria of the desired sustainability (society) goal for an actual project. It is recommended that the approach be used as an additional tool together with the two others when making a framework for ensuring sustainability outcomes of forthcoming project decisions.

The increasing complexity of assessing sustainability compared to ordinary environmental impact assessment (EIA) is shown in Figure 4.3, adapted from Hacking and Guthrie (2008).

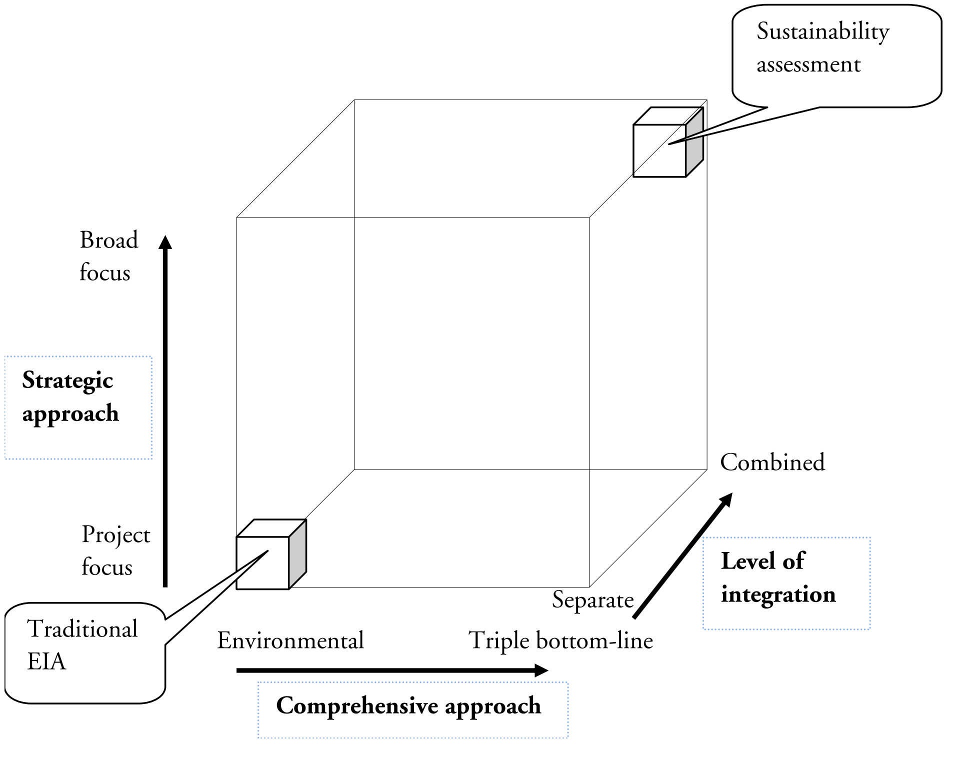


Figure 4.3 The complexity of assessment methods (adapted from Hacking and Guthrie, 2008).

A survey of the participants in the LEnSE project (Kornadt and Wallasch, 2008) showed that most of the participants (more than two-thirds) expected the time to perform an assessment covering sustainability of a typical residential building of eight units ought to be no more than two days (about half of the participants expected the time to perform an assessment to be no more than one day).

To enable sustainability in construction works there are three different types of interdependent and multi-dimensional enablers for making the stakeholders take action for sustainability according to du Plessis (2007). The enablers are technology, institutions and value systems and are informed by:

- Local need of development or human needs, and
- Local and global environmental limits or considerations.

The technology enablers consist of hard technology (e.g. equipment, material and processes), soft technology (e.g. systems or model that support decisions, assessments and evaluations), knowledge and information. To carry out the process of construction towards sustainability it is essential that the institutional enablers, e.g. government, authorities, researchers, professional associations and NGOs, adopt sustainability. There is also a need for re-evaluating the value systems to motivate people to act towards sustainability, du Plessis added.

To assess a facility it is necessary to formulate a definition of its performance. Facility performance could be defined as the "compliance of user/owner requirements with corresponding building characteristics and attributes" (Lützkendorf and Lorenz, 2005: p. 222) or simplified as behaviour in use. To extend this to a sustainability performance these authors include requirements of sustainability formulated by stakeholders.

There is a need for more participation from stakeholders if sustainability in construction is to become more natural or mainstream. Assessment tools developed so far were merely aimed at building-related aspects (Jensen and Gram-Hanssen, 2008). Today, the focus of assessment tools is to integrate stakeholders into the construction process, to concentrate on management and ownership and how to disseminate the new practices and processes in the sector.

4.4 Evaluation tools

There are a lot of useful tools, commercially available or under development, for construction works regarding the evaluation of triple bottom-line assessment. Most of these are focused on environmental assessment and economic evaluation. Lützkendorf and Lorenz (2005) argue that it is not appropriate to decide whether to use complicated or simple-to-use tools. It is important to use complicated tools and to decide how to present the assessment results to different users, e.g. construction professionals, households or other stakeholders. This section presents very briefly some examples of different tools.

4.4.1 Environmental impact assessment tools

These kinds of tools are divided into LCA- (life-cycle analysis) or criteria-based tools or a combination of the two. In spite of a powerful time-stretching (cover aspects over time) accounting approach, LCA is not well integrated into construction management, because of the limit of location variables (Moffatt and Kholer, 2008). The building site is a key variable of design and management decisions, e.g. the indoor environment of users which implicates aspects such as productivity, health, comfort and safety.

Edwards and Bennett (2003) present some LCA-based tools mainly for the design stage of a construction project – see Table 4.1. Boonstra and Dyrstad Pettersen (2003) mention a couple of criteria-based tools intended for existing buildings from various countries – see Table 4.2 and tools with a combination of LCA and criteria (SBIS, 2008) are shown in Table 4.3.

Table 4.1 LCA-based assessment tools (from Edwards and Bennett, 2003).

Tool	Country
Athena	Canada
Build-It	Germany
BEAT 2000	Denmark
Escale	France
LCA House	Finland
Eco-Quantum, Greencalc	The Netherlands
Eco-Effect	Sweden
Envest	UK

Table 4.2 Criteria-based assessment tools (adapted from Boonstra and Dyrstad Pettersen, 2003).

Tool	Country
NABERS	Australia
Miljöstatus	Sweden
Ecoprofile	Norway
Green Globes	Canada
HQE	France
CASBEE	Japan

.

Most of these tools are developed for the local market of each mentioned country (Edwards and Bennett 2003) and apply credit systems unique for each tool. There are some concepts of assessment leading to certification. A critical literature review of 16 of known and well representative environmental tools had been conducted by Haapio and Viitaniemi (2008). Their conclusions is that it is almost impossible to make a comparison between the tools. The economic and social aspects of the triple bottom-line are missing. The prediction of the service life of products and systems is a default without further comment or analysis, i.e. it should contain an analysis of maintenance and replacement aspects in the assessment methods.

Table 4.3 Combination of criteria- and LCA-based assessment tools (adapted from SBIS, 2008).

Tool	Country
GBTool	International
LEED, SpiRiT	USA
Equer	France
BREEAM	UK
OGIP	Switzerland
H-K BEAM	Hong Kong

A more general instrument for determining the environmental impact of materials, 'ecological rucksack', is mentioned by Wallbaum and Buerkin (2003). With this rucksack as input, it is possible to estimate resource productivity with the method of MIPS, a monitoring tool for material flows. COMPASS (companies' and sectors' path to sustainability) is a tool to provide the managers with sufficient information for integrated analysis and decisions. The ecological footprint (Rees 1999) is another method of estimating resource consumption. The footprint is expressed in the amount of land and water required to produce the resources consumed and to assimilate the generated waste by a specific population.

4.4.2 Economic tools

Evaluation of Life Cycle Costs (LCC) could be used in the sense of whether higher initial costs are justified or not by reductions in future costs (new building or replacement of elements in existing buildings) and if a proposed change is more cost-effective than the do-nothing alternative (Clift, 2003). LCC usually consists of initial capital costs, managing and operating costs, costs for maintenance and renovation and costs of deconstruction (Lützkendorf and Lorenz, 2005). Examples of some commercially-developed LCC-tools are presented in Table 4.4 (SBIS 2008).

Table 4.4 LCC-based tools (adapted from SBIS, 2008).

Tool	Country
Cost Reference Model	The Netherlands
BLCC, QuickBLCC, LCCID	USA
GaBi3	Germany
LifeCycle	UK

LCC has become a popular way of solving environmental issues such as recycling and demolition costs. However, Gluch and Baumann (2004) argue that this may not be entirely appropriate since the LCC tool was developed to rank investment alternatives, and not to consider environmental concerns. "It is important to emphasise that a traditional LCC does not become an environmental tool just because it contains the words life cycle" (Gluch and Baumann, 2004: p. 571). Cole and Sterner (2000) argue that the limited use of LCC depends on current design practice and data accuracy. The major role of LCC is to provide managers with a better framework for decisions and the evaluation of specific choices.

Total cost of ownership, (TCO), considers the total life-cycle of a facility where all the facility costs are taken into account during each of the phases below (Hodges, 2005):

- Planning, design and construction,
  - Client needs,
  - Space utilization,
  - Design and construction, and
  - Commissioning.

- Capital asset management,
  - Facility operation,
  - Planned maintenance,
  - Requested maintenance,
  - Emergency repairs,
  - Renovations,
  - Retrofits,
  - Upgrades, and
  - Improvements.

Another economic tool, often used to evaluate different investment alternatives, is cost-benefit analysis. Cost and benefits can be evaluated on a variety of levels, e.g. cost-benefit analysis (CBA), and social cost-benefit analysis (SCBA) (Barrow 1997). The most basic level is the purely financial analysis, which assesses the impacts of different alternatives on the organization's own financial cost and revenues. When it comes to assessing more than the purely financial impacts, a CBA or SCBA is often used, which tries to value the environmental, social and cultural impacts of different alternatives in monetary terms alongside with purely economic factors. These tools are often used to assess public investments, thus attempting to evaluate the full impact of different alternatives in monetary terms. In practice, it is hardly ever realistic to value all the costs and benefits of options in monetary terms. Most cost-benefit analyses will incorporate some additional items which are either not possible to value, or not economical to do so. But where the most important costs and benefits have been valued, the others can be set alongside and included in the decision process.

Some powerful stakeholders can use or provide fiscal economic instruments to promote sustainability in construction works. These instruments can be divided into 10 categories according to Drouet (2003):

1. Preferential credit conditions for sustainable buildings,

2. Reimbursement, rebate and investments aid offered by energy or water utilities, suppliers, equipment producers etc.

3. Preferential insurance conditions for sustainable buildings and new insurance products,

4. Setting up specialized funds for sustainable construction works,

5. Fiscal bonus for the construction or renovation,

6. Heavier fiscal burden on non-sustainable construction works,

7. Grants and subsidies,

8. Density bonus and/or accelerated building permit processing for sustainable construction works,

9. Business rating indexes including sustainable construction works management criteria, and

10. Trade of CO2-certificates.

4.4.3 Social and cultural assessment

According to Barrow (1997), there are techniques and methods of social impact assessment such as social surveys, questionnaires, interviews and available statistics. The latter include census data, nutritional status data and findings from public hearings, operations research, social-cost benefit analysis, marketing and consumer information, reports from social, health, crime prevention and welfare sources, and field research by social scientists. Among these, the use of census and demographic data tends to be the easiest and causes few challenges and problems. Environmental psychology issues of design and construction (Cassidy, 1997) point to the necessity of participation of stakeholders, especially the end-users, in the process of designing a construction project. One major aspect of the design, argues Cassidy (1997), is privacy, both the need for interaction and of not interacting. Optimization is also needed for homogeneity and heterogeneity in neighbourhoods and separation of different land use into commercial and residential areas. Designers should bear in mind better health, comfort, satisfaction, less crime and a peaceful existence.

4.4.4 Multi Criteria Analysis

In decisions concerning sustainability, multiple factors are involved. Multi-criteria analysis (MCA) establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved (Persson and Olander, 2004). The evaluation does not give an optimal solution because one single alternative is rarely the best when all criteria are taken into account. The MCA gives the best compromised decision regarding all relevant criteria. Multi-criteria analysis is one of the disciplines that have found fertile ground in environmental applications. Managing the environment implies dealing with dynamic systems that are only partly understood, with multiple interests and multiple actors, having long-term implications that range from the local to the global scale.

4.5 Conclusions

A tool to use indicators or key-figures to validate a construction works level of sustainability is to combine the standards of ISO 15392, the technical specifications ISO/TS 21929-1 and ISO/TS 21931-1. Another help is to use some of the key performance indicators suggested by Lützkendorf and Lorenz (2005). There are a lot of tools or combination of tools to assess whole buildings or part of buildings regarding the triple bottom-line of sustainability. To compare these tools with each other seems to be hard and most of them are 'snap-shot' assessment tools. A framework of assessment is necessary, objective-led, following the triple bottom-line and taking into concern of site-specific, corporate-specific and service-life issues.

5 Management systems

5.1 Introduction

Construction work is a complex task with a number of different actors each having different interests in dealing with multiple activities during a specific timeframe requiring the right level of quality to a specific cost on a given site (Landin, 2000). The possibility to change the outcome of the product (i.e. the building) during the construction process decreases considerably with time. Work is undertaken by a project based organization, i.e. the work start from zero on a new site with new combinations of performers and, although having a common goal, i.e. the building or facility. This demands a need of a system for managing the process from different perspectives. This chapter concerns environmental, quality, work safety, stakeholder and knowledge management, and their connections to sustainability issues in the context of construction works.

