State-of-the-Art of Benchmarking in Construction and Real Estate
Developing indicators for Transparency
CREDIT Report 1
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## Content

Content ............................................................................................................ 3  
Preface ............................................................................................................. 4  
Executive summary .......................................................................................... 5  
1 Introduction and objectives ......................................................................... 6  
   1.1 The objectives and the project programme of CREDIT .................... 6  
   1.2 Main partners in the CREDIT project ............................................ 7  
   1.3 CREDIT work packages and meetings ........................................ 8  
   1.4 CREDIT reports, deliverables and eRoom ................................... 11  
   1.5 Purpose of WP3 State-of-the-Art............................................... 12  
   1.6 Research Design ........................................................................ 12  
2 State of the art in Norway ......................................................................... 13  
   2.1 What makes a good Indicator? ..................................................... 13  
   2.2 Efficiency and Productivity of the Norwegian Industry ............... 16  
   2.3 References .................................................................................. 21  
   2.4 Life Cycle Costing and Economic Indicators ................................. 22  
   2.5 Benchmarking ............................................................................. 24  
   2.6 References .................................................................................. 30  
3 State of the art in Finland .......................................................................... 32  
   3.1 Capturing User Needs .................................................................. 32  
   3.2 References .................................................................................. 40  
   3.3 Building Performance and Value Creation .................................... 43  
   3.4 References and recommended reading ...................................... 49  
   3.5 Life-Cycle Commissioning Processes ........................................ 51  
   3.6 References .................................................................................. 57  
   3.7 Benchmarking ............................................................................. 58  
4 State of the art in Sweden ........................................................................ 68  
   4.1 International Review of Methods and Tools ................................ 68  
   4.2 Review of Swedish real estate organisations ................................ 75  
   4.3 Methods and Tools in Use in Sweden today ................................. 78  
   4.4 Conclusions ................................................................................ 81  
   4.5 References .................................................................................. 83  
5 State of the art in Denmark ....................................................................... 87  
   5.1 Requirements for performance in the building regulations ........... 87  
   5.2 Experiences from Danish Pilot Studies of Benchmarking ............ 88  
   5.3 Benchmarking in Denmark ......................................................... 90  
   5.4 References .................................................................................. 96  
6 State of the art in Iceland .......................................................................... 100  
   6.1 Benchmarking and Performance Indicators in Iceland ................. 100  
   6.2 References: ................................................................................ 103  
7 State of the art in Lithuania ..................................................................... 104  
   7.1 Customer Requirements, Needs and Satisfaction / Emotions ....... 104  
   7.2 Utility Degree and Market Value Model ..................................... 105  
   7.3 Lithuania Review ........................................................................ 106  
   7.4 Benchmarking in VGTU, Lithuania ............................................. 108  
   7.5 References .................................................................................. 110  
8 State of the art in Estonia ....................................................................... 112  
   8.1 Dwelling stock in Estonia: set of criteria for assessment ............. 112  
9 Discussion and Conclusion ..................................................................... 119  
   9.1 Scope and Contributions ............................................................. 119  
   9.2 Conclusions and Recommendations .......................................... 119  
CREDIT reports ............................................................................................. 123
This report describes the state of the art of benchmarking in construction and real estate undertaken as the first part of the Nordic/Baltic project CREDIT: Construction and Real Estate – Developing Indicators for Transparency. The report presents state of the art reports from Denmark, Finland, Norway, Sweden, Iceland, Estonia and Lithuania executed in work package 3 Stat of the art (WP3) coordinated by SINTEF Byggforsk, Norway. In WP3 both national and international experiences are studied as background for the issues to be dealt with in four work packages reported in CREDIT Report 2, 3, 4 and 5.

CREDIT includes the most prominent research institutes within benchmarking and performance indicators in construction and real estate, namely SBi/AAU (Denmark), VTT (Finland), SINTEF (Norway) and Lund University (Sweden). Moreover, three associated partners joined CREDIT for the Norwegian part of the project. The three associated partners are The Icelandic Center for Innovation (Iceland), Tallinn University of Technology (Estonia) and Vilnius Gediminas Technical University (Lithuania).

The project has been managed by a steering committee consisting of the following persons representing the four main partners:
- Kim Haugbølle, SBi/AAU (project owner), Denmark.
- Niels Haldor Bertelsen, SBi/AAU (project coordinator), Denmark.
- Pekka Huovila, VTT, Finland.
- Päivi Hietanen, Senate Properties, Finland.
- Ole Jørgen Karud, SINTEF, Norway.
- Magnus Hvam, SKANSKA, Norway.
- Bengt Hansson, Lund University, Sweden.
- Kristian Widén, Lund University, Sweden.

The steering committee wishes to thank our industrial partners and all the contributors to the CREDIT project. In particular, the steering committee wishes to thank the four Nordic funding agencies that sponsored the project as part of the ERABUILD collaborative research funding scheme: The Danish Enterprise and Construction Authority (Erhvervs- og Byggestyrelsen) in Denmark (funding SBi), TEKES in Finland (funding VTT), The Nordic Innovation Centre (NiCe) (funding SINTEF) and FORMAS in Sweden (funding Lund University).

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Executive summary

This State-of-the-art report in the CREDIT project has identified and examined a number of existing sets of performance indicators, methods and tools for understanding user needs, requirement management, databases and mandatory reporting. The report has also focused on approaches to better benchmarking schemes in the Nordic and Baltic countries that can compare end-user and client needs, and performance requirement on building parts as well as performance measures on real estate in use.

The report covers a range of different subjects as well as practices. The participating countries have chosen different, but complimentary themes, which also have a special local interest and focus in each country.

The national and international experiences are studied as a background and as part of the recommendations to the following work packages in the CREDIT project.
1 Introduction and objectives

This chapter describes the objectives, organisation and work packages of the CREDIT project as well as the deliverables including the reports published by CREDIT. The chapter also describes the tasks for Work Package 3 'State of the art' (WP3) and is an introduction to this first CREDIT report.

1.1 The objectives and the project programme of CREDIT

Sir Winston Churchill once said, “We shape our buildings, afterwards our buildings shape us” (28 October 1943). This quotation underlines how strongly a building can influence its occupier or user. It is not without complications to provide complex public facilities for example for hospitals, schools, universities and libraries able to meet both the internal and external stakeholders’ needs and experience. The aims and demands of different stakeholders within a project may sometimes conflict with other stakeholders’ interest. Understanding the needs and experience of the stakeholders is essential to stay competitive in today’s market. A client who pays attention to the needs of the end-users will be rewarded with a high-performance property. Concurrently, this shift seeks to solve many ills associated with inadequate building conditions that result in poor building function.

The amount of both public and private money that are invested in delivering public and private facilities calls for decisive measures to be adopted. Collaboration with the relevant stakeholders helps building owners to identify performance indicators required for creating high-performance facilities. The project aims to define a model for the implementation of performance requirements that ensures fulfilment of various types of users’ and stakeholders’ needs and demands. The model should also allow for the continuous measurement of the effectiveness of the applied requirements and the model as such, so that it can be improved as more knowledge and experience of it is gained.