5.2 Environmental, quality and work safety management

The assembly of information relevant to a project is part of the requirements of the managerial system generally (Persson et al, 2008b). This is expressed in the set of international standards ISO 9001:2000 and ISO 14001:2004, which are commonly used in the construction sector. The complexity of the construction process means, however, that special measures are called for if the collection of relevant information, including the experience that has been gained and made available to those in need of it, is to function properly. The continual public debate regarding what takes place within the construction sector is considered by many to reflect flaws in the quality assurance system and the lack of a well-functioning system for collecting and distributing knowledge. There is, therefore, good reason behind the construction sector's endeavour to identify ways in which the functioning of these two systems can be improved

In Sweden at the beginning of the 21st century about 90% of construction companies with more than 50 employees had an environmental policy and about 80% had or were in the process of implementing an environmental management system, EMS (Gluch, 2005). An EMS addresses the process and that is probably the reason why it has gained acceptance in construction works. It regards sustainable development as a process and not an outcome. Gluch (2005) concludes that it is necessary to integrate technical and social aspects into environmental management, since individuals in an organization act from the existing social and organizational practices.

Quality systems based on ISO 9001 are accepted by companies within construction works, but certain parts of the standard are considered more important than others (Landin, 2000). These were found to be used more frequently in practice, and there were also parts that were misinterpreted. Landin (2000) concludes that there is a lack of connection between the quality systems and improvement of knowledge transfer and innovation in the construction sector.

Work safety aspects are well covered by legislation, especially in the case of Sweden in the Work Environment Act (2009) and related demands from the Swedish Work Environment Authority (Arbetsmiljöverket). This regulation contains a set of mandatory measurements.

5.3 Stakeholder management

Project stakeholders are defined as individuals and organizations who are actively involved in a project, or whose interests may be affected by the execution of a project or by a successful project (Olander 2006). A stakeholder could be any individual or group with the power to be a threat or a benefit to the project. The stakeholders can be divided into internal and external (Gibson 2000). Internal stakeholders are those who are members of the project coalition or who provide finance; the external stakeholders are those others affected by the project in a significant way (Winch and Bonke, 2002). An important part of the management of the project systems environment is an organized process to identify and manage the probable stakeholders in that environment, and determine how they will react to project decisions (Cleland, 1999).

The stakeholder dimension of sustainability is mainly to determining the social aspects of sustainability, in combination with the other triple bottom-line aspects. The social aspects of the project must be fully considered and integrated into decision making (Mahi, 2001). With regards to the social aspects, it appears that information between the stakeholders in a construction project is one essential missing part, especially regarding complex relationships and interactions related to sustainability issues.

The communication of sustainable issues can mean the difference between a successful project and a failure (Persson et al, 2008b). In order to obtain acceptance to construct a facility from various stakeholders, it is often a requirement to communicate the triple bottom-line impact that the facility will make. Communication should thus be seen as an essential part of the project manager's efforts to manage stakeholder interests with respect to the purpose of the project and to the impacts of sustainability that accompany it.

If the project management team, through communication, can create a working dialogue, it may be easier to pinpoint the real conflicts in a project and eliminate false conflicts and misunderstandings, thus reaching acceptance for the project (De Laval, 1999). In other words it is essential to know who the stakeholders are and their needs and concerns in relation to the purpose of the project. In the construction sector, stakeholders include a wide range of entities that directly or indirectly can provide support or resistance to the accomplishment of project objectives. Karlsen (2002) points out that there are at least four reasons for adopt a stakeholder management process. First, to be acquainted with the project's stakeholders; second, to ensure the balance between contribution and reward in the relationship with stakeholders; third, to plan and define how to manage stakeholder concerns; and last, to set a base for deciding which stakeholders are to be involved in determining the project goals and the measurement of success. As noted above, external stakeholders are those affected by the project in a significant way, but not directly involved in the execution of the project (such as neighbours, the community, the general public, and trade and industry).

There is a variety of methods for mapping different stakeholders with respect to their potential impact on project execution. Olander (2006) introduces the concept of stakeholder attributes where the potential impact from stakeholders depends on their possession of the attributes of power, legitimacy and urgency. Powerful stakeholders have the possibility to force their claims on the project. The legitimate stakeholders are affected by the project and bear some risk or benefit because of its implementation. The urgent stakeholders have claims that need immediate attention. It is not enough just to identify the stakeholders, there is also a need to assess their interest to impress their expectations on project decisions and if they have the power to do so.

To effectively manage stakeholder interests it is not enough to just identify their demands and needs. Project management must also identify the relative power different stakeholders have on the implementation of the project. A method to do this is stakeholder mapping (Johnson and Scholes, 1999). A tool in stakeholder mapping is the power / interest matrix (Figure 5.1) which analyses the following questions: How interested is each stakeholder group to impress its expectations on the projects decisions? Do they mean to do so? Do they have the power to do so? Olander (2007) gives examples of where the power/interest matrix has been applied to evaluating stakeholder demands in construction projects.

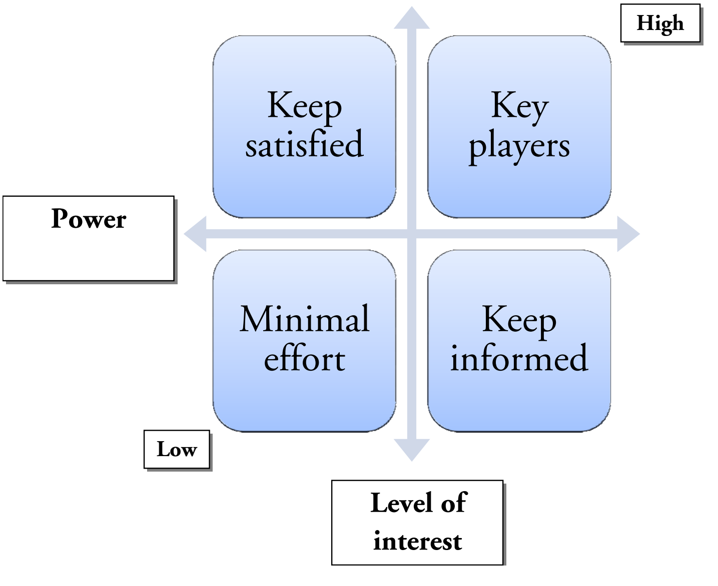


Figure 5.1 The power / interest matrix (adapted from Olander, 2007; Johnson and Scholes, 1999).

Often, both proponents and opponents to a construction project argue their case from the perspective of sustainable development (Persson et al, 2008b). This means that it is important for the project management team to clearly and openly evaluate all possible options to obtain the project purpose with respect to the relevant sustainable issues from the perspective of the project stakeholders. It is thus relevant for a construction project manager to have tools and methods to combine the goals and purpose of the project with the concerns and needs of various stakeholders with the triple bottom-line aspects of sustainable construction works.

5.4 Knowledge management

As sustainability issues increase total complexity in a construction project, the ability and knowledge of the project management team have to be deeper and broader. Knowledge, according to Persson (2006), consists of tacit, i.e. knowing but not how to explain, and explicit knowledge. In temporary organizations, such as those in performing construction work, knowledge of a specific project and the use of routine checklists often play a central role. Knowledge and information often need to be handed on to the next actor in a sort of relay race. It can be difficult at times for the craftsman to understand from explicit sources how a particular step in the construction process is to be carried out to satisfy the demands for sustainability. Tacit knowledge can play a major role under such circumstances, meaning doing what one is accustomed to do, without studying drawings or written materials. The willingness to work in this way (i.e. figure things out on the spot) can be a positive trait, especially when no drawings or descriptions of the exact procedures to carry out are available. Yet, it can lead to insufficient precision and result in quality, environmental and sustainability requirements not being met (Persson, 2006).

As mentioned in chapter 3, knowledge management is very closely linked with corporate sustainability, but there is a lack of methods to implement this successfully. STEPS (Start-up, Take-off, Expansion, Progressive, Sustainability) maturity roadmap – see Figure 5.2, developed by Robinson et al (2006) is a proposal for a structured approach to benchmarking and implementing knowledge management efforts. It is a strategy for development in order to attain a higher level of maturity regarding a construction organization's tacit knowledge.

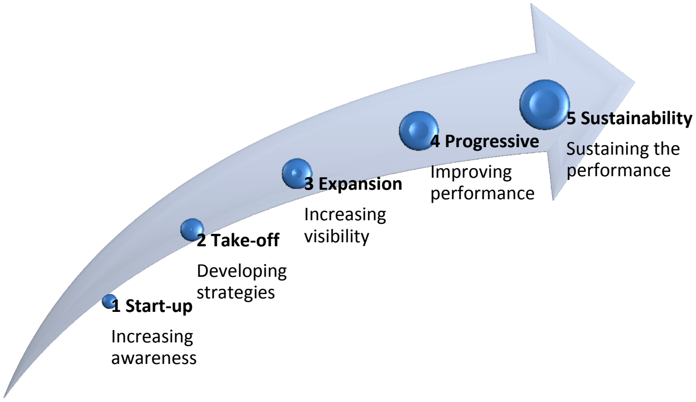


Figure 5.2 STEPS maturity roadmap (adapted from Robinson et al 2006).

The STEPS maturity roadmap contains the following:

1. Start-up – increase the awareness of benefits for business improvements,

2. Take-off – develop a strategy and working definition to knowledge management including structure, resources, identify barriers and risks,

3. Expansion – increase visibility of knowledge management leadership and initiatives. A structure to implement and change of management for addressing barriers and risks,

4. Progressive – improve the performance of knowledge management activities. Measure and monitor the performance to verify the knowledge management strategy, and

5. Sustainability – sustain the performance of knowledge management activities; expect to be a normal routine in the entire organization.

From a case study conducted by Robinson et al (2006) of eight large construction companies in the UK of which four could be considered international, the latter were somewhere between steps 2 and 3 and the remaining four national companies were around step 1. This may mean that these large international construction companies have a greater need to manage their knowledge because of a more diverse and dispersed nature of the knowledge in their organizations.

A sustainability strategy starts with the facility manager of the organization, according to Hodges (2005). He (or she) is the key performer when it is a question of implementing sustainable strategy and the starting point is to understand the organization´s philosophy and handling of finance. The next step is to develop a strategic plan for sustainability including (compare the similarity with the implementation of ISO 14001):

- Evaluation of the organizations attitude to the triple bottom-line,
- Completion of a SWOT analysis,
- Develop a sustainable mission, vision and values, i.e. the sustainability policy,
- Develop objectives to support the policy,
- Develop an assessment process, i.e. how to handle the measurable targets connected with the objectives and including evaluation of LCC and the total cost of ownership (TCO) of construction works, replacement and repair systems,
- Define the critical factors of the strategy, and
- Communicate the strategic plan to all stakeholders

Then it is time to implement the strategy, first with a small socially-driven, low-cost programme, continuing with implementing green practices in planning, design and construction followed by continual evaluation of LCC and TCO alternatives.

5.5 Conclusions

To meet the holistic conditions of sustainability according to ISO 15935, it is crucial to implement a platform of multiple corporate management systems such as those focused on quality-, environmental-, work safety-, stakeholders-, and knowledge into an integrated system of sustainability in construction works. By utilizing the STEPS maturity roadmap, it is possible to achieve continual improvement in knowledge management in a 'many-small-steps' approach combined with development and implementation of a sustainability strategy suited to the company's ability and level of knowledge is essential.

6 STURE – a model approach

6.1 Introduction

As mentioned in chapter 4, there are various tools for assessing a project's level of environmental impact. Most of them are tailor-made for a certain region with the focus on assessing the final product, i.e. the building or facility (Ding, 2008). The tools are designed to assess different types of buildings and different phases in the life cycle with reliance on different databases, questionnaires and guidelines (Haapio and Viitaniemi, 2008). To compare these tools is difficult, probably impossible and there are almost none which address the whole spectra of sustainability. Furthermore, there is a lack of tools or methods dealing with the process from the perspective of the client's desired level of sustainability.

In this chapter, a model approach is described with respect to a client's desired level of sustainability in projects covering from construction works life-cycle to construction work process. In the end of this chapter, it is an example of a sustainability assessment method of a construction works site.

6.2 STURE - a model approach

An assessment model, the Stakeholder-Urban Evaluation model (STURE) has been developed. It began as a purely environmental construction work project management model (Persson 2001), then improved with additions such as considering the triple bottom-line of sustainability, the sustainability construction works concept, considering stakeholder influences and demands, considering usefulness of environmental or sustainability assessment tools, and links to other facility developments or processes (Persson, 2002; Persson, 2003; Persson and Olander, 2004; Persson et al, 2005; Persson et al, 2008b). All this additions was made by using and adapting the model in different real construction works projects, some of them described in chapter 7.

STURE covers the soft technology enablers of sustainable construction works mentioned in chapter 4 and could be described as an objectives-led integrated assessment applied at the project level. However, it also could be the prototype of a sustainable assessment method of the kind suggested by Pope et al (2004), if sustainability criteria for an actual project were developed. The model is a way of systematizing the issues of sustainability in construction works in accordance with principles of an environmental management system (EMS), se chapter 5, combined with empirical studies of stakeholder management (Olander 2007). The model optimizes the sustainability objectives and targets of a client's management organization and the specific conditions of an actual project and the particular site of the project. The model has been developed with the aim of structuring different sustainability aspects in order to evaluate the development of new and existing construction works based on the requirements and needs of stakeholders. It is supported by literature studies on stakeholders, sustainability, environmental and EMS issues. The international standard for EMS, ISO 14001:2004, is the basis of the structure of the model and with terms of environmental (sustainability) objectives and environmental (sustainability) targets defined by the standard. Other terms used are also similar to the standard.

The principle of STURE (Figure. 6.1) can be described by four steps: *stakeholder analysis*, STURE conditions by *specific conditions* for the actual application, *general conditions* that need to be addressed and the *sustainability programme.* The last step acts as a synthesis of the other three and the concept corresponds to ISO 14001. The information gathered in these steps is then used as input to a relevant application, e.g. plan of operation and maintenance for a real estate company or an analysis of alternative solutions in the design and location of a new facility.

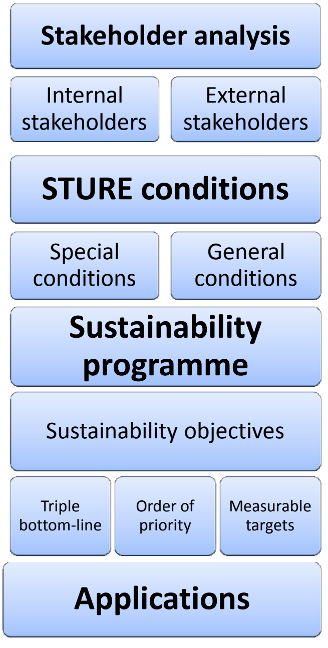


Figure 6.1 The STURE model (Adapted from Persson, 2003; Persson and Olander, 2004; Persson et al, 2005).

6.2.1 Stakeholder analysis

A stakeholder analysis is to identify the stakeholders and their claims on the project. When identifying stakeholders it is not enough to focus on formal structures of project organisation. It is also necessary to have a look at informal and indirect relationships between stakeholder groups and to assess their importance and to identify the relative power different stakeholders has on the implementation of a project (Johnson, Scholes 1999), see chapter 5. The stakeholder analysis should consider the following aspects:

- Identify all potential stakeholders, external as well as internal,
- Assess each stakeholders claim on the project, are they proponents or opponents in relation to the goals of the project, and
- Assess each stakeholder's interest and power to influence project decisions.

The power/interest matrix (see chapter 5) is a useful tool to conduct the stakeholder analysis. Some powerful stakeholder can also use or provide economic instruments to promote sustainability in construction works, according to Drouet (2003), see chapter 4 for further details. From this analysis STURE conditions as the external demands on the project, general conditions, as well as the internal demands, specific conditions, can be specified, see below.

6.2.2 STURE conditions

STURE conditions are divided in two categories; general conditions and specific conditions. The general conditions include a client's activity and organization's project-related issues directly linked to the organization and the way it functions. An important part is the client's *environmental policy* and the related relevant objectives and targets of the environmental management system. The general conditions of the client also include conditions from relevant economic activities, generated social impacts and general project descriptions, standard solutions and standard blueprints. Other conditions are the concerns of the client raised by external stakeholders and legal and regulatory boundaries set by government and authorities.

The specific conditions contain parts of the *sustainability review, significant sustainability aspects* and *documented decisions* made during the process of construction works development.

The sustainability review is an assessment of the conditions specific to the final product, the site and the surroundings of the site of a construction works described in triple bottom-line terms. Input to this review is the demands of the client and other internal stakeholders relevant to the specific facility development. An evaluation of sustainability impacts is undertaken with this review as the base. Significant sustainability aspects are set from this evaluation according to the definitions in ISO 14001.

As the documented project decisions during the process of a construction works development changes, so do the conditions for the final outcome (e.g. property development, product- or project finish). During this process of changes, the conditions for the sustainability review also changes on a continuous basis and this is important to have in mind when assessing the sustainability review. This could also affect the sustainability programme, see below.

6.2.3 The sustainability programme

The sustainability programme is the outcome of an optimization of the specific and the general conditions. It consists of three parts: *sustainability objectives, priority of sustainability objectives and sustainability targets.*

The sustainability objectives depend on the specific and general conditions. An optimization of these conditions, with respect to the purpose of the construction works development, the site and concerns of internal and external stakeholders, defines the sustainability objectives in terms of the triple bottom-line. This part decides the direction of the development from a sustainability perspective, i.e. it formulates the main thread of the development as regards sustainability.

Priority of the sustainability objectives is a relative order of preference of sustainability objectives because of preparation for forthcoming related conflicts and to meet other impending demands during the process of the construction works development.

The sustainability targets are sustainability objectives differentiated in detailed and measurable units. The methods of verification of the measurable targets are established, preferably with standard measures adapted to the project. It is, however, possible to adjust the targets and, when a change in significant conditions occurs, the objectives during the process of development. This should be verified with confirmation in connection with documented project decisions as mentioned in section 6.2.2.

A plan of sustainability checks should be drawn up by all players involved in the development process, based on the verifiable sustainability targets and other quality requirements. The aim is to verify all the sustainability targets according to the verification methods mentioned in the sustainability programme. Divergence and change of verification are a part of the documented decisions. The plan of sustainability checks should be a part of the plan of quality checks.

6.2.4 Applications

The design of STURE makes it possible to adapt on several applications connected to construction works. The sustainability information from the model is possible to use in a continuous sustainable real estate management as, for example, basics for operation and maintenance, input to the organization's environmental management system and information to users, tenants and to other important stakeholders.

The verifications act as the basis of the final documents for the project together with other documentation related to the project. From the final documents, sustainability information for the project is able to find its way to the property owner's organization for operation and maintenance, to users and to tenants, according to the organization's environmental management system. Furthermore this sustainability information can be used as input to sustainability indicators.

Another possibility is to use the model and the evaluation tools for a sustainability decision of alternative choices of methods, systems or components. The sustainability programme is a valuable input to MCA, EIA, LCC, CBA and other evaluation tools in order to make choices between different alternatives. It is also possible to use the model and the toolbox for a single sustainability facility inventory or a more continuous sustainable real estate management.

6.3 Assessing sustainability aspects of the site

The uniqueness of construction works can be of two kinds: the facility (the product) and the site where the facility or building is situated. The site or the location of use of a building is a key variable of design and management decisions (Moffat and Kohler 2008). When the building addresses aspects such as energy use, indoor climate and material productivity, the site of a building addresses aspects on both local and regional levels. Examples of local aspects are urban microclimate, accessibility to neighbourhood buildings, security and local biodiversity. On the regional level there are examples of aspects as community demands, transportation systems, air quality, public health and emergency preparedness.

Most of the assessment tools mentioned in chapter 4 focus on the product and very few, if any, assess the particular site. In accordance with a conventional EIA, e.g. as described in the Swedish Environmental Code (2000), it is possible to modify an EIA into a simplified triple bottom-line sustainability assessment of a construction works site, i.e. an EIA-led integrated assessment. Persson (2001) proposed such a simplified sustainability assessment as given below and this assessment is used in chapter 8 for STURE case studies. This simplified site assessment is easy to include in the specific conditions (concerning the specifications of sites in question) of a STURE evaluation. Tables 6.1 to 6.3 shows the aspects of the triple bottom-line in the assessment.

6.3.1 Ecological aspects

Ecological aspects of the assessment procedure are shown in Table 6.1

Table 6.1 Ecological aspects (from Swedish Environmental Code, 2000; Persson, 2001).
Geology and hydrology.

Topography	The conditions of the surrounding landscape´s effect on the site.
Type of soil	The conditions of the nature of the ground that effect the site
Wet areas	Risk of water penetration
Polluted ground areas	High risk with demands of and costs of decontamination
Water areas	Conditions for recreation, for rich flora and fauna and opportunities for eco-cycling
Wetland areas	Conditions for recreation, for rich flora and fauna and opportunities for eco-cycling
Ground water level.	Ground effects on the site, conditions for recreation, for rich flora and fauna and opportunities for eco-cycling

Flora and fauna.

Biotopes	Occurrence of trees worth protecting (in general and for the actual site)
	Occurrence of plants worth protecting (in general and for the actual site)
	Occurrence of animals worth protecting (in general and for the actual site)
Biodiversity	Conditions for preservation of biological variations of trees, plants and animals
Panhandles and swathes	Conditions for continuous green panhandles for plants and animal biodiversity

Climate and air quality.

Normal variation of climate data on annual-, seasonal- and daily basis	
Wind and shelter	Conditions affecting the orientation of a facility and the base of the facility's energy system
Sun and shadow	Conditions affecting the orientation of a facility and the base of the facility's energy system
Damp or dry	Conditions affecting a facility's construction and energy system
Cold or warm	Conditions affecting a facility's construction and energy system
Air pollution	Conditions affecting a facility's indoor climate

6.3.2 Economic aspects

Economic aspects of the assessment procedure are shown in Table 6.2.

Table 6.2 Economic aspects (adapted from Swedish Environmental Code, 2000; Persson, 2001).
The cultural part.

Land use	
Historical use	What was the land used for in the past?
Archaeology	Extent of archaeological content
Present use of the land	
Surrounding buildings and facilities	Presence, extension and ages of surrounding buildings for housing
	Presence and extension of surrounding industries and of risk of expected disturbing emissions
	Presence, extension, age and type of activity of other surrounding buildings and facilities with risk of expected disturbing emissions

Local construction tradition	The characteristics
Conveyance	Former important roads, paths and sea lanes for transportation of goods and persons

Existing infrastructure.

Heating	Existing systems of central heating supply
Water	Existing systems of water supply
Sewage	Existing systems of sewage and drainage
Body of water	Existing water area for buffering sewage and drainage
Roads	Existing roads
Waste management	The community's local handling of waste
Electricity	Supply systems and the local owner of the network

Broadband	Local networks and operators of the networks
Telephone	Local networks and operators of the networks
Mobile phone	Networks and operators of networks
Broadcasts	Networks and operators of networks

Existing conveyance.

Traffic	Main typicality of traffic, traffic security measures and traffic intensity in the surroundings
Transportation of the surroundings	Typicality of existing transport and intensity of transports of hazardous materials

Market aspects.

Market values of surrounding properties	
Taxation values of surrounding properties	

Demand and supply of similar properties	
Level of rental agreements of commercial properties	
Level of rental agreements of similar types of flats	

6.3.3 Social and cultural aspects

Social and cultural aspects of the assessment procedure are shown in Table 6.3

Table 6.3 Social and cultural aspects adapted from Swedish Environmental Code, 2000; and Persson, 2001).

Human needs.

Territory	Prerequisites for private, semi-private, semi-public and public zones
Security	Information concerning and amount of the most commonly crimes perpetrated in the neighbourhood
Well-being	Factors concerning the turnover of tenants and of commercial premises in the neighbourhood
Comprehension	How the design of the surroundings could be explained, the ease of orientation and the ease of understanding, operate and maintain technical systems of importance
Accessibility	The level of accessibility for disabled persons to the actual site and generally in the neighbourhood
Flexibility	Are there needs for flexible solutions of importance in the actual project?

Affinity.

Groups	The basis of division of groups in the neighbourhood
Common facilities	The selection of facilities for common activities and meeting-points in the neighbourhood
Service	The selection of service facilities in the neighbourhood
Urban life	The supply of culture, sport, amusement, commerce, nature etc. in the region
Participation	
Aesthetics	

6.4 Conclusions

A model where the client's ability and desired level of sustainability is included within construction works is an important part of the discussion of improving the future impact on our environment and our well-being regarding construction works. The developed STURE model is such approach to optimize the sustainability demands and abilities of a client, stakeholders and authorities relevant to a single or multiple construction works.

Assessment regarding a construction works site and its surroundings is fundamental because of the specific conditions a particular site and its surroundings influences the construction works performance and vice versa. A simplified assessment method based on a regular EIA-concept is a site specific complement to STURE´s specific conditions. Thus, STURE need to be validated with a well-defined constraint regarding sustainability and construction works as ISO 15932, see chapter 3.

7 Case studies

7.1 Introduction

The selected case studies are adopted from different projects in different stages of a construction works life-cycle, see Table 7.1.

Table 7.1 Chosen case studies.

Case study	Art of case study	Construction works stage
A	Residence buildings and student flats	Exploitation phase
B	A new office building	Design and construction phase
C	Residence and commercial buildings	Maintenance planning project for a real estate company
D	Residence buildings	Maintenance and refurbishment project with construction work during tenants use.
E	A coal and oil based power factory	Dismantling project in the procurement phase

The aim is to apply on-going construction works to the STURE model from chapter 6, and if these could be connected to the arguments of sustainability described in earlier sections. This chapter contains a brief presentation of the chosen case studies.

7.2 Case study A – Exploitation project

Between a local authority in Southern Sweden and four main clients, an agreement of cooperation was made concerning exploiting a part of community owned ground for future resident buildings. The four main clients were allotted by the local authority to the main part, but there were two minor parts left to other developers to build student flats, flats for rent, social housing and a kindergarten. A contest to allot these two parts was announced by the authority. The winner of the contest was allowed to develop the part in accordance with the winning proposal. This case describes how the contest of ground allotting was evaluated by the authority with focus on sustainability.

A request was made by the local authority to clients that previously had announced their interest to develop and construct resident buildings in the community. About a dozen clients were positive to participate. All participants were informed of the contest´s rules and guidelines including demands and limitations. The two areas allotted for the contest were; Area A, which was assigned to 70 to 90 student flats, and area B, which was assigned to resident buildings with 50 flats for rent and one part of social housing.

For limitations there were restrictions of design, sizes and the mix of sizes of the buildings. There were also restrictions in noise levels and regarding parking norms. Further on, there were special programs of accessibility and environmental demands that was mandatory to fulfill by the developers for an acceptable submission. In the environmental program the demands were divided in design and construction stages with subheadings as durability, environmental impact, health, comfort, protection of damage from damp, protection from noise, energy savings and conservation of resources. There were also demands how to prepare to manage operation and maintenance and how to manage a follow up during the second year of tenant use. The submitted proposals had to include a drawing of the area with proposed buildings, external (facades and cross-sections) and internal (ground plans) drawings and a program of how to deal with the environmental demands.

The participated clients were free to submit proposals to one or to both areas. The client of the winning proposal had to be prepared of developing the area together with the local authority with regards to the proposal and to follow the preliminary time schedule set by the authority.

7.3 Case study B – Construction project

This case study is about how the environmental program for an office building was developed and implemented in the construction work process.

The construction project was a commercial building for offices of about 4000 m^2 situated in southern Sweden; the West Harbour district in the city of Malmö. The client was a real estate company, owning considerable number of real estates in the southern part of Sweden. With the international standard of environmental management system, ISO 14001, as basics, the company had developed an environmental policy and was working with environmental programs in all major construction and maintenance projects.