Adhering closely to the themes laid down in Erabuild, the aim of CREDIT is to improve transparency of value creation in construction and real estate. Thus, the objectives of CREDIT are:

– To capture end-user needs and experience in order to identify and quantify – where possible – value creation in the constructions and real estate sectors,
– To develop compliance assessment and verification methods,
– To define and develop benchmarking methods and building performance indicators for the construction and real estate,
– To propose recommendations for international benchmarking of key performance indicators of buildings.

Consequently, the deliverables of CREDIT are:

1. The establishment of a network of Nordic and Baltic researchers of benchmarking and performance indicators by frequent interaction in workshops across the Nordic and Baltic countries.
2. A State-of-the-Art report to identify and critically examine a number of existing tools, databases, mandatory reports, approaches and benchmarking schemes to capture and measure end-user needs, client demands and public requirements to performance and value creation.
3. A strategic management and decision-making tool to guide the definition and development of benchmarking methods and building performance indicators in different business cases.

4. A comprehensive performance assessment and management tool with associated key performance indicators to capture end-user needs and experience and to continuously measure and verify the compliance of performance throughout the life cycle of an actual building project linked to building information models.

5. Recommendations of how sector and national indices of performance indicators can be designed in order to promote international benchmarking of construction and real estate.

6. Dissemination of the lessons learned and tools developed through news articles, press releases and workshops with actors from the construction and real estate sector.

The expected impact of CREDIT on the construction and real estate sector at national and European levels are as follows:

- Improved understanding of end-user needs and client's demands to performance requirements and level of satisfaction.
- New and improved tools to make the costs/value ratio of products and services more transparent throughout their life cycles.
- A more solid and evidence-based background for launching new public policies to improve the competitiveness of construction and real estate business.
- Improved opportunities for more accurate comparisons with neighbouring countries via improved methods.

More information about the background is given in the CREDIT project programme (CREDIT, 2007).

1.2 Main partners in the CREDIT project

The CREDIT project was a cooperative research project including four Nordic research institutes:

- Danish Building Research Institute (SBi), Aalborg University, Denmark – funded by The Danish Enterprise and Construction Authority (DECA) (Erhvervs- og Byggestyrelsen).
- VTT, Technical Research Centre of Finland, Finland – funded by TEKES
- SINTEF Byggforsk, Norway – funded by The Nordic Innovation Centre (NICe)
- Lund University, Construction Management, Sweden – funded by FORMAS.

Another three associated partners joined CREDIT for the Norwegian part of the project:

- The Icelandic Center for Innovation, Iceland.
- Tallinn University of Technology, Estonia.
- Vilnius Gediminas Technical University, Lithuania.

The Danish Building Research Institute (SBi) was project owner and project coordinator of the project as well as legally responsible according to ERABUILD on behalf of the four main partners. SBi, VTT, SINTEF and Lund University were the national coordinators for the project in Denmark, Finland, Norway and Sweden respectively, and moreover SINTEF was responsible for the coordination with the three associated partners.
The project was managed by a steering committee chaired by the project owner, the project coordinator was secretary and each of the four main partners had two seats. The steering committee saw to the overall coordination and operation of the project, and was responsible for making the decisions necessary in this regard. The following persons represented the four main partners in the steering committee:

- Kim Haugbølle, SBI (project owner), Denmark.
- Niels Haldor Bertelsen, SBI (project coordinator and DK project manager), Denmark.
- Pekka Huovila, VTT (FI project manager), Finland.
- Päivi Hietanen, Senate Properties, Finland.
- Ole Jørgen Karud, SINTEF (NO, IC, ES and LT project manager), Norway.
- Magnus Hvam, SKANSKA, Norway.
- Bengt Hansson, Lund University (SE project manager), Sweden.
- Kristian Widén, Lund University, Sweden.

In relation to national activities, different partners from the construction and real estate sectors were involved in the case studies and the discussions of the findings. All these national contacts and cooperative partners were referred to as national reference group members. They represented different users of performance data and benchmarking systems in the Nordic and Baltic countries and are therefore the target group for the CREDIT results. Together with policy makers, funding agencies and researchers they constituted the Nordic Baltic Reference Group.

More information about the organisation is given in the CREDIT cooperation agreement (CREDIT, 2008).

Figure 1. The main partners and funding agencies in CREDIT

1.3 CREDIT work packages and meetings

Through seven work packages (WPs), the national research groups studied international experiences and examined a number of existing and new methods, tools and systems for performance assessment and international benchmarking. WP1 and WP7 dealt with the general project management and dissemination of results from CREDIT. WP2, WP3, WP4, WP5 and WP6 represented different steps of the research activities from a general study of the state-of-the-art in WP3 through the performance model in WP2, project
assessment in WP4, national case studies in WP5 and international benchmarking in WP6 and returning with the final conclusions and recommendations to WP2. Coordination of the specific research in WP4, WP5 and WP6 were also handled by WP2, and WP2 therefore had the following three tasks:

1. To formulate the research model and coordinate the research in CREDIT.
2. To classify performance indicators in the CREDIT benchmarking model.
3. To summarise the CREDIT reports including national recommendations.

WP3 studied literature and general national practice as background for the specific research in WP2, WP4, WP5 and WP6, and this resulted in a formulation of more specific tasks and objectives for the four other WPs. WP4 studied different project assessment methods and tools and how the different enterprises worked with indicators, assessment and benchmarking. WP5 studied 28 different case studies in the Nordic and Baltic countries, which were grouped and compared within different building segments. WP6 surveyed sector, national and international benchmarking systems of key performance indicators and experience from front-runners in the construction and real estate sector.

According to the CREDIT project programme (CREDIT, 2007), a number of deliverables (D) were agreed for each of the seven WPs. A final list of the specific deliverables (D) is given in Appendix A, and an overview is given below of each of the seven WPs:

- **WP1: CREDIT project management.** (Responsible: SBi/DK)
  Deliverables: Steering committee (SC) and SC Meetings (D1), CREDIT project meetings (D2) and Progress reports and accounts (D3).

- **WP2: Performance models.** (Responsible: SBi/DK)
  Deliverables: Stimulus paper, draft report and final report (D4a) on performance indicator and a draft and final summary report (D4b). D4b is an extra deliverable according to the project programme. CREDIT Report 3 and 6.

- **WP3: State-of-the-Art.** (Responsible: SINTEF/NO)

- **WP4: Project assessments and tools.** (Responsible: Lund University/SE)
  Deliverables: Stimulus paper, draft report and final report (D6) on project assessments and enterprises. CREDIT Report 4.

- **WP5: National case studies.** (Responsible: VTT/FI)

- **WP6: International benchmarking.** (Responsible: VTT/FI)

- **WP7: CREDIT dissemination.** (Responsible: SBi/DK)
  Deliverables: CREDIT project web (SINTEF eRoom) (D9), reference group and user workshops (D10), press releases (D11), news articles in trade journals (D11) and research articles (D12).