The major tenant for most of the available space of the office building was involved in the design process at an early stage as the rental contract with the client was signed. The tenant´s organization comprises of skilled and experienced personnel in environmental issues regarding buildings and the construction work process in general. In the rental agreement between the tenant and the client there were several conditions from the tenant's requests regarding environmental issues of the building. These requests had to be coordinated with the conditions of the real estate company's environmental programme. During special project sessions with focus on environmentally issues held within a month due to the ongoing work of the design team, both the tenant and the client agreed of the following:

- The general rules of considerations from the Swedish Environmental Code (2000) are fundamental in the project,
- Reduce the number of environmental objectives to three objectives, prioritized in relative order,
- Make descriptions of the environmental objectives according to the client's standard,
- To use digital documentation and verification,

- Formulate environmental targets according to the standards of a commercial Swedish tool of environmental considerations in construction design, Miljömanualen, and
- The tenant compiles proposals of environmental objectives and the client compiles proposals of environmental targets.

The final environmental objectives were agreed and prioritized as follows:

- Create a healthy indoor environment,
- Minimize the capacity utilization and only use renewable energy sources, and
- Avoid using materials that is dangerous or hazardous for health and environment.

From these objectives there were several environmental targets formulated to each of the objectives above and according to the systematic of environmental tool mentioned earlier, Miljömanualen.

7.4 Case study C – Maintenance planning project

This case concerns a small real estate company with six real estate properties situated in a minor city in northern Sweden. One of the properties was a commercial office building of approximately 3700m^2, and the other five properties were apartments for rent, of approximately 9700m^2. The buildings were erected between 1950 and 1972. The company had neither an environmental management system nor a quality system. The operation and maintenance responsible was procured and preformed by a contractor. The rental notifying was also on a contractor. The economic administration and accountancy were within the real estate company's organization. The aim of this project was to try to plan the company's future maintenance works of the properties within a frame of sustainability concerns

An environmental assessment was carried out with a Swedish tool "Miljöbedömning av fastigheter", (Environmental assessment of real estate properties) developed by a Swedish consultant company, It was one of a few Swedish commercial environmental assessment tools concerning buildings and construction. The tool was based on a number of environmental checkpoints of a building and its surroundings which was performed by a certified reviewer. The results of the performance were then evaluated according to certain environmental criteria based on Swedish national legislation, recommendations and standards by national authorities.

Evaluations were made in twelve different groups divided into Indoor environment and Outdoor environment as follows:

Outdoor environment contained:

- Biodiversity,
- Water consumption,
- Energy consumption,
- Hazardous waste (waste of environmentally hazardous components and substances, regulated by national legislation),
- Dangerous waste (other environmentally hazardous waste, not regulated by national legislation), and
- Recirculation of components and materials (re-using components, reclaiming materials and recovering energy).

Indoor environment contained:

- Tenants' questionnaire (a qualitative questionnaire of the tenants' subjective experience of the indoor environment of the actual building),
- Electro-magnetic radiation (measured),
- Noise,
- Light,
- Radon radiation (measured), and
- Indoor climate.

Every single group collects individual points depending on the assessment evaluation. The groups are then put together by individual weight on a scale between 1 and 10, with a distribution of 6 points from the Outdoor Environment groups and 4 points from the Indoor Environment ones.

The final result of the review was an environmental classification with a score, in relative terms, between 1 and 10, where the lower number indicates a poor environmental status for the building and the higher number indicates otherwise. This method did not contain LCA's (Life Cycle Assessment), but the evaluation of the performance results was made with a lifecycle perspective. The result of the assessment of the case's six properties were classifications between 5.94 and 7.06, see Figure 7.4.1. This indicated a fairly good environmental status. A result scoring by 7 to 8 was generally considered very good by this method. A result scoring by over 8 of a "normal" building was almost impossible to reach. If the commercial building was excluded, the results of the remaining actual buildings exceeded the score of 6.5 each.

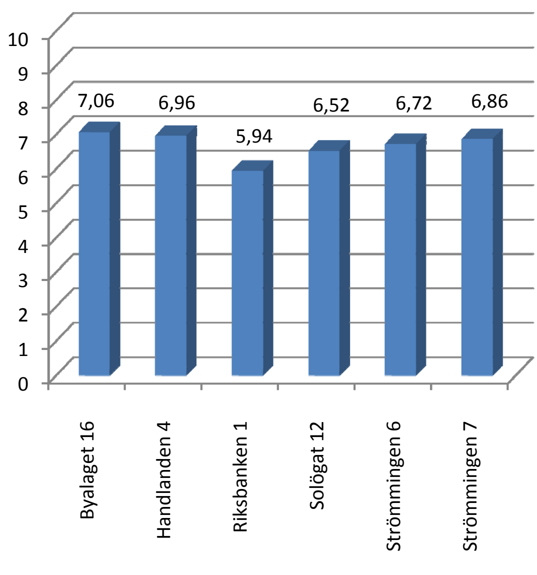


Figure 7.4.1 The final classification of the environmental review by "Miljöbedömning av fastigheter" (Persson 2003).

The commercial building, Riksbanken 1, was erected in 1972 and all the others between 1950 and 1963. This indicated a possible difference in materials between the commercial building and the others. A lot of new materials were introduced in the building sector in the late 60's. The knowledge, compared with today, of the behavior of these materials was limited regarding aspects of human health and environmental impact. Thus, compared with the elder buildings, the commercial building contained, with certainty, plenty of these new and environmentally hazardous materials.

The main question was what sort of environmental criteria were the most important, or which were the most significant environmental aspects (ISO 14004) of the real estate company's properties? Through an evaluation of the groups mentioned above in relative comparisons of the six properties, see Figure 7.4.2, energy consumption, environmentally hazardous waste and indoor climate were the most significant environmental aspects.

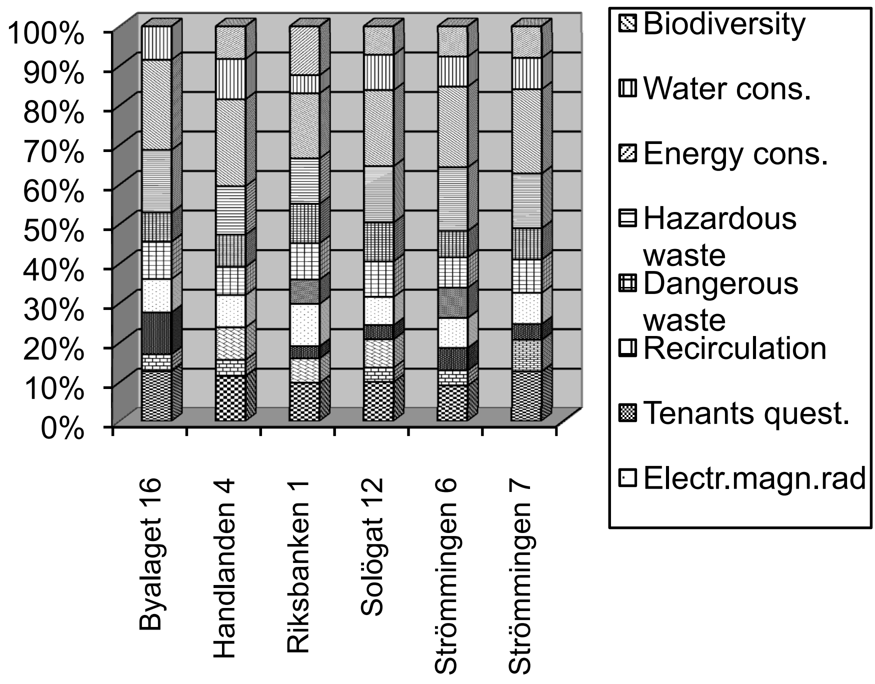


Figure 7.4.2 The evaluated groups in relative comparisons of the six properties (Persson 2003).

7.5 Case study D – Maintenance and refurbishing project

This case was a construction work concerning maintenance and refurbishment of two nine store resident buildings with 81 flats divided by three stairwells each, i.e. a total of 182 flats. The owner of the buildings was a local real estate company. The buildings were erected 1958-1959. The construction work included replacement of windows, maintenance of balconies, maintenance of facades, refurbishment of bathrooms and replacement of sewing pipes. The building was in occupancy during the refurbishment work.

The client (the real estate company) had an approved environmental policy for the organisation, which was used by the operation organisation and by the construction project teams. The construction project department had also developed standard proceedings regarding re-construction and refurbishments.

Previous attempt to perform maintenance work such as installing new lifts, replacing stairwell and maintenance of balconies were refused by the tenant´s committee. During the years ahead, more maintenance work with urgent prioritizing were discovered, especially the frequency of damp related damages in bathrooms and kitchens were increasing during the last five years. About twenty flats had to refurbish due to leaking water pipes, blockage in the sewage system or leaking floor drains. These kinds of damages were not only affecting the concerned unit but also adjacent units. This time, the tenant´s committee had proposed a maintenance assessment to the client. The client did the assessment and established an action programme. The tenants reacted positively on the programme and approved to the following measures:

- Replacement of water and sewage piping in the bathrooms,
- Refurbishing of bathrooms,
- New safety equipments of the electrical system in the flats,
- Replacement of unit entrance door,
- Replacement of windows and balcony door,
- New kitchen fans, and
- New surface in the lift cages and sound insulation of the lift machine room.

Some of the tenants were eager to have their kitchen refurbished and proposed this work should be included in the project. But the cost estimation seemed to be too high and the client decided not to include this work in the project.

A number of house meetings were made where the client informed and discussed details of project performance with the tenants. In average, 80 to 100 representatives from 180 flats were present at the meetings. The client announced a rent rise of 3.5% due to the measures included in the project. The argument was that there were some elements of work in the project that lead to increasing flat standard. After negotiation, the tenants approved to the rent rise. A very important demand from the tenants was a continuous use of the flats during the performance of the work. This implied interference of use of the flats according to the rental agreement. The Swedish Housing Act supports the tenants of such interferences by compensation of lower rent during the time of interference. The client offered a rent free month based on the estimation by every flat of three weeks of refurbish works and total one week cleaning, restoring and adjusting works. The Swedish Housing Act demands if a major maintenance or refurbishing work is to be performed, all concerned tenants, e.g. those with valid rental agreement, have to sign an approval agreement of the work. The client secured agreements from every tenant and the project was ready to be preformed.

The total time to perform the work was 7 ½ months, from middle of February to the end of October. The tenants were notified a week in advance before work will commence. The final compensation to the tenants was 1.5 month rental free use of the flat. Concerning works in the lifts, there was a necessity of closing for one week (Monday to Friday). In case of a tenant needed help with transportation, the client had an agreement with the fire brigade for transportations of people in stairs. Fortunately, no such help was needed.

The contract work was as a functional contract work and maximum 36 craftsmen were involved in the performance. The client had a project coordinator situated at the contractor's site office, who dealt with issues regarding the tenants and the contractor's performance. This was an experienced janitor and was available during work hours and on Mondays one hour after work. He also helped and coordinated the tenants with add-ons besides the contract work. Furthermore, he was assisting the tenants, especially the elders, with moving furniture between the flats and the flats' store rooms. This solution with a project coordinator on site was very appreciated by the tenants and became a very good link between the client, tenants, involved contractor and sub-contractors. This solved big problems for the tenants, but for the project performance it was matters of minor importance. Information between tenants and the contractors' site management was more simplified due to more informal way of communicating at the site office with the presence of the project coordinator on site. Even when the share of elder tenants (more than five persons between the age of 80 years - 92 years) in the buildings was high, their attitude was very positive and they were expecting a more temporarily way of living in their flats during the time of performance. The cooperation between the client and the public welfare was good. The client had also a furnished overnight flat available for tenants when the work in the flat was too busy for the tenant. This flat was randomly used and most during the days, but in the last stair well, the demand for such flats increased to four full booked flats. As a summary, the client considered the performance and the result of the project was overall to the tenants satisfactory and the dialogue between the tenants and the client was extensive, this due to the solution of site coordinator.

7.6 Case study E – Dismantling project

This case concerns a dismantling project of a former power station in southern Sweden. The aim of the project was to dismantle the power station's interior of old coal- and oil-based power equipment and retain the cover of the building for a future new gas technology power and district heating plant. The aim of the case was to steer the procurement of the dismantling contractor to a performance which met the principles of sustainable construction works and the client's ISO 14001 certified environmental management system with its environmental policy. The client was a power supply company with considerable amount of power plants within Sweden and in Northern Europe.

The operation of the power plant stopped in the 1970's and the equipment remained more or less untouched the last 30 years. There were three elder and two newer combustion boilers making steam for the turbines which generated electrical power. The three eldest was solely on coal based fuel, one of the newer was converted from coal based fuel to the use of oil and the newest and biggest boiler from the mid-60's was made for oil fuel only. The majority of the power plant equipment was originally from the 1950's, except the newest boiler, and this indicated a large presence of hazardous materials.

An extensive investigation of environmentally hazardous and dangerous components and substances was carried out, where the hazardous components and substances were defined by Swedish Environmental Code (Avfallsförordning, Ordinance of waste, 2001:1063). The hazardous (see definition in section 7.4) waste included asbestos, oil contaminated materials, organic contaminants from coal and oil combustion, mercury, polychlorinated biphenyls (PCBs) and acids. The dangerous waste (see definition in section 7.4) included led, copper, phthalates (plasticizers), brominated flame retardants, arsenic, and the metals of vanadium, nickel and zinc. From the envelopment of the boilers there were 30000 meters of sealing, 2000 meters of sealing in sheet metal channels, 2100 valves and 4700 meters of pipes containing asbestos. Further on, there were more than 500 electrical pumps containing copper and oil, 6400 meters of copper rails and 4300 meters of copper pipes. Electrical wires in different sizes containing copper, led and PCBs was estimated to roughly 365000 meters at the whole site.