Seven two-day meeting packages (MPs) were held in 2008, 2009 and 2010 in the different countries to strengthen the innovative cooperation between the researchers and the national reference groups comprising the main players in planning, construction, real estate, benchmarking and the responsible authorities. Each meeting package (MP) focused on a specific work...
package (WP) and consisted of a one-day project meeting, a half-day user workshop, a reference group meeting and a steering committee meeting.

The seven CREDIT meeting packages alternated between the participating countries:
1. Helsinki, Finland, 24-25 January 2008: Kick off and end-user values.
6. Tallinn, Estonia, 26-27 October 2009: Discussing the final CREDIT Reports 1, 2, 3, 4, 5 and 6. An extra meeting according to the project programme.
7. Copenhagen, Denmark, 25-26 January 2010: Final reports and closing of CREDIT.

The CREDIT project plan (CREDIT, 2007) outlines the relations between work packages (WPs), meeting packages (MPs) and deliverables (D). Every six months a project status was prepared and a progress report sent to Erabuild at the Danish Enterprise and Construction Authority, and in February 2009 it was extended to a ‘CREDIT Progress and Mid-term Report’ of 36 pages (CREDIT, 2009). A final version of the project and meeting plan is given in Appendix A.

Figure 2. The seven work packages (WPs) in CREDIT with the responsible countries (DK, FI, NO or SE) in bracket. WP2-WP6 are the main research WPs, and WP1 and WP7 include the project management and dissemination of results of CREDIT respectively.
CREDIT reports, deliverables and eRoom

The work of each of the main work packages (WP3, WP5, WP2, WP4 and WP6) were documented in five reports - CREDIT Reports 1, 2, 3, 4 and 5 - and in various scientific articles and news articles. For example Report 1 describes the state-of-the-art as a result of the work of 'WP3 State-of-the-Art'.

The work of 'WP5 National case studies' resulted in 28 Nordic and Baltic case studies with focus on performance indicators, assessment tools and benchmarking in front-runner building projects, enterprises and benchmarking organisation and reported in CREDIT Report 2. Each case study is described in accordance with a common guideline and together with results from the state-of-the-art report they form the background for the research and proposals for future improvements presented in CREDIT Reports 3, 4 and 5.

CREDIT Report 3 describes the CREDIT performance indicator framework as a result of 'WP2 Performance models', and the indicators are relation to national regulations; international standards and research; and:
- Report 4: Project Assessment in Construction and Real Estate.
- Report 5: Internal, National and International Benchmarking.

The results of the five CREDIT reports are summarised in this CREDIT Report 6 together with recommendations on how to implement the results nationally in the Nordic and Baltic countries.

In Figure 3 a graphical illustration is given of the three levels of the hierarchy of CREDIT reports, and after Chapter 8 all CREDIT reports are listed. Through the research all deliverables were filed in the common CREDIT project web in eRoom in SINTEF, Norway, and a complete list can be seen in the minutes of the CREDIT Steering Committee Meeting 8 (CREDIT, 2010).

Figure 3. Graphical illustration of the hierarchy of CREDIT reports.
1.5 Purpose of WP3 State-of-the-Art

The purpose of WP3 State-of-the-Art is to identify and examine of a number of existing sets of performance indicators, methods and tools for understanding user needs, requirement management, databases, mandatory reporting, approaches and benchmarking schemes to capture and measure end-user and clients needs and requirements on performance in the Nordic countries.

The WP3 State-of-the-Art will also give input to the following WPs.

1.6 Research Design

The methods used to obtain the information that is included in the WP3 report, include studies of literature, articles, cases and internet searches. Workshops and interviews with researchers as well as industrial partners involved in the building process (including architects, contractors, real estate firms, public authorities and contractors) have also been carried out.
2 State of the art in Norway

2.1 What makes a good Indicator?

*Dag Fjeld Edvardsen, SINTEF*

2.1.1 What is an Indicator

There are many ways to define the word “indicator”. The following is the definition on Wikipedia:

_Etymology, From Latin indicare, from in- + dicare, "to proclaim", to indicate (third-person singular simple present indicates, present participle indicating, simple past and past participle indicated)._ 

1. To point out; to discover; to direct to a knowledge of; to show; to make known.
2. To show or manifest by symptoms; to point to as the proper remedies; as, great prostration of strength indicates the use of stimulants.
3. To signal in a vehicle the desire to turn right or left
4. To investigate the condition or power of, as of steam engine, by means of an indicator.

Based of the first point in the list above, we can think of an indicator as something that gives us knowledge about what we are interested in.

The philosopher, Immanuel Kant, wrote about what things we could know. His main and most interesting idea is "Ding an Sich" or "Things in themselves." Following Kant, we can never know the things in itself, only get different impressions of it. Indicators are one way of getting an impression of something. One could argue that, according to Kant, every subjective impression is an indicator.

There are also more practical reasons why we sometimes focus on an indicator instead of trying to measure the things in themselves. It might be that it was possible to get perfect information about the thing we are interested in, but that there are reasons that we choose to focus on an indicator of something instead of the thing itself.

One example could be that we were interested in the average square meter price of living flats in a country. It would be possible to get information about every property transaction that has taken place, but this could be costly and time requiring. It might be better to examine a smaller and random sample of living flats, and based on this calculate an estimator of the average square meter price of all living flats in the country.

Another reason for using an indicator could be that the set of relevant facts are multidimensional, and that we want a single number since it might be easier to relate to. "BMI" (Body Mass Index) is an example where one single

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1 http://en.wiktionary.org/wiki/indicate
2 http://en.wikipedia.org/wiki/Body_mass_index

13
number is used instead of more complicated, but also more precise, measures.

All in all, we often use indicators when the real facts are difficult or costly to get hold of, or difficult to relate to or explain.

2.1.2 Reliability, Validity and statistical properties
The most important thing about an indicator is that it should tell us something relevant about what we are interested in. But it is also possible to define some more formal aspects when it comes to the quality of an indicator. Key terms are reliability and validity – and related to these, the statistical properties of the indicator.

Reliability
Reliability is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials.

Validity
Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While reliability is concerned with the accuracy of the actual measuring instrument or procedure, validity is concerned with the study’s success at measuring what the researchers set out to measure.

Statistical properties
The following is based on the text on http://en.wikipedia.org/wiki/Statistic:

1. In statistics, a consistent sequence of estimators is one which converges in probability to the true value of the parameter. In many cases, this is referred to simply as a consistent estimator. A sequence is said to be strongly consistent if it converges almost surely to the correct value.

2. In statistics, sufficiency is the property possessed by a statistic, with respect to a parameter, “when no other statistic which can be calculated from the same sample provides any additional information as to the value of the parameter”.

3. In statistics, the difference between an estimator’s expected value and the true value of the parameter being estimated is called the bias. An estimator or decision rule having nonzero bias is said to be biased. Although the term bias sounds pejorative, it is not necessarily used in that way in statistics. Biased estimators may have desirable properties. Not only do they sometimes have a smaller mean squared error than any unbiased estimator, but in some cases the only unbiased estimators are not even within the convex hull of the parameter space, so their use is absurd.

4. In statistics and signal processing, a minimum mean square error (MMSE) estimator describes the approach which minimizes the mean square error (MSE), which is a common measure of estimator quality. The term MMSE specifically refers to estimation in a Bayesian setting, since in the opposing frequentist setting there does not exist a single estimator having minimal MSE.

5. In probability theory and statistics, the variance of a random variable, probability distribution, or sample is one measure of statistical dispersion, averaging the squared distance of its possible values from the expected value (mean). Whereas the mean is a way to describe the location of a
distribution, the variance is a way to capture its scale or degree of being spread out. The unit of variance is the square of the unit of the original variable. The positive square root of the variance, called the standard deviation, has the same units as the original variable and can be easier to interpret for this reason.

The variance of a real-valued random variable is its second central moment, and it also happens to be its second cumulant. Just as some distributions do not have a mean, some do not have a variance. The mean exists whenever the variance exists, but not vice versa.

6. Robust statistics provides an alternative approach to classical statistical methods. The motivation is to produce estimators that are not unduly affected by small departures from model assumptions.

7. Computational convenience. ... self-evident.
2.2 Efficiency and Productivity of the Norwegian Industry

Dag Fjeld Edvardsen, SINTEF

In 2001 SINTEF Building and Infrastructure started a project to examine the efficiency and productivity of the Norwegian construction industry. The financing came from the Research Council and the construction industry in Norway. It was finalized in 2007, and two people got their PhD’s as a part of the project.

In the previous years it was observed that at a macro level the total factor productivity of the construction industry was not keeping up with other industries. The research project was started in order to investigate the causes, and discover if something could be done to change this at the micro level.

2.2.1 An introduction to the approaches of the Norwegian research project

Measuring efficiency

The core research task was to develop a methodology to measure technical efficiency at the project level. The DEA-method (see below) was chosen as the estimation tool. It allows measuring the efficiency of a unit (a firm or a project) and can take into account that the production process might simultaneously include both multiple inputs and multiple outputs.

Figure 4. The principle behind the estimation of efficiency; “Black box”

Figure 4. illustrates the approach used in the Norwegian research project. This kind of approach is often referred to as “Black box”. The reason for this name is that we do not go into details of the technology of the production as such, but we estimate the efficiency of the a certain construction project’s production process based on how much input is required to produce how much output – relative to the other construction projects we examine. We are also interested in Actions of management and Environmental conditions, so that we can both explain what actions give the best results, and also adjust the calculations for environmental conditions so that we create a level playing field.

The estimated efficiency, the efficiency score, is a number with a possible range between 0 and 100 percent. 100 percent means that the unit is fully efficient; no other units produce the same (or more) output with less input.
Choosing variables
To identify which aspects of output and input should be included in the estimation model we had to make some trade offs. If we included too few aspects we would risk that the measurement did not capture the inputs and outputs at a detailed enough level. On the other hand, if we included too many aspects the model would become too "heavy" and not be able to discriminate between efficient and inefficient projects. This is referred to as "the curse of dimensionality" in statistics.

To get some support for choosing the right inputs and outputs we used Stepwise DEA. In concept this is very similar to stepwise regression analysis. The key is that we use the computer to discover which inputs and which outputs are most influential, and prefer to include those who influence the efficiency score much instead of those who does not make any great difference.

The variables used in the DEA model
Production:
- Quality of Product
- Number of elevators
- Saleable area in m2
- The rest of the area in m2
Input:
- Total cost of the building(s)

Indicators and meta-indicators
This approach used in this research is interesting when it comes to a discussion about the nature of indicators. The efficiency score is itself an indicator; it says something about the difference between observed input usage and how much lower the input usage could have been if the production process was fully efficient.

In order to calculate the efficiency score with DEA we use observations of different inputs and outputs. In this research project one output was the total living area in a block-of-flats. This is itself an indicator, and exactly how to define it was not obvious. This means that in a sense, the efficiency score is a meta-indicator – an indicator based on other indicators.

Can measuring increase efficiency?
It was desired from the start that one of the goals in this research project was to create something that can be used as a tool in the construction industry.

Figure 5. The principle approach

Figure 5. shows the principle approach used in the research project. One very important bit is part 5 (compressed report to the contributing Project Manager) and part 8 (experience based learning in the companies). In the
research project we put a lot of effort into creating report generator to create relevant feedback to the participating project managers and companies.

What explains the differences in efficiency?
Using a regression analysis we identified 14 statistically significant factors affecting efficiency (The sign in parenthesis show which direction efficiency was influenced by each factor, "+" means higher productivity, "-" means lower).

1. Very small property to build on (-)
2. Clean building each day (-)
3. No bonus for leaders (-)
4. Committing agreement with supplier of construction products (+)
5. Large construction company (-)
6. Large percentage of costs as wages to leaders (-)
7. High share of building cost used to fix errors (-)
8. Demands of improvement in labour conditions/safety (+)
9. High number of persons getting hurt per m2 (-)
10. PM (project manager) very focused on economy (+)
11. PM very concerned with catching up with delays (+)
12. PM was very unwilling to let people work more than the agreed number of hours per week (+)
13. PM had separate meetings with representatives for the employees to reduce the number of people not going to work because of health problems (-)
14. PM in a large degree bought services from internal or external experts (-)

Feedback to the participants – who needs what?
Figure 6 is a bar chart showing the efficiency of each of the contributing companies. This is interesting for the researcher and possibly also the larger companies.

The E-scores range from ca. 50 % to 100 %. The Best Practice project is situated to the far right in the diagram. General interpretation: Each of a certain (anonymous) companies building projects are represented by the black bars. The distance to the top (Best Practice) is for this company in average 28 %, which indicates the improvement potential to reduce all costs with 28 % if all projects became fully efficient.

For the project managers this information it is probably too aggregated to be very relevant. For this reason the research project also created a very detailed report (8 pages) for the project manager each of the building projects. This shows in detail how his/her project performs at a much more detailed
level, including which of the sub-cost were higher or lower that the average. The thinking behind this was that in addition to use the correct indicators to measure efficiency, it is also important to consider which indicators are relevant for different participants.

2.2.2 More technical info about efficiency scores and DEA

The basic idea behind DEA is to use the closest linear envelope of data as an estimate of the border of the production possibility set ("the front"). The efficiency of an observation (often referred to as a "DMU", "Decision Making Unit", in the DEA literature) is calculated as the relative distance to the frontier. The efficiency score is a number between 0 and 1, and the units positioned on the frontier is assigned the efficiency score of 1. Farrells concept "input oriented efficiency" is a measure of how much it is possible to simultaneously reduce all types of resource usage proportionally, without decreasing any of the production aspects. Farrells "output oriented efficiency" is the inverse measure – how much is it possible to simultaneously increase all production aspects without increasing any of the inputs.

Banker et al. (1984) formalized the mathematical axioms an envelopment has to satisfy, and showed that the production possibility set in DEA is the smallest area (the closest front) that satisfies the following: (x1,x2 are vectors of resource usage; y1,y2 are vectors of production aspects):

*All observations are possible:* If we observe (x1,y1), then it is possible to produce y1 using x1.

(Convexity: If (x1,y1) and (x2,y2) are observed, then a(x1,y1)+(1-a)(x2,y2) is possible for all a between [0,1] (assuming "variable returns to scale" (VRS). If we assume “constant returns to scale" (CRS), any positive a is allowed.