In this investigation a rough fractionation and division of ecocycle content was also defined. The totally recyclable content of iron was app. 11000 tons, of copper 340 tons and aluminum and led about 20 tons each. Further on, there was app. 2000 tons of brickwork in the combustion boilers to be recycled. A detailed program of how to handle and verify the handling of the different fractions was made.

During the pre-procurement phase of the project numerous project meetings were held where the demands of the client and the stakeholders were set. There was also a design stage where the technical preconditions of the demolition performance were investigated, evaluated and designed. In the procurement documents there were besides the sustainability demands, see chapter 8, also demands of relevant education of environmental skills for the contractor's personal and demands on preventive measures as emergency plans and availability of relevant equipment in case of accidents during performance. During performance, demands were also on preventing pollution to the surroundings by water, air, noise and vibrations when handling the dismantled equipments on site. Restrictions were also made regarding chemical products and materials that could be used when handling the dismantled equipments on site. All chemical products in use have to be documented and approved by the client.

The client was to be allowed to make assessments on site to follow up the demands stated in the contract. The contractor was procured internationally and was handled by the client's procurement department.

7.7 Conclusions

Five cases from construction works are going to be used as case studies input to validating the STURE model in line with the principles of the ISO 15932 standard. The case studies are of different phases in the life-cycle of construction works and they are also in different stages of construction process. Further on, the cases represents buildings with different functions.

8 Validation of sustainability management model

8.1 Introduction

Sustainability in construction works is an issue of great global and local importance. As the building sector is a considerable contributor of global resource depletion (e.g. Rees 1999, Lorenz et al 2008) and many of the industrial countries have set national strategies of sustainable development to measure the national or regional share of the global depletion (Atkinson 2008). The concept of sustainable development set guidance measures with the content of correction of market failures, ensuring regenerative capacity of renewable resources, avoidance of cumulative pollutions, steering product processes more eco-efficient including the substitution to renewable resources and to a precautionary approach to development (Turner 2006). This is adapted and defined to construction works in the international standard of sustainability in building construction, ISO 15392 (2008). There are various tools, many tailor-made for a particular region, for assessing the result of a construction project's level of sustainability (Ding 2008). But there are fewer tools or methods to manage the process towards a client desired level of sustainability. However, are these tools or levels of sustainability corresponding to the definitions and principles of ISO15392?

This chapter intends to validate the interdisciplinary process-orientated model, STURE, from chapter 6 with ISO 15392, described in chapter 3. Terms used in this chapter correspond to terms and definitions used in ISO 15392.

8.2. Principles applied to make validation

The case studies from chapter 7 was used to obtain data input to the STURE model for further validation of the model with the international standard ISO 15932 (2008), see Figure 8.1.

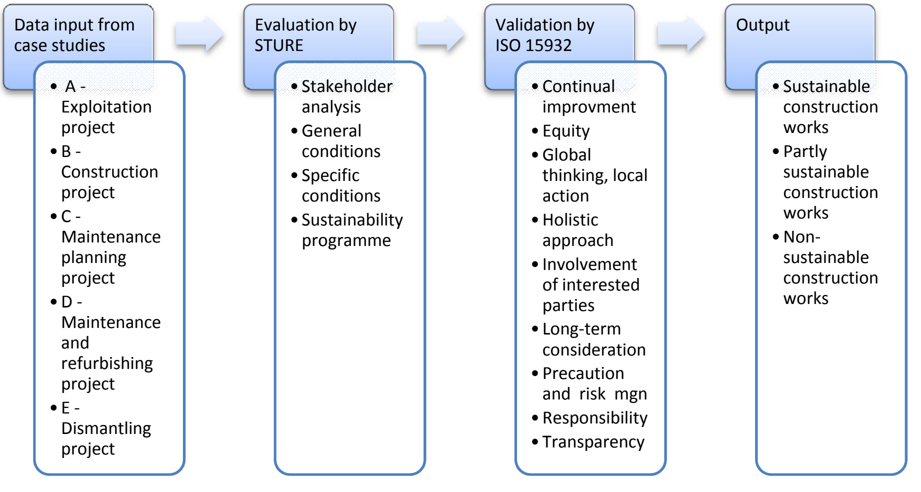


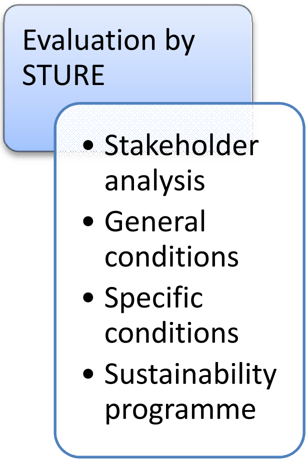
Figure 8.1 The process of validating STURE by case studies data input

The first stage of the discussion focus on evaluation of each case study based on the STURE model and the results are summarized in Table 8.1 in the end of section 8.3.5. The next stage of discussions will concentrate on the validation of each case study with ISO 15932 nine principles of sustainability and the results are summarized in Table 8.2 in the end of section 8.4.5. The expected results will either meet the following level of sustainability:

- Sustainable construction works,
- Partly sustainable construction works, or
- Non-sustainable construction works

In the end of the chapter discussions are made if it is possible to integrate the standard's principles to the STURE model.

8.3 Evaluation by STURE



The principle of STURE can be described by four steps according to chapter 6: *stakeholder analysis*, *specific conditions* for the actual application, *general conditions* that needs to be addressed and the *sustainability programme.* The last step act as a synthesis to the above stages and the concept correspond to ISO 14001. The information gathered in these steps is then used as input to a relevant application, e.g. plan of operation and maintenance for a real estate company or an analysis of alternative solutions in the design and location of a new facility.

8.3.1 Case study A – Exploitation project

The *stakeholders* involved were the local authority and the clients that were committed in the developing allotment contest. These could be considered as internal stakeholders. The external stakeholders were the four clients that already got their allotment of exploit a certain piece of ground and had an agreement with the local authority. The public concerned of the area and presumed tenants was also considered as external stakeholders.

The *general conditions* in this case were merely the Swedish construction and environmental legislation plus general demands of accessibility issued by the local authority, which is mandatory in every single construction project by the authority as a client. There was no reference to the authority's environmental policy. A limitation was to follow the preliminary detailed plan for the actual area.

The *specific conditions* or demands of the clients of the allotting contest were formulated in the contest programme as:

- The agreement of cooperation between the local authority and four clients to exploit a certain area within the community was to be included in the final allotting agreement with the contest winners,
- The detail planning work of the area was in progress and the winners of the contest had to cooperate in the continuing work,
- Specification of the areas in concern for the contest:
    - Amount of flats,
    - Design demands,
    - Noise demands, and
    - Parking norms actual for the area,
- To follow the time schedule set by the local authority,
- Specified price of the allotted ground by square meter,
- Concerning area B:
    - Construct and operate the social housing part with a rent similar to other social housing situated in the municipality, and
    - Let two flats to the local authority for social purposes,
- Apply for occurring national subsidies concerning flats with rights of tenancy,
- Follow the local authority's demands of accessibility except for one-person student flat, where demands of the Swedish legislation only were taken to account,
- A description how to organize the operation of the flats,
- Concerning area A, how to ensure the proposed buildings to be used as student flats, and
- To describe how the demands of a particular environmental programme is to be fulfilled.

The documented decision is in this case was the result of the impartial jury's decision concerning the winner of the contest.

No *sustainability programme* could be set in this case, it was in a too early stage, but if the programme of the contest was formulated otherwise, with focus on sustainability matters as significant sustainability aspects from the local authority's perspective it should have been appropriate for sustainability programme. But in the next step of the exploitation, it was possible to formulate such demands in the negotiations with the contest winner for an exploitation agreement.

8.3.2 Case study B – Construction project

Two internal *stakeholders* were identified in this case. It was the client and the forthcoming tenant for most of the available space. The external stakeholders were the other presumed tenants and the local authority.

Both the client and the tenant had formulated each environmental policy, and these policies were to be considered as *general conditions*. The Swedish construction and environmental legislation were also put into the general conditions.

The *specific conditions* were formulated from an emphasis by the general considerations according to the Swedish Environmental Code (2000), a performed construction site assessment of sustainable aspects and finally, documented meetings between the internal stakeholders; the client and the tenant. The documentation during the whole design stage including project meetings was digitalized.

In the *sustainability programme*, the objectives were merely environmental objectives, but with accordance to the STURE model. The input aspects were evaluated by the client and tenant together. They agreed of the following environmental objectives, in prioritized order:

1. Create a healthy indoor environment,

2. Minimize the capacity utilization and only use renewable energy sources, and

3. Avoid using materials that is dangerous or hazardous for health and environment.

These objectives were then in the sustainability programme broken down to measurable verifiable targets and documented through the Swedish tool Miljömanualen. A routine was developed to handle differences between the target and performed work by documentation and cost regulation between the client and the responsible contractor. These documented verifications including the reports of differences were then put into the project documents for forthcoming operation and maintenance planning. The internal stakeholders made their own environmental programme with a schedule of where, how and by whom the verification of a target was to be made. This schedule was coordinated to the project's plan of quality checks. The final application was a quality plan to be used during the construction stage, but this plan was divided in two parts. Firstly, according to the Swedish construction legislation, a person with a licensed responsibility of quality matters had the responsible of the ordinary quality plan. Secondly, a third part auditor responsible to assess the project's environmental programme according to ISO 14010-14012.

This construction project was a normal-sized office building project with high demands of environmental performance, both from the client and from the tenant. Even though, or perhaps hence, the rental agreement between the client and the tenant was ready at an early stage of the project, they succeed to coordinate the important environmental issues from both parties. The aim of the result was to achieve high environmental performance compared to normal construction standard. The environmental programming was ambitious with demands on every actor in the project to establish their part how to fulfill and verify the environmental objectives and targets.

But the focus was only on environmental issues; the social and economic parts of sustainability were more or less neglected or treated in the project with no connection to the environmental programme. Another obstacle was the handling of the control; it was divided into two different systems, where the risk of remarks from these two different control systems could be uncoordinated and wrongly attempts of putting it right.

8.3.3 Case study C – Maintenance planning project

The internal *stakeholders* were identified as the real estate company, the property management contractor and the tenants. The relevant external stakeholders for the project's completion were the financiers, the Swedish Ecocycle Council and the national government. The company saw the need to be more efficient in real estate management process. To achieve this, it chose to develop a real estate management process with the focus on sustainable development. The National Government had specified the national goals of sustainability, which then had been developed and adapted to the construction and real estate sector by the Swedish Ecocycle Council.

In order to be successful, the company needed support and interest from the property management contractor and tenants. Creditors with claims on the property were interested in ensuring that any changes will not affect the company's possibility to fulfill its commitments. The analysis proved that the company had little or no external conditions that would be in conflict with its own demands.

Concerning the *general conditions*, the real estate company was working with a new organizational policy and within this work a preliminary environmental policy was formulated. This policy followed the principles of the Environmental Programme 2010 by the Swedish Ecocycle Council for the Building Sector (2003), an association of organizations within the Swedish building and real estate sector. The policy included commitment of reducing use of energy, avoidance of use of harmful substances, improvements of indoor environmental quality and a commitment to continual improvements.

The first input of *specific conditions* was an environmental assessment by a commercial tool, see chapter 7. The assessment covered a building's ecological and some social aspects. The results of the assessment were evaluated with respect to different quantitative and qualitative criteria of national legislation, recommendations and standards by national authorities. The final result was an environmental classification between 1 and 10. By a relative comparison of the six properties' classification, energy consumption, environmentally hazardous waste and indoor climate were the most significant environmental aspects.

The second input was a complementary qualitative sustainability assessment, see chapter 6, preformed by the company concerning site and surrounding specific aspects of the triple bottom-line of sustainability.

The site specific ecological aspects were about issues of geology, hydrology, flora and fauna, climate and air quality. The significant aspects were to be found in the issue of climate and air quality in terms of local climate, predominant wind, solar radiation, humidity, temperature and local air pollution. The sites were situated in North of Sweden in the mountain area with long cold snowy winters, long season of heating, relative dry humidity, dominant arctic winds from Northwest and low rates of solar radiation.

The site specific economic aspects contained issues of cultural influences, present condition of the infrastructure, state of present communications, and market aspects. The site significant economic aspects were to be found in market aspects in terms of market value of the properties, value of taxation, local supply and demand of similar properties and rental charge of the tenancy agreements.

The site specific social aspects were about, human needs, solidarity, participation, democracy and aesthetics. The site significant social aspects were to be found in participation in terms of owner structure of the properties and tenancy influences on decisions concerning property use and maintenance.

In the *sustainability programme*, the objectives depended on the real estate company's environmental policy and the significant sustainability aspects of the properties. To create the objectives it was necessary to mix the significant aspects with the company's environmental policy and to be assured that various aspects from the triple bottom-line were included.

From the sustainability review there were significant aspects regarding energy consumption (from environmental assessment), environmentally hazardous waste (from environmental assessment), indoor climate (from environmental assessment), outdoor climate and air quality (sustainability review, ecological aspects), market aspects (sustainability review, economic aspects) and participation (sustainability review, social aspects).

A proposal was made to and decided by the real estate company's management regarding the following sustainable objectives, in order of priority:

1. Market aspects – Includes a business factor for the real estate company's economic survival (aspect of economy),

2. Use of energy – Reduces problems of resource availability, meets the Kyoto targets (ecology aspects) and reduces the operational costs (aspect of economy),

3. Indoor environmental quality – Aims to reduce dangerous and harmful components and substances (ecological aspect), an important health aspect (social aspect) for the tenants, and

4. Participation – Encourages participation by the tenants to influence decisions regarding operation and maintenance (social aspect) and, in a qualitative way for the long run, reduces the costs of operation and maintenance (aspect of economy).

From these sustainability objectives measurable sustainability targets should be set by the real estate company's management regarding operation and maintenance according to the STURE model. The management also had to define the methods of verifying the sustainability targets.