*Free disposability:* Higher resource usage always implies that it is possible to produce the same or more. It is also possible to produce less using the same or higher resource usage.

Formally we have the production aspects ym (m = 1,...,M) and the resource usage x_s (s = 1,...,S). DMU "i"s resource oriented efficiency score with variable returns to scale (VRS) can then be calculated mathematically as a linear programming problem ("LP") in the following way:

\[
E_{ij} = \text{Min } \theta_i \\
\text{s.t. } \\
\sum_{j \in N} \lambda_{ij} y_{mj} - y_{mi} \geq 0, \quad m = 1,...,M \\
\theta_i x_{si} - \sum_{j \in N} \lambda_{ij} x_{ij} \geq 0, \quad s = 1,...,S \\
\lambda_{ij} \geq 0, \quad i, j \in N \\
\sum_{j \in N} \lambda_{ij} = 1
\]

3 The main ideas of DEA was originally introduced in Farrell (1957), but the name was coined in Charnes et al. (1978), where they further developed how the efficiency numbers can be calculated using linear programming.

4 A more detailed introduction to DEA can be found in Coelli et al. (2005) (basic) and Cooper et al. (2000) (advanced).
The point $\left( \sum_{j \in N} \lambda_{yj} x_{sj}, \sum_{j \in N} \lambda_{yj} y_{mj} \right)$ is on the frontier and is a reference point for this DMU. The Linear Programming problem above assumes VRS (variable returns to scale). If the last line is dropped, it calculated assuming CRS (constant returns to scale).

**DEA illustrated in 2D**

![Figure 7. DEA illustrated in 4 dimensions](image)

Figure 7 shows DEA illustrated in four dimensions. The grey line from the origin shows the efficiency frontier with constant returns to scale, while the stepwise linear black line shows the efficiency frontier assuming variable returns to scale. Some key terms are shown. See the DEA literature for details.
2.3 References


2.4 Life Cycle Costing and Economic Indicators

Guri Krigsvoll, SINTEF

Norwegian standard for Lifecycle Costing, NS3454, defines the cost classification system to be used in life cycle costing in construction. The standard clarifies the relationship between life cycle costs, annual costs, lifetime costs and annuity costs and establishes the main categories for each of them. This allows for the registration of empirical data, the compilation of key number indicators and the comparison of different buildings and civil engineering works.

Annual costs include the costs of management, operation, maintenance and development throughout the entire functional lifetime.

2.4.1 Benchmarking in Facility management

The Norwegian Society of Facility Management NBEF (http://www.nbef.no) consists of former Byggherreforeningen, The Network Key number for Benchmarking (NFB - http://www.nfb.no) and Network Facility Management. NBEF is a non-profit organization for companies and persons working in facilities or property management.

The purpose of NBEF is to create a common communication and development platform for property owners, institutions/corporations, users/tenants and other individuals who have property-, building- and service management as their prime professions.

The NFB goal is to focus on activities that contribute to more efficient use of resources in the facility management, and hence using the key number (Key Performance Indicators) as support tools.

The key numbers are in three main categories:
1. Key numbers related to costs, as management, operation, maintenance (MOM) costs per m2 or per working space. The cost categories are from NS3454.
2. Key numbers related to area, as m2 per working space in office building or per pupil in school
3. Key numbers related to consumptions, as energy consumption per m2, water use, waste

The key numbers are actual numbers, not theoretical numbers. The key numbers express the consequences of activities.

The purpose of the key numbers is description of actual use, giving an overview for benchmarking and improvement. The key numbers can be used as input information in early stage life cycle costing. Aspects from life cycle costing may also be used as indicators, for instance to compare between building or to compare results from one year to another.

2.4.2 Environmental indicators and benchmarking

Ecoprofile is a method for simplistic environmental assessment of buildings and gives a good picture of the building’s resource and environmental profile. A good environmental classification can lead to a market advantage in the sale and rental of commercial buildings. Ecoprofile can also be used as an internal management and steering tool for the building owner.
The Ecoprofile of a building is divided into three principal components. These components consist of the “External environment”, “Resources” and “Indoor climate”. The principal components are divided into sub-areas that have different consequences for the principal components and are therefore weighted. Several of the sub-areas also have underlying sub-areas. Each sub-area and underlying sub-area contains a number of parameters. There are currently 82 parameters included in the method. Each of the parameters is individually evaluated and given a grade. A description of the classes is similar to that found in NS 3424 Condition Evaluation of Structures.

The grading scale is from 1 to 3 where:
- Class 1 = Lesser environmental impact
- Class 2 = Medium environmental impact
- Class 3 = Greater environmental impact

Eventually a class 0 is going to be included that will represent a sustainable construction, but there is currently no basis for defining such a level. Currently there are levels worked out for parameters that are important for office and residential buildings.

![Figure 8. Structure of the 3 principle components of Ecoprofile](image)

When a building is assessed by use of Ecoprofile, the results are sent to Byggsertifisering as the owner of the system. The results are compared with the average results for the building category, and these results are sent to the building owner. The next figure is showing results from a specific building compared with the average results.

![Figure 9. Environmental consequences](image)
2.5 Benchmarking

Bjørn Andersen, NTNU, and Lars E. Onsøyen, SINTEF

The first section gives a brief introduction to benchmarking. The second section provides examples of benchmarking from industries other than construction and real estate.

2.5.1 Introduction to benchmarking

The attraction to benchmarking has grown strongly since 1979 when Xerox introduced it (Camp, 1989). Benchmarking has spread geographically, now being used in large parts of the world, and can be found in a variety of businesses as well as in the public sector (Camp, 1995).

Benchmarking is a tool for comparison, learning and improvement. Benchmarking can be defined as:

(...) the practice of being humble enough to admit that someone else is better at something, and being wise enough to learn how to match and even surpass them at it.

American Productivity & Quality Center (1993)

A more operational definition of benchmarking was offered by Andersen and Pettersen (1995):

Benchmarking is the process of continuously measuring and comparing one's business processes against comparable processes in leading organisations to obtain information that will help the organisation identify and implement improvements.

Andersen and Pettersen (1995)

Depending on what is being compared, three types of benchmarking can be defined (Camp, 1989):

1. Performance benchmarking is comparison of performance measures.
2. Process benchmarking is comparison of methods and practices for performing business processes.
3. Strategic benchmarking is comparison of the strategic choices and dispositions made by other companies.

Depending on whom one compares against, four types of benchmarking can be defined (Camp, 1989):

1. Internal benchmarking: comparison between departments, units, subsidiaries, or countries within the same company or organisation.
2. Competitive benchmarking: direct comparison of own performance/results against the best real competitors, i.e., that manufacture the same product or deliver the same service.
3. Functional benchmarking: comparison of processes or functions against non-competitor companies within the same industry or technological area.
4. Generic benchmarking: comparison of own processes against the best processes around, regardless of industry.
The rationale behind these recommendations build partly on the expected benefits to be achieved by the different combinations and partly on how easy it is to gain access to data and information and carry out the benchmarking in general. Furthermore, these recommendations were originally developed in 1995, and some combinations might have found new applications, making the recommendations somewhat inaccurate. Some explanations are probably in order:

- **Internal benchmarking**: In organizations where there are several similar units (e.g., a bank with many bank offices, a manufacturing company with several similar facilities, or a construction company divided into regions), benchmarking across these units can be highly useful:
  - Performance benchmarking can be beneficial in determining which unit displays good/best practice as a basis for telling others where to find learning sources and for creating incentives through internal “championships”, often linked to some bonus system.
  - Process benchmarking is also often used and is suitable as there are no issues of not gaining access to facilities or information. However, the magnitude of improvements can often be less than when benchmarking against external organizations, simply because the likelihood of radically new practices existing with the organization is slim.
  - Strategic benchmarking seems to have limited value, unless different units have been given the freedom to pursue strategies independently of one another, thus having gained experiences that the others could learn from.

- **Competitor benchmarking**: The main problem with competitor benchmarking is the access to relevant benchmarking partners. Many organizations hesitate to share information with competitors, at least unless it is anonymized, and in some countries and for some business areas, such cooperation is even illegal. However, if willing benchmarking partners can be identified and a study carried out without infringing on legal matters, there is a clear potential for all three types of benchmarking:
  - Performance benchmarking can provide insight into industry standards and rankings, motivating improvement.
  - Process benchmarking, given access is obtained, probably offers more chances of finding new practices than internal benchmarking.
– Strategic benchmarking can be useful in comparing choices of technology, markets served, pricing, etc.

– Functional/generic benchmarking: While it was common to separate between these two 15-20 years ago, the common view today seems to view these as one approach, characterized by finding benchmarking partners outside one's own industry sector. The main challenge is to find benchmarking partners with similar challenges/processes, but if this can be achieved, generic benchmarking has in many cases proven very powerful for process benchmarking:

– Performance benchmarking is often less relevant, however, since the conditions affecting performance levels usually vary substantially from sector to sector. Even though both a bank and a hospital run recruiting processes, comparing numbers of applicants, vacancies, wages, etc. can be difficult.

– Process benchmarking, on the other hand, is much more fruitful across sectors. The bank and hospital can compare their recruiting processes and learn from one another, even if their situations are quite different.

– Strategic benchmarking is again less relevant when comparing across industries, although questions about for example outsourcing of production to low-cost countries, being small and independent versus merging with competitors, degree of vertical integration, etc. probably can have some value in being compared in generic benchmarking.

Objectives
According to Andersen (1998) the current interpretation of benchmarking is:
– Measurement, of own and the benchmarking partners' performance level, both for comparison and for registering improvements.
– Comparison, of performance levels, processes, practices, etc.
– Learning, from the benchmarking partners to introduce improvements in your own organization.
– Improvement, which is the ultimate objective of any benchmarking study.

Benchmarking process model

![Benchmarking process model](image-url)
Considerations when Defining Performance Indicators

We recommend that you take the following elements into consideration when defining performance indicators:

- Balance different dimensions of performance (quality, time, cost, flexibility, safety, environmental impact, ethics, etc.)
- Balance leading and lagging indicators
- Focus on measuring drivers of performance
- Subjective/qualitative data are often the only option and can be as accurate as surrogate quantitative data
- Be careful not to stimulate dysfunctional behavior
- Ensure that the required data is possible to obtain
- Consistency of measurements across organization/sectors/countries (where relevant)
- Data collection cost/burden
- Data quality
- Don’t overlook snoozing alligators (http://viscog.beckman.uiuc.edu/grafs/demos/15.html)
- Avoid extensive measurement and data collection unless there is a real need for the data

2.5.2 Benchmarking examples from other industries

ENAPS

The ENAPS project (European Network for Advanced Performance Studies) funded by the European Commission through the ESPRIT programme was carried out in the period 1995-1999.

The objective of ENAPS was to establish and test a permanent European network for advanced business process performance studies in European manufacturing industry. ENAPS was a network established by leading industrial and academic partners and agents covering most of the countries in the European Union and the European Economic Area, as well as some other countries. ENAPS was mainly limited to three sectors within the manufacturing industry; electronic, aerospace, and automotive.

The ENAPS project produced the basic infrastructure for a performance benchmarking network, which included (Andersen and Jordan, 1998):

- A set of performance indicators
- A European network of agents
- An ICT infrastructure for collecting, storing and analysing benchmarking data

Among the achievements from the ENAPS project was a database holding large amounts of performance data on European enterprises, and being a
starting point for conducting benchmarking across Europe, thus helping European industry improve. ENAPS tools such as the performance measurement questionnaire, the benchmarking tool, and manuals for these made the database accessible to industry.

Information flow to and from the ENAPS database is described in the figure below.

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In 1997 ENAPS consisted of 126 Performance Measures and 95 Performance Indicators (Browne et al, 1997). According to the ENAPS Final Report (ENAPS, 1999), using the quantitative ENAPS scan and the qualitative EFQM scan together are excellent tools to give the company a reliable SWOT analysis (Strengths & Weaknesses, Opportunities & Threats) by a consultant in a short time.

After the project the ENAPS Company was established to exploit the project results commercially. According to a member of the ENAPS project, interviewed in 2008, the attempt to establish ENAPS as a commercial service failed due to:

- Cumbersome manual data collection and registration for the companies.
- Doubts about the quality of the data (many obvious errors).
- Confidentiality issues – one main selling point was the potential for follow-up process benchmarking, but companies were concerned about sharing information more openly.
- The database reached about 500 entries, but even this did not leave useful samples for queries.
ENAPS - GENERIC - FRAMEWORK

**BUSINESS PROCESSES**

- **PRODUCT DEVELOPMENT**
  - Product Research *
  - Product Engineering and design
  - Process Engineering and design
  - Co-engineering

- **OBTAINING CUSTOMER COMMITMENT**
  - Market Development (Analysis?)
  - Marketing and Sales
  - Tendering

- **ORDER FULFILMENT**
  - Procurement and inbound logistics
  - Production planning & control
  - Manufacturing and assembly
  - Distribution and outbound logistics
  - Order processing

- **CUSTOMER SERVICE**
  - After sales-service
  - Product take back

**SECONDARY PROCESSES**

- **SUPPORT**
  - Financial management
  - Human resource management
  - Information management
  - Maintenance
  - Internal control of health, environment and safety

- **EVOLUTION**
  - Continuous business process improvement
  - Product research *
  - Production technology research
  - Human resource development
  - Supplier base development
  - Development of external relations
  - Strategic Planning

* It is possible for a function to belong in more than one process.

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**Benchmarking - COST Action C18 Performance assessment of urban infrastructure**

The following sections appear in the report COST Action C18 Performance assessment of urban infrastructure (2008). The material is rendered with permission.5

**Benchmarking as tool for learning about the water and wastewater services**

The interest for benchmarking as tool for learning about the water and wastewater services and their quality and efficiency has increased in Norway for the last couple of years. With exception of the municipality of Oslo, that has participated in the 6-cities benchmarking network, there has only been a few benchmarking networks. Later on as Norwegian Water (the former NORVAR), initiated a benchmarking scheme that has gradually developed and increased it’s participation since 2000 (www.Norskvann.no).