The status of the case after the decision of the proposed sustainability objectives was to continue the work with formulating the sustainability programme including proposals of sustainability targets, kind of verifications of sustainability targets and a plan of sustainability checks concerning operation and maintenance. Unfortunately, the company was sold to another national real estate company and the work and knowledge performed so far was not transferred to the new owner and thus became without importance.

8.3.4 Case study D – Maintenance and refurbishing project

The most important *stakeholders* were the client and the tenants, where the mandatory agreement of approval of the work and the tenant's demand of constantly use of the flats during the work were the main conditions to begin the work. Two other important involved stakeholders were the contractor and the special project coordinator on site, where the latter was an important link to hand over information between the tenants, the contractor and the client. Secondary or external stakeholders were the subcontractors and the local authority, especially the authority's welfare office and the fire brigade where the client had an agreement of person transportation when the lifts had to be out of order due to the work.

The client's environmental policy in use and the standard proceedings for new buildings, maintenance and refurbishing projects developed by the client's project department were to be considered as the case's *general conditions.*

The maintenance assessment carried out before the tenants approval of the work added with a sustainability assessment of the site was the input to the *specific conditions*. The final approval of the action programme, originated from the maintenance assessment and approved by the tenants, was also included in the specific conditions together with the mandatory agreement with tenants of the performance of the project. The client also took in consideration tenants requests from the house meetings (see chapter 7). Finally, during the performance of the work, the ongoing dialogue between the tenants and other internal stakeholders, handed over by the project coordinator on site, was adjusting the prerequisite of the project on a very detailed level. This was very important for the tenants' positive satisfaction of the work.

The action programme from the maintenance assessment (see chapter 7) was the starting point for a sustainability assessment on site. With the method described in chapter 6, the results of this assessment were:

Ecological aspects:

- Occurrence of trees worth protecting, and
- Wind and shelter – conditions affecting the orientation of a facility and the base of the facility's energy system

Economic aspects:

- Surrounding buildings and facilities,
- Presence, extension and ages of surrounding buildings for housing,
- Presence, extension, age and type of activity of other surrounding buildings and facilities with risk of expected disturbing emissions,
- Traffic – main typicality of traffic, traffic security measures and traffic intensity in the surroundings,
- Transportation – typicality of existing transport and intensity of transports of hazardous materials of the surroundings, and
- Market and taxation value – is the project performance increasing the value of the properties?

Social aspects:

- Security – information concerning and amount of the most commonly crimes perpetrated in the neighbourhood,
- Well-being – factors concerning the turnover of tenants and of commercial premises in the neighbourhood, and
- Participation – a request by the tenants to participate in the project.

In the *sustainability programme*, the objectives were evaluated and formulated from the assessments, from the approval of the action plan, the agreements of approval to perform the project, the tenants' requests from the house meetings (see chapter 7) and the client's environmental policy. The result from this evaluation was the following objectives in prioritized order:

1. Prioritize energy efficient solutions,

2. Use of material with high environmental productivity and low environmental impact, and

3. The client and the tenants participate to minimize interruptions of the tenants' continuous use of their flats during the work.

These objectives cover the requisites of the triple bottom-line of sustainability. The first is an economic (operation) and ecological (resource depletion) objective, the second a ecological (recourse depletion) and economic (maintenance) objective and the last is a social objective (participation).

Measurable targets of the objectives was then established in the sustainability programme according to the tool Miljömanualen the client's standard proceedings and routines of verifications.

8.3.5 Case study E – Dismantling project

In this case the internal *stakeholders* were identified as the power company's sub-divisions and other users of the power plant site that were directly involved in the project. External stakeholders were community and government. The community was acting as environmental controller due to the Swedish Environmental Code and as supplier of the water and sewage system. The government as a stakeholder has concern about environmental and work environmental legislation.

The *general conditions* of the dismantling project were identified as internal and external conditions. The internal conditions were mainly the client's environmental policy with the content of promotion of sustainable development, be in the front-line concerning environmental issues in the sector of electric power, have a holistic approach to daily work, promote actual research and promote continual improvements. The external general conditions were the Swedish Environmental Code, the Swedish Work Environment Act and the authority of environmental control performed by the local authority.

The *special conditions* were mainly based on the investigation of hazardous and dangerous material including fractionation and division of ecocycle content, see chapter 7. But also project meetings during the pre-procurement phase and input from the design team regarding technical preconditions of the dismantling performance were included in the special conditions. Adaptation to a international context was also in consideration, because of the intention to procure the contractor internationally.

The base to formulate the *sustainability programme* was the general consideration rules in the Swedish Environmental Code including the precautionary principle, the principle of ecocycle components and materials, the BAT (best available technology) principle and substitution principle. The optimization and analysis process of sustainability aspects from the general and specific conditions gave the following result according to STURE´s sustainability objectives in order of priority:

1. Work environment considerations – A human health social aspect that needed attention during the dismantling work, especially if the contractor was internationally procured,

2. Optimize high levels of ecocycle components and materials – An ecological and economic aspect according to the principle of recycling. Maximizing of re-use and minimization of material to dump sites,

3. Disposal of dangerous material – An aspect of social (human health) and ecology (protection of ecological diversity) concerning present and future risks. Managing hazardous material is regulated in the Environmental Code, and

4. Global distribution of available resources – A social aspect considering promoting more equal distribution of available resources globally, especially concerning developing countries. This concerned the recycled components and materials.

These four objectives were then in the sustainability programme divided in measurable targets with defined demands of verifications. As an example, the targets for the second objective were divided in material fractions, levels of recycling, end-functions and demands of specific verifications of the end-function. The levels of recycling were described as material and component re-use, material re-use, energy re-use and disposal of material by destruction or to special dump sites.

In terms of the sustainability programme this case shows the process of target-setting and the demands of verification of the targets. It also seems to be able to insert the demands in the contractor's quality verifications of the contract work.

The sustainability programme was attached to the administrative regulations for the dismantling contract work. This was especially important because the administrative regulations were given a higher priority than the other procurement documents, i.e. the demands of the sustainability programme were of high importance, in accordance of the client's intention, when to interpret different regulations in case of contradiction of details in the contract documents.

Table 8.1 Summary of the case´s inputs and outputs in STURE.

STURE steps	Stakeholder analysis		General conditions	Specific conditions	Sustainability programme				Application
	Internal	External			Method	Sustain-ability objective aspects	Sustainability objectives and order of priority	Sustainability targets	
Case study A - Exploitation project	The local authority The participated clients of the contest	Four clients with exploitation agreements Presumed tenants The public	Swedish construction and environmental legislations The preliminary detailed plan Accessibility demands	Allotting contest programme	Quality evaluation by an impartial jury	N/A	N/A	N/A	A contest winner client for allotting an area and negotiate a exploitation agreement
Case study B - Construction project	The client and the major tenant.	The other tenants. The local authority	The environ-mental policies of the client and the tenant. The Swedish construction and environ-mental legislation	General considerations from legislation Site assessment of sustainable aspects Coordinated view of the project Documented decisions	Quality evaluation by the internal stakeholders	Environ-mental aspects	Healthy indoor environment Min. capacity utilization with using renewable energy recourses Avoid dangerous and hazardous materials	Yes, measurable with defined demands of verifications Using the tool of Miljö-manualen	Construction stage, use of quality plan: one quality check according to legislation and one third part auditor assessing the environ-mental programme

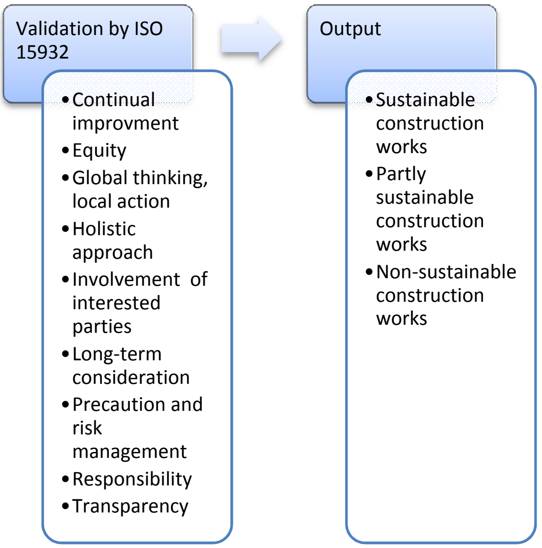
Table 8:1 Summary of the case´s inputs and outputs in STURE (cont.).

STURE steps	Stakeholder analysis		General conditions	Specific conditions	Sustainability programme				Application
	Internal	External			Method	Sustain-ability objective aspects	Sustainability objective and order of priority	Sustainability targets	
Case study C - Maintenance planning project	The real estate company The property management contractor Tenants	Creditors Gov. Ecocycle Council	Preliminary environmental policy	Environmental assessment of properties Sustainability assessment	Quality evaluation by the real estate company	Economy, ecology and social aspects	Market aspects Use of energy Indoor env. quality Participation	Not developed	Plan of operation and maintenance
Case study D - Maintenance and refurbishing project	The client, the contactor, the project coordinator and the tenants	Sub-contractors Local authority (e.g. the fire brigade)	The client´s environmental policy and project standard proceedings	Maintenance and sustainability assessment Approval of action programme and agreement of the work Tenants request Informal dialogue on site	Quality evaluation by the client	Economy, ecology and social aspects	Energy efficient solutions Use of material with high env. productivity and low env. impact Participation to min. interruptions of use of flats.	Yes, measurable with defined demands of verifications Using the tool of Miljö-manualen	Project steering documents and basic data for future maintenance

Table 8.1 Summary of the case´s inputs and outputs in STURE (cont.).

STURE steps	Stakeholder analysis		General conditions	Specific conditions	Sustainability programme				Application
	Internal	External			Method	Sustain-ability objective aspects	Sustainability objective and order of priority	Sustainability targets	
Case study E - Dismantling project	The power plant company's subdivisions Tenants of the site	Community Gov.	Environmental policy Environmental Code Work Environment Act Environmental control by the community	Investigation of dangerous and hazardous materials Technical preconditions Documented decisions	General considerations from the Env. Code Quality evaluation by the power plant company	Economy, ecology, social and regulative aspects	Working environment Recycling of materials Disposal of dangerous material Global distribution	Yes, measurable with defined demands of verifications	Project procurement documents

8.4 Validation by ISO 15392



This section discusses the findings of the case studies from chapter 7 adapted to STURE, see chapter 6, in comparison with the principles of sustainable construction works stated in ISO 15392, see chapter 3. It is whether the cases are to be considered sustainable or non-sustainable or partly sustainable and what to do to improve the outcome of the case studies to fulfill the principles according to ISO 15392. A summing-up of the comparisons between the cases and the principles are made in Table 8.2.

8.4.1 Case study A - Exploitation project

The exploitation project was a contest between clients to gain an agreement of allotment to exploit and develop an area owned by a local authority. The authority had made a contest programme with design, construction and environmental demands to be followed by the contributors. The contributions were evaluated and judged by an impartial jury out of two architects and one environmental expert.

By comparing the outcome of the case with the ISO 15932 general principles of sustainable construction works it seems to be a lack in several corresponding relationships. The principle of continual improvement is not fulfilled by a compulsory demand in the contest programme. There was only one contributor that addressed this principle by a voluntarily commitment by a promise of formulating a project specific environmental policy. Unfortunately, it was not the winner of the contest. The equity principle was covered partly by the demands of social housing adaption: intra-societal (partly) and intergenerational, and by the condition of accessibility. There were no explicit demands of holistic approach, responsibility, precaution management and risk management. Finally, the principle of long-term consideration only covered the short-term (two years) condition. Nothing explicit was found in the programme of medium- and long-term considerations.

This case had a long way to reach and fulfill the principles of ISO 15932. The emphasis of the contest programme was on design and environmental aspects only. This could not to be considered as a future sustainable construction works and the output status should be a *non-sustainable construction works* if the agreement of allotment followed solely the contest programme. But the local authority could include more sustainable aspects that follow the principles of ISO 15392 in the negotiations of the agreement with the winner of the contest.

8.4.2 Case study B - Construction project

This case was from the construction phase of the life-cycle of construction works, a new office building during the middle of the design stage where the major tenant of the office space and the client coordinated their views and demands to an environmental programme in common.

A comparison of the outcome of the case structured by STURE and the general principles of ISO 15392 gave the result of lacking of correspondence in parts considering equity, holistic approach, responsibility and precaution and risk management. The correspondence with the principle of continual improvement was well covered by both the client and tenant was using an environmental management system according to ISO 14001, with the underlying and main demand of continual improvement. By laying the emphasis on the General Principles of the Swedish Environmental Code (2000) and structure the targets by the tool of Miljömanualen, it could be considered to cover the correspondence with global thinking and local action. The holistic approach was only applied on environmental aspects; the rest of the triple bottom-line was missing. Regarding the involvement of interested parties, it was only the internal stakeholders who was involved in and coordinated the work of the environmental programme. The objectives, especially the second objective, cover the correspondence of long-time consideration; the obligation to minimize capacity utilization and only use renewable energy resources. The transparency condition corresponds to the case's use of basics from ISO 14001, adapt aspects by use of STURE and the use of Miljömanualen to structure the targets.

This case could be considered as *non-sustainable construction works* because of lacking parts corresponding to three principles according ISO 15932, only environmental aspects considered and it only addressed the internal stakeholders. But it also may be considered as a *partly sustainable construction works* by emphasis on environmental aspects and good correspondence with the remaining principles.

8.4.3 Case study C - Maintenance planning project

The case of the maintenance planning project offers an example of planning of operation and maintenance with the STURE model as a base complemented by a building environmental assessment by a Swedish commercial tool and a site assessment of sustainability of actual buildings.

By comparing the outcome of the case with the ISO 15932 general principles of sustainable construction works, it seems to be a lack in some corresponding relationships. Regarding the principle of continual improvements there is a weak correspondence because the EMS-policy is only preliminary. The board of the company have to confirm the policy if the conformity could be adequate.