A breakthrough for the interest of benchmarking within the municipalities came with the project "VARFIN", financed by the Norwegian ministry of municipalities, where the possibilities to implement a national benchmarking system with a new regulation system was studied (Sjøvold et al. 2003).

The project studied possible means to improve efficiency and serviceability of the Norwegian water and wastewater services, involving the establishment of a new information system handling a mandatory national benchmarking scheme to keep track of costs and quality of the services (metric benchmarking). The ministry wanted to evaluate possibilities to implement a regulation model based on experiences from the grid power supply sector. The findings of this study concluded that the system should be transparent and internet based in order to serve several target groups. The recommen-

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5 The COST Action C18 Performance assessment of urban infrastructure (2008) report states that "No permission to reproduce or utilise the contents of this book by any means is necessary, other than in the case of images, diagrams or other material from other copyright holders."
dation was to start a national benchmarking scheme initially with the existing finance system (full cost system) in a preface period, before implementing a new regulation regime in order to enhance the efficiency of the services. The VARFIN report is available in Norwegian at: http://www.odin.no/krd/norsk/publ/rapporter/016051-220007/dok-bn.html

After the VARFIN project, there was a political resolution to carry on regulation based on the full cost system. As a result of that, the ministry funded the project “Målestokkonkurranse i VA-sektoren” to define a benchmarking model to support the full cost system where the goal is to improve the transparency of the services and to give the municipalities better knowledge about their improvement potential. With the political change with the new government in 2005, the progress with a national benchmarking scheme initiated by the national authorities was halted. The work still put new focus on benchmarking and provided inspiration for other networks. The Norwegian Water benchmarking network has increased its members, and other initiatives have also been initiated.

Benchmarking of the Norwegian municipal solid waste management

Benchmarking of the Norwegian municipal solid waste management started in 1999. The municipal solid waste service is monopolised and the benchmarking project was started because of some cities wishes for a market-correlation. The first project included some few Norwegian cities and inter municipal companies (companies that are owned by the municipalities), also included was the city of Copenhagen, Denmark. The benchmarking was based on the method called Effometer, benchmarking collection of waste from households and on so-called recycling points.

The Effometer for the municipal solid waste sector has been developed by a Norwegian consultant; Erland Eggen. The method is based on a stochastic frontier analysis tool, originally developed for the energy sector. The method includes efficiency in resource utilisation, quality, working conditions and contentment of the customer. This also reflects the performance indicators that are used.

In 2001 the Norwegian Association of Solid Waste Management (NRF) started a new project based on the same method; Effometer This time the benchmarking include the whole waste management chain and 6 Norwegian cities/companies took part. With this project there is build a model for benchmarking of municipal household waste in Norway. In 2003 10 cities/companies took part in a benchmarking, which is recently presented.

The benchmarking is carried out on two levels of detail; the first level gives the total efficiency for the company and the other level gives comparison on activity level. A third level where you compare the process behind the activities has not been used so far. The results able comparison of your own company against other companies, and you can find your potential of efficiency. You can also find out where to improve and if it gives short-term profit or long-term profit (Eggen, E. 2004).

2.6 References

American Productivity & Quality Center (1993). Basics of Benchmarking (Course Material), APQC, Houston, TX.


3 State of the art in Finland

3.1 Capturing User Needs

Tarja Häkkinen and Seppo Valli, VTT

3.1.1 Definitions

This section presents a summary of definitions given for usability, serviceability and performance. The definitions are dealt with in the context of sustainable building and construction.

Sustainable building is a comprehensive process which is able to understand user needs and requirements, to create design options that fulfil these requirements while minimising environmental impacts and life cycle costs. ISO TS 21929 defines that sustainable building brings about the required performance with the least unfavourable environmental impact, while encouraging economic, social and cultural improvement at a local, regional and global level.

ISO TS 21929 defines a framework for sustainability indicators of buildings. Environmental indicators address environmental aspects in terms of environmental loadings or impacts assessed on the basis of life cycle inventory or assessment. Environmental loadings are the use of resources and the production of waste, odours, noise and harmful emissions to land, water and air. Consequential environmental indicators express environmental impacts in terms of building performance or location either quantitatively or qualitatively.

The economic indicators indicate monetary flows connected to the building life cycle. Social indicators of buildings are used to describe how buildings interact with issues of concern related to sustainability at the community level. Community level issues that may be relevant are for example urban sprawl, mixed land use, development of brown-fields, safety, and noise and air quality. Social aspects can also be addressed on the building level like for example (ISO 2006): quality of buildings as a place to live and work, building-related effects on health and safety of users, barrier-free use of buildings, access to services needed by users of a building, user satisfaction, architectural quality of buildings and protection of cultural heritage.

The three main functions of indicators are quantification, simplification and communication. Changes over time and the development of changes in relation to stated objectives can be monitored with the help of indicators. One of the important functions of an indicator with reference to decision-making is its potential to show a trend. Indicators should be objective and the results should be repeatable. When developing and selecting indicators the starting point is the identification of the main users and user needs (Häkkinen et al. 2002).

ISO 6707-1 provides definitions for performance, performance requirement and serviceability:
– Performance - ability of a product to fulfil required functions under intended use conditions or behaviour when in use
– Performance requirement - minimum acceptable level of a critical property
– Serviceability - ability to meet or exceed relevant performance requirements

According to ISO 9241-11 usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. CIB W111 (CIB) focuses on the concept of usability of workplaces including commercial buildings and buildings for healthcare and education. Usability, with focus on the user perspective, is often a neglected aspect of building performance. Several aspects influence a building’s usability and whether a building is fit for a specific purpose. As a common understanding, the term usability describes whether or not a product is fit for a specific purpose. Usability, or functionality in use, is concerning the buildings ability of supporting the user organisations economical and professional objectives (Nylåna 2005). The quality of use for a building means that it is efficient in use (use of resources, productivity, effectiveness, rationality), offers the desired effect in use (increasing the value), and/or offers the desired quality in use (user satisfaction). Usability focuses on user perceptions of the ease and efficiency with which they can use the building. Serviceability, on the other hand, describes the capability of a building to provide a range of performances for which it is designed, used or required to be used, over time. While usability states a demand perspective, serviceability states a supply perspective. The CIB W060 (CIB) focuses on performance based briefing in relation to client requirements and performance indicators and measures in relation to sustainable building.

ISO 9001 specifies quality system requirements for achieving customer satisfaction by preventing non-conformity. ISO 9001 concerns usability because improving usability of a product is essential to quality. True quality of product design is a result of a usability process that includes measuring and improving usability (Dick 1999).

According to CIB report ‘Working with the performance approach of building’ (1982) performance approach is concerned with what the building is required to do, and not with describing the technical solutions i.e. how it is constructed. A prescriptive approach describes an acceptable solution while a performance approach describes the required performance. The performance approach is, in essence, the practice of thinking and working in terms of ends rather than means. Performance requirements do not say anything about the ways and means of buildings, e.g. the type of materials, the thickness, dimensions, and size of building parts, or the method of construction, but they state the required end result.