In accordance with the principles of equity and responsibility there is no explicit relationship to the case and to the principle of global thinking and local action there is only an indirectly relation by bridging through the sector-mutual Environmental Programme 2010. Concerning the principle of precaution and risk management there is lack in conformity of risk management: no such assessment is addressed in the case. This case should not be considered as to fulfill the principles of ISO 15932 and therefore to be considered as *non-sustainable construction works.* The case needs to be reworked with STURE addressing the missing connection to adequate principles mentioned above.

8.4.4 Case study D – Maintenance and refurbishing project

This was a construction work project regarding maintenance and refurbishing resident buildings with flats during tenants constantly use. During the performance an informal dialogue between the tenants and the other internal stakeholders was made by a project coordinator on site.

By comparing the outcome by the STURE model of the case with the ISO 15932 general principles of sustainable construction works it seems to be a lack regarding the correspondence with the principles of responsibility and precaution and risk management.

The principle of continual improvement was covered by a commitment in the client's environmental policy. The equity principle was covered by the process of tenants' involvement which were documented in the specific conditions and committed in the objectives. Global thinking and holistic approach was well covered by the objectives and to the objectives connected measurable targets and the condition of verifiability. The process of involvement of the tenants in the project, documented in the specific conditions, and their possibility to made dialogue with the contractor and the client during the performance of the project in addition to the third objective covered well the principle of involvement of interested parties. The two first objectives and connected targets with verifiability conditions complied with the principle of long-term consideration. Finally, the use of the STURE method in addition with the client's environmental policy covered the transparency principle of ISO 15932.

With an addition of a responsibility commitment and precaution and risk management programme, this project could be considered to fulfill the principles of *sustainable construction works* according to ISO 15932.

8.4.5 Case study E - Dismantling project

The case of the dismantling project was intended to show the STURE applicable in a procurement situation and of, where the client's demands of sustainability are prioritised on a high level in the contracting documents.

By comparing the outcome of the case with the ISO 15932 general principles of sustainable construction works it seems to be conformity between the principles and the outcome. The only discrepancy is the principle of responsibility, where an indirectly linkage through the objective of work environment consideration. But this link is strong because the connection with the Swedish legislation in Work Environment Act. This case should be considered as to fulfill the principles of ISO 15932 and therefore to be considered as *sustainable construction works*. The case shows that with using the framework of STURE it is possible to address the principles of sustainability according ISO 15932.

Table 8.2 Comparing the outcomes of STURE in the cases with the general principles of ISO 15932.

Principles of ISO 15932	Continual improvement	Equity	Global thinking and local action	Holistic approach	Involvement of interested parties	Long-term conside-ration	Precaution and risk manage-ment	Respon-sibility	Transparency	Output
Case study A Exploitation project	No compulsory commitment according to programme. One contribution refers to make a policy with continual improvement	Partly by the demands of social housing adaption and accessibility	Covered by the environ-mental programme included in the contest programme	Nothing explicit	Internal stakeholder: Yes. External stakeholders: Nothing explicit	Partly by the conditions of preparation of operation and two years follow-up	Nothing explicit	Nothing explicit.	Yes, according to the aim in the programme	Non-sustainable construction works
Case study B Construction project	Both the client and tenant using ISO 14001 and the underlying commitment of continual improvement	Nothing explicit	Covered by emphasis on the General Principles and targeting by Miljö-manualen	Only be evident by environ-mental aspects	Internal stakeholder: Yes. External stakeholders: Nothing explicit	Covered by the objectives, especially the second objective	Nothing explicit	Nothing explicit	Covered by using basics from ISO 14001, STURE principles, targets by Miljömanualen and well defined verifications	Partly sustainable construction works

Table 8.2 Comparing the outcomes of STURE in the cases with the general principles of ISO 15932 (cont.).

Principles of ISO 15932	Continual improvement	Equity	Global thinking and local action	Holistic approach	Involvement of interested parties	Long-term conside-ration	Precaution and risk mana-gement	Respon-sibility	Transparency	Output
Case study C Maintenance planning project	Commitment according to the preliminary EMS-policy. Not certified to ISO 14001	Nothing explicit in the preliminary EMS	Only indirectly by the preliminary EMS content adapted from the Swedish Ecocycle Council's Env. Programme 2010	Covered by the STURE objectives	By using the stake-holder power/ interest model applied to STURE	Covered by the STURE objectives except explicit according to the legacy part	Precaution part in the STURE objective of indoor environ-mental quality. No risk mana-gement performed	Nothing explicit.	Covered by using STURE and if the documen-tations and verifications	Non-sustainable construction works
Case study D Maintenance and refurbishing project	Commitment according to the client's environmental policy	Covered by the specific conditions and the objectives	Covered by the objectives and the connected targets	Covered by the objectives and the connected targets	Covered by the specific conditions and the third objective	Covered by the two first objectives and the connected targets	Nothing explicit	Nothing explicit	Covered by the client's environmental policy and the use of STURE	Sustainable construction works

Table 8.2 Comparing the outcomes of STURE in the cases with the general principles of ISO 15932 (cont.).

Principles of ISO 15932	Continual improvement	Equity	Global thinking and local action	Holistic approach	Involvement of interested parties	Long-term considera-tion	Precaution and risk mana-gement	Respon-sibility	Transparency	Output
Case study E Dismantling project	Commitment according to the ISO 14001 certified EMS	By addressing global distribution in the STURE objectives. Indirectly by promoting sustainable development in the EMS-policy	Covered by the investigation of hazardous materials and by the STURE objectives	Covered by the STURE objectives	By using the stakeholder power/ interest model applied to STURE	Covered by the STURE objectives except according to the legacy part	Precaution by the STURE objective of disposal of dangerous material. Risk mana-gement in work env. conside-ration	Indirectly by the objective of work env. con-sideration	Covered by using STURE and having a certified EMS to ISO 14001	Sustainable construction works

8.5 Integrating STURE and ISO 15932

The previous section intended to validate a process-oriented model, STURE, of how a client could set preference of sustainability aspects in a construction project process, with ISO 15932's principles of sustainable building construction works.

The case studies were evaluated by, and in some cases also converted to, the model. The outcome from this were validated with the nine principles of ISO 15932 to see if the use of the STURE model could be a tool to make sustainability estimations and if the cases with help by the model could possibly be estimated as sustainable or not, see Figure 8.1.

8.5.1 Input from the case studies

To do this validation practically, a set of case studies were used reflecting different stages of a construction works life-cycle and also different phases in the process of a construction project. The cases were not in the forefront of environmental or sustainability adapted construction work. Even if some of them had some higher ambition than average by addressing, especially, the environmental part of the triple bottom-line, were the cases overall quite standard and common project performed during the last ten years and reflecting different stages in a facility's life-cycle during different phases of the process of a facility development. The case studies cover a quite broad spectrum addressing construction works. Looking at the time aspect shows that little have happened concerning re-thinking and improvement of how to perform the process of a construction project. The refurbishing project performed almost ten years ago was, according chapter 8, quite close to fulfill the ISO 15932 principles of sustainable construction works.

8.5.2 Evaluation by STURE

The cases used the STURE model from chapter 6, see fig 8.2, in different applications and of different purposes: conditions of an exploitation agreement, demands in procurement documents, construction and maintenance work contracting conditions to strategic operation and maintenance planning. The STURE model enables the client of a facility development to gain an insight into relevant sustainability concerns and needs of different stakeholders. It also clarifies significant sustainability aspects of the actual application's dependence on planning, operation, maintenance, recycling, site, system and components. By translating these significant aspects into objectives and prioritising them according to the client's environmental management system, the STURE method intends to assess the process of sustainable development and to fulfill the principles of ISO 15932. The connection to the client's environmental management system and the standard of ISO 14001 adds the facility development to the client's commitment of continual improvement, i.e. each client starts on its own level of ability and improves continually towards more and more sustainability.

The stakeholder analysis done in the cases shows the importance to crystallize that or those of the stakeholders, external and internal, who has significant impact on the facility development and, consequently, should attract more attention by the client during the development process. This part in the STURE method ensures identification of the interested parties and decrees an involvement with the most important of these stakeholders.

The general conditions set the platform of the facility development regarding the clients' business and environmental policy, management systems, organization and standard procedures. By this part, the client's ability and knowledge of sustainability are formulated and is also the starting point of the client's commitment of continual improvement regarding the particular facility development.

The specific conditions are the base of the facility development's site related aspects. This implies to carry sustainability site and product assessments through to gain aspects of sustainability for the facility development. It also implies to take decisions made by the client and other important stakeholders in to account during the development process to compare the impact on relevant aspects produced hitherto. These procedures have to take the whole triple bottom-line in account to fulfill the holistic approach regarding the state-of-the-art circumstances of the facility development.

When evaluating and formulating the sustainability objectives, it is necessary to compare all the aspects and facts from the parts of general conditions and specific conditions qualitatively or, if it is possibly, quantitatively. To produce significant aspects it is important to take both general commitments (e.g. sector mutual agreements) and corporate commitments (e.g. business policy, environmental policy or other commitment made by the individual company) in account. The objective formulating is depending on the most significant aspects adapted to and evaluated by the client. During this evaluation procedure, aspects from the whole triple bottom-line are to be considered. The final objectives also reflect the triple bottom-line by cross-references with each main aspect. Sustainable objectives along with added targets address long-term consideration, global thinking and local action. The measurable and verifiable targets meet the principle of transparency, where the targets are traceable with underlying data and comprehensive by the condition of standardized verifications.

The STURE model implicates a usable, flexible and adaptable model, especially concerning when a client dealing with significant sustainability aspects of the client's organization in a facility development project. It is usable to different project applications. It is flexible and adaptable to suit different project purposes. But is the model useful to estimate a construction works' or a construction work project's level of sustainability?

8.5.3 Validation by ISO 15392

Sustainability adaption in construction and construction works was discussed in previous chapters, especially in chapter 3, and there are many different ways to define and adapt sustainable development to construction works. But there is one concrete, particularly adapted to building construction and international defined in the standard of ISO 15392, Sustainability in building construction – General principles, with connections to environmental management systems as ISO 14001, the Brundtland Report (1987) definition of sustainable development and the triple bottom-line where the internal relationship is set to equal importance. This is the reason to use this standard to validate if the STURE method could be a tool to estimate if a construction works or a construction work project is sustainable or not. This section discusses from the standard's sustainability principles the outcome of the STURE adapted case studies.

The principle of continual improvement is a condition stated by a client´s environmental management system in its environmental policy and accordingly included in the general conditions of STURE. It is of course very important that this aspect is covered in a STURE application.

Global thinking and local action is covered by the STURE method during the evaluation process of general conditions and specific conditions. In general conditions there are aspects from global, regional and governmental perspectives by recommendations, sector agreements or legislation. In specific conditions there are aspects on a local level, especially from the actual site of the facility development.

The holistic approach is obvious by STURE's objective setting and the underlying sustainability assessments of supposed aspects.

By stakeholder analysis of influence importance and defining internal and external stakeholders, the principle of involvement of interested parties is covered.

The principle of long-term consideration is fundamental in STURE, particular in the objective and target setting. But this depends of what kind of client is involved in the facility development. Is it a short-termed thinking client with focus only on putting the developed property on sale could this principle fail, even if using the STURE model.

The transparency principle covers by the model's condition of verified targets and the condition of including project decisions during the process for comparison of hitherto significant aspects. A limitation of this principle occurs when to transfer the facility developments knowledge after a project finish to an operation organization, internal or external, or when a shift of corporation culture occurs, especially the case of new owners.

8.5.4 Re-modeling STURE

The six principles mentioned above are quite possible to fulfill when using the STURE model. If the client also uses an environmental management system as ISO 14001 or similar it is most certain to control and maintain these six in the long run. But there are missing references in the model to the principles of equity, responsibility and precaution / risk management.

Equity and responsibility should be included and highlighted by the social aspects during assessments and objective settings. The principle of precaution and risk management should become a new input, especially as the latter is a common part in project management and compulsory in quality or environmental management systems. The precaution principle was already stated in the Rio meeting 1992 and is legislated in Sweden by the Environmental Code since 1998, so it is already a compulsory part concerning environmental and sustainability issues. Figure 8.3 shows a re-modeled structure by the findings from the validation of the STURE model with the case studies.

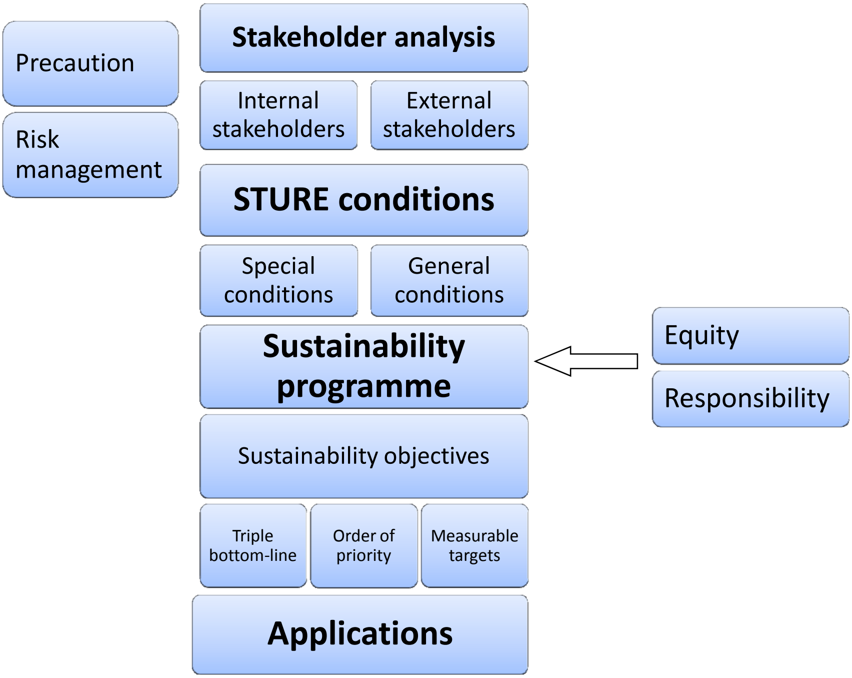


Figure 8.3 Re-modeled structure of STURE method.

The output (see Figure 8.1) from the validation in chapter 8 implicated that the cases D, the refurbishing project, and E, the dismantling project, fulfilled the conditions of STURE. A partly fulfillment shows the case C, the maintenance planning project, by addressing only a preliminary environmental policy. The case studies of A and B had missing parts of STURE conditions in input. These had to be re-worked to replenish the missing parts and, consequently, these are non-sustainable construction works.

The cases of D and E could be considered not to fulfill all the principles of ISO 15932, but if the former STURE conditions according to Figure 8.1 was fulfilled and therefore also six of nine principles, these could be considered as partly sustainable construction works, especially the refurbishing project, case D, that carried out its intention all the way out of the project. The dismantling project, case E, could be considered as a sustainable building construction work by the procurement phase. It had to be verified during the rest of the project performance to be a sustainable construction works.

The maintenance planning project, case C, had all the opportunity to gain success in sustainability, the company's management had to decide of a permanent environmental policy, replenish with a equity commitment and perform a risk management system. It was not completely partly sustainable as above, but yet not fully non-sustainable. But all its intention of sustainability failed when the management transferred the company and its properties to a new owner and no conditions or knowledge transfers of the work carried out so far was made during the transaction of the company because of no interest of such matters from the new owner.

From a client's perspective and ability to deal with sustainability issues, the result of the validation of using this model is an approach to evaluate and manage the most important sustainability aspects according to the principles of sustainable construction works, the client's activity and its stakeholder's demands during a facility development. From a business perspective is this very important step in the process of sustainable development.

8.6 Discussion of generalizations

It is clear that initiatives at the governmental level such as legislation and regulations for a better environment exist in many countries and even some countries have formulated an agenda for sustainability. This is also the case on regional and community levels; some objectives are already formulated in different agendas. The work of formulating sustainability objectives on national and regional levels is in progress. The global market demand for green or sustainable solutions in construction will increase rapidly in the next five years, especially in the Asian market. A major threat is severe consequences for our built environment related to the climate change, and this is already evident. A risk assessment regarding the consequences of climate change is becoming mandatory. Another consequence is the demand for zero carbon or negative carbon solutions, i.e. regenerative constructed buildings instead of sustaining the pressure of our environment. To make such a paradigm shift is urgent and it needs both top-down and down-up knowledge transfer. From the latter perspective, many small steps on the corporate level are in the pipeline. Research has examined ways of dealing with this complex question: how to manage sustainability issues in construction. One milestone is the international standard ISO 15392 which deals with general principles of sustainability in construction works. This standard defines the main terms of sustainability concerning the built environment and construction works; there are no obstacles in the form of confusing interpretations. All is a matter of knowledge transfer, to promote value to clients or facility managers acting on their behalf for the mainstream projects. This process, which started as a valuing discussion of sustainability properties, has been taken onboard by the international research community (Lorenz et al 2008)

On the corporate level it is very important to formulate objectives of sustainability that suits the company's activity, ability and business policy and to let these objectives permeate the activities and projects of the company. Awareness of corporate sustainability or corporate social responsibility is increasing and is expected to be the main driving force of the Asian green building market for the next five years (Bernstein and Bowerbank 2008). The construction industry is very fragmented; a majority of companies are very small. The knowledge and ability to deal with sustainability is on quite different levels. Transferring knowledge internally and between organizations as well as from global, national, regional, and local levels and from ad hoc or empirical levels is crucial if these differences is to decrease.

A path for this is to adapt the maturity roadmap to sustainability, STEPS, developed by Robinson (2004) and mentioned in chapter 5. It is also important to interact with the management systems, also mentioned in chapter 5. A good start might be to systematize the activities according to the environmental management system of ISO 14001 without necessarily prioritizing certification. Certification only shows if the company is aware of its activities' environmental impact, not if it is a "*good*" environmental company. By these means, the formulation of proper objectives suited to the company's activities should not be difficult, especially if sector agreement is provided (as in the case of Sweden). A way of dealing and prioritizing the objectives of the organization and to break them down into a single project together with project-specific objectives is to use the STURE model.

To measure if a company is committed to continual improvement requires assessment. Many different assessment methods are available, but they are mostly regionally or nationally adopted and EIA-driven. When assessing the targets or indicators of sustainability objectives it is important to change the direction of assessment tools from solely EIA-driven or "*snap-shot*" tools to objective-led assessment methods as for example STURE. Here, the client's organizational objective is measured together with the assessment outcome of the actual project or facility combined with the assessment for sustainability with defined sustainability criteria. The international standards ISO/TS 21929-1 and ISO/TS 21931-1 set the baselines of such indicators and assessments. Key sustainability performance indicators, suggested by Lützkendorf and Lorenz (2005) and mentioned in chapter 4 are a good start for defining the targets of the activity to be fulfilled. In the long run, it should be possible for a third certified part to make the assessment, similar to ISO 14001.

8.7 Conclusions

The validation of STURE shows there is a possibility to use such models, with minor compliments as in Figure 8.3 and with an environmental management system in use of the client, to assess a construction work or works to determine whether it is heading towards being a sustainable, a partly sustainable or non-sustainable development. This is an example of an objective-led assessment, avoiding the snap-shot statements.

It is time to prioritize the objectives to make it easy for mainstream property developers, clients and project managers to obtain information on how to act and formulate procedures or opportunities to motivate the mainstream construction work and works towards sustainability. It is obvious that a general global agenda of sustainable construction has to be complemented with the specific conditions of the actual site, the specific project or facility, the ability or knowledge of the client, design and project management team and, of course, regional and local conditions and the context of the triple bottom-line of sustainability. It is, in fact, a question of knowledge transfer from locally adapted bottom-up and top-down perspectives, whether the site is located in a northern arctic mountain area or in a southern tropical urban area. The challenge is to adapt this to a simplified and user-friendly method that suits the needs and abilities of a mainstream construction project management team. This research may be a step in the right direction of this challenge. The timeframe is very limited; our planet is already suffering from irreversible damage. The construction sector's and especially the property developer's responsibility to minimize this damage are huge.

9 Summary and final conclusions

9.1 Introduction

This chapter presents a summary of the thesis where if the objectives from the research question in the first chapter has been answered. Further on, it contains the final conclusions of the thesis, the contribution to the body of knowledge and lastly, makes recommendations for further work.

9.2 A summary

The aim of this work was to define sustainability in construction works, systematize aspects of sustainability and validate sustainability in construction works from a client and construction project manager perspective divided in the following objectives:

1. Define the basics of sustainability in construction works, corporate sustainability and the connection with knowledge transfer,

2. Critically review the use of the terms sustainable construction and sustainable building, and

3. Apply a model for enabling a client to deal with significant aspects of sustainability during construction works and validate this model with a well-defined context of sustainability in construction works, with input from real cases and from well-defined sustainability constraints.

With respect to the first objective, the basics of sustainability and the adaption to construction works are presented and discussed in chapter 1, 3 and 5. In chapter 1 it started by a definition of sustainable development and arguments of the definition continued in chapter 3 with how to interpret the broad term of sustainability. Fundamental terms as triple bottom-line, ecological modernization, Factor 4 and Factor 10 were also discussed. How sustainability has been adapted to the construction sector and to construction works was discussed regarding the sector's context, issues of user expectations of sustainability and the complex content of how to manage the process of construction works.

The basics of corporate sustainability were also explained in chapter 3 and its connection to the importance of knowledge management and transferring, if sustainability on a corporate level was to be on the agenda. The discussion of knowledge transfer continued in chapter 5, where an example of a method to implement knowledge management in corporate sustainability by STEPS maturity roadmap.

The second objective was also answered in chapter 3, where all the diffuse terms of green building, sustainable building and sustainable construction were discussed and with respect to the international standard of ISO 15392, sustainability in construction works was clearly defined by its nine principles and six objectives. Further on, this definition was used in chapter 8 for a validation of an assessment model with data from a couple of case studies by the constraints of those principles. It seems there are accordant parts between the principles and the assessment model in question, see below.

By introducing assessment methods, indicators of sustainability and management systems of an organization in the chapters of 4 and 5 together with the fundamentals of sustainability, the base for a model to enable a client to deal with significant aspects of sustainability in construction works was set. The model, STURE, was described in chapter 6 together with an example of an important complementary part of the model, an assessment method of the site and surroundings of a construction works project. The model was applied in chapter 8 on a couple of construction works case studies described in chapter 7, which covered a construction works life-cycle, and validated, also in chapter 8, with the standard of ISO 15392 with its nine sustainability principles. The output from the validation was a need of additions of four principles to the model. Further on, it was possible to make statements of sustainability to construction works project as; sustainable construction works, partly sustainable construction works, or non-sustainable construction works. As mentioned earlier, accordance between the model and the nine principles of ISO 15392 was good. Some minor adjustments of the model were made to make a completely accordance between the standard and the model.

9.3 Final conclusions

The findings of the study could be divided in three parts. Firstly, on the macro level, the progress towards sustainability in construction works is rather slow, in spite of the short timescale before potential irreversible damage occurs from climate change. In the long run it is not enough to sustain on the level of present environmental depletion, it has to be a regenerative development. By these means it is time for action by transferring current and new knowledge from the research community into an adaptive and practical framework for implementation. This knowledge must be complete with clearly defined economic incentives and the gap between researchers and practitioners must be bridged with arguments of economic value. It is also very important to bridge the gap of knowledge transfer in both directions between industrialized and developing countries, as local decisions and solutions affecting the built environment have both local and global impact.

On the meso level, it is crucial to transfer knowledge horizontally, when a real estate change owner, thus the information of work done so far on sustainability improvements be transferred to the new owner. This could be done by voluntarily business agreements, governmental subsides regarding property value/ taxation or by legislation of mandatory information/ indicators following the property's life-cycle by registration of title.

Regarding relationship between community and single companies, the conclusion is that if the community´s demand for sustainability is to be met, it is crucial for the corporate part to formulate its policy regarding sustainability, to translate the activities into adequate key figures/ indicators in order to fulfil the commitment of continual improvement and meet the community´s sustainability objectives. A tool for this is to combine the standards of ISO 14001, ISO15392, ISO/TS 21929-1 and ISO/TS 21931-1. Another possibility is using a single model like STURE which combine all these standards into one.

Finally, on the micro or construction works project level, there is need for an easy and user-friendly framework for managing the issues of sustainability in an already complex context such as a construction works project. It is essential to apply a ‘many-small-steps’ approach towards sustainability. The proposed STURE method and the connection to STEPS maturity roadmap on a corporate level and the combinations of the above-mentioned ISO-standards are a way of structuring stakeholder demands or outcomes of expectancy. This with regard to sustainability objectives, optimized from national, regional, local and corporate levels together with technical and functional demands. As shown in chapter 8, it is possible to determine if a construction project is heading along the sustainability path by taking into consideration the client’s own organizational objectives and stakeholder demands with respect to the specific project in hand. With improvements of the STURE model suggested in chapter 8 it could be possible to determine more specific if the project is heading towards sustainability as: *sustainable, partly sustainable* or *non-sustainable construction works.*

To use these methods also promotes continual improvement in project performance and basic organizational activities. Thus, this is a ‘many-small-steps’ approach depending on the client’s ability, level of knowledge and inclination. The aim should not be to become a world leader, but to recognize that improvements comes through successive small steps and thus an ability to measure improvement along the path of sustainability in the field of construction works can be achieved. It is the client/owner/developer, as the responsible performer of activities concerning construction works who has the main responsibility concerning construction works and the obligation to commit sustainability. At the same time there is an opportunity and challenge for make the built environment more sustainable and begin a regenerative development in the earnest.

9.4 Research contribution

A main contribution of this research to the knowledge of sustainability issues in construction works is the proposal of a model to deal with sustainability in construction works in a more systematic and simplified way, the STURE model, validated by the recent international standard of ISO 15932. The outcome of this validation shows a possibility to estimate whether a construction work or works is heading towards sustainability or not in three levels; sustainable, partly sustainable or non-sustainable construction works. Another contribution is a review of the current debate regarding sustainability in building construction and its complex context from a client and project manager perspective with emphasis on the latter. It confirms the importance of using an adequate definition of sustainability in construction works; the principles of ISO 15932, avoiding multiple other interpretations. A contribution is also a focus on the very importance of the role of corporate sustainability and the single company's ability and responsibility to deal with these complex issues. Last but not least, a substantial contribution is the importance of horizontally knowledge transfer with the suggestion of mandatory sustainability information lies within the property instead of the client/owner.

9.5 Future research

One essential task in the near future is to using the re-modeled STURE from chapter 8 with some more case studies from construction works life-cycle to refine the framework containing the proposed procedure and a combination of the aforementioned standards where practitioners are able to easily compile basic sustainability data for project decisions. There should also be evaluations of more cases using the entire procedure proposed above from the initial stage into implementation and during assessment. It is also important to measure the economic outcome and compare with normal process procedures with respect to the arguments concerned with economic value. Moreover, it is important to know how to formulate adequate information for stakeholders the content of the procedure and how the procedure can work effectively. This work concerns also how to transfer this present knowledge to future generations by the properties, not by the owners of the properties, to fulfill the intergenerational part of the equity principle

Another issue for future research is the development and evaluation of a framework for further sustainability criteria, locally adapted for the assessment of the sustainability approach.

Finally, it is very important in the near future to begin a framework for regenerative construction works, where it is possible to make a beneficial impact with regards to the triple bottom-line, to turn the negative degradation of our surroundings to renewed and regenerated biotopes. To make this turn it is necessary to ensure the regenerative measures in the long run.

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