The performance approach is dual in a sense that first there is a need to identify and quantify two types of constraining sets i) basic and intrinsic aims that the end product is expected to satisfy, ii) restraining general forces and environmental conditions (Becker 1999). It is essential to distinguish performance issues between i) design features and ii) management, operation and process issues (Cole 2000).

With reference to building performance Prior and Szigeti (2003) make a distinction between demand and supply: Demand includes descriptions of functionality needs of owners and users; Supply includes indicators of serviceability describing the performance of materials, components and structures as features of the whole asset. Based on such information it is possible to
address the quality of fit, matching performance with need and analyse suitability of a building or other constructed asset to meet the required functionality of the users.

Lützkendorf et al. (2005) deal with performance as a major concept which is divided into categories including functional, technical, environmental, economic, social and process performance. Functional performance describes the suitability with planned use and it also covers aspects of accessibility and adaptability. It is closely related to the needs of the building users. Social performance refers to the health, comfort and safety of building users. Building regulations provide a base for these aspects but clients often choose to demand more.

3.1.2 Objectives
The principles of sustainable development define the ecological, economic, social and cultural framework for the activities of communities, enterprises and individual citizens. Vision for a Sustainable and Competitive Construction Sector by the European Construction Technology Platform states (ECTP 2006) that "In the year 2030, Europe's built environment is designed, built and maintained by a successful knowledge- and demand driven sector, well known for its ability to satisfy all needs of its clients and society, providing a high quality of life and demonstrating its long-term responsibility to the man-kind's environment. …In order to meet this vision, objectives and research targets are specified for two key aspects of construction: Meeting client requirements and reaching sustainability."

This SoTA paper discusses usability and capturing user needs from the viewpoint of sustainable building. The specific focus is to try to define the significance and importance of building performance and usability as aspects of sustainable building. The specific scope of this paper is buildings as places to work.

There is a wide consensus that sustainable building is a comprehensive process which is able to understand user needs and requirements, to create design options that fulfil these requirements while minimising environmental impacts and life cycle costs. ISO TS 21929 defines that sustainable building brings about the required performance with the least unfavourable environmental impact, while encouraging economic, social and cultural improvement at a local, regional and global level.

The three main types of benefits associated with sustainable construction are environmental, economic and health and community benefits. Environmental benefits include improved air and water quality, reduced energy and water consumption and reduced waste disposal. Economic benefits include reduced operational costs, reduced maintenance costs and increase revenue (sale price or rent). Health and community benefits include enhanced occupant comfort and health, reduced absenteeism and turnover rate, and reduced liabilities (Andrews et al. 2006).

According to Cole (2005) assessment methods of buildings have overtaken other approaches for the management of sustainable building within building industry. Those methods are increasingly considered as the most potential mechanisms for affecting change while the initial intention was to ensure a specific assessment role to avoid problems from unverified claims on environmental performance. The majority of the existing assessment methods evaluate environmental performance of buildings relative to explicitly declared or implicit benchmarks. The point of view has gradually widened from sole environmental assessment to overall assessment of sustainability aspects of buildings. Existing systems are several; for example the following:
BREEAM (2008) (UK BRE), LEED (2008) (US Green Building Council), Green Star (2008) (Australia), PromisE (2008) (Finland Motiva). These systems are useful not only when rating buildings but also in setting requirements. The strengths of the systems include that those are easy to use, they cover a wide range of sustainability aspects, support target setting, provide a common set of criteria. Weaknesses - on the other hand - include that the true meaning of the selected indicators is not defined, indicators may be overlapping, indicators may depend on each other and the relationship between indicators is not clearly defined. Typically, indicators concern not only environmental performance of buildings but also functional and social performance of buildings.

Building performance is paid stronger consideration within the building sector’s ongoing activities in the field of sustainable building. Performance based building and sustainable building are complementary (Sjöström and Holmgren 2005). There is a growing interest in both the public and private sectors for more sustainable approaches to buildings. Influencing factors are the need to reduce energy use, and greenhouse gases output. However, even more important than mitigating these adverse impacts may be the potential of amplifying the positive impacts of occupant satisfaction and performance (Andrews et al. 2006). Understanding and considering user needs is essential in sustainable building discussed for example in Häkkinen (2007). An integrated design approach may be a basic reason for successfulness of sustainable construction projects (Riley et al. 2004). There is a need to develop methods that support the identification and understanding of user needs, and the interpretation of these needs as requirements for building performance and spaces of building.

Functional performance and social performance are becoming more and more important aspects of sustainable building. The reasons for this can be summarised as follows:

1. Minimising and optimising the environmental impacts of building happens with help of comparing alternative design options. In order to compare we have to be able to define a functional unit against which the comparison takes place.

2. Sustainable building fulfils the required performance and at the same time causes the most favourable environmental impacts while encouraging economic, social and cultural improvement. On the basis of this definition, functional and social performance belongs to aspects of sustainable building, because those are essential targets of user requirements and because the user satisfaction mainly depends on functional and social performance. According to Trinius (2005) performance approach is a key element in sustainable construction: as the performance approach starts off with an expression of what is expected from a building in terms of functionality, the identification of performance requirements can perform as an anchor in other elements of sustainable construction.

In addition, functional and social performance may also be seen as aspects of sustainable building, because those have an effect on the potentiality of buildings and built environment to encourage economic, social and cultural improvement and sustainable development on the whole. Built environment and buildings may be linked to sustainable development through their ability to support work towards sustainability. Sustainable development requires changes compared to the current situation; sustainable development can be defined as an innovation process. There are different strategies to proceed towards sustainable development, but in each case innovations are needed.
(Gerlach 2000). Work spaces and built environment should be able to sup-
port organisations’ activities in the innovation process.

1. It can also be presented as a self-evident conclusion that the better the
building corresponds to the requirements of the owner and the needs of
the users and the better the coming needs have been able to foresee the
longer the building can be used (after new building or refurbishment) by
its users before any needs for making changes and thus needs for demol-
ishing and rebuilding. Thus good functional, technical and social perform-
ance probably saves both economical and environmental resources and
environmental loadings. This can be taken as one of the reasons for de-
fining functional and social performance as aspects of sustainable build-
ing.

2. Organisations seek new solutions for office buildings and efficient space
use in order to achieve direct benefits such as savings in energy use and
costs. The development has proceeded from closed to open spaces, from
personal to shared workstations, and towards telework enabled by ad-
vanced ICT. It is also possible that the threat of climate change forces the
building sector to seek these solutions not only in order to save energy
and costs but also primarily to save environmental impacts. In addition, if
the building sector will be forced to make significant improvements, such
indicators as CO2 per square meter might not be adequate but indicators
like CO2 per employee and/or organisation or CO2 per occupant might be
more effective.

In this kind of situation functional and social performance becomes an impor-
tant issue of sustainable building because it can offer compensation and po-
tential for increasing space efficiency. Improved functional performance may
enable improved efficiency in space use (and thus savings in CO2) without
impairing the quality of building.

There are a number of studies on new work space solutions and their abili-
ties to support satisfaction and productivity (see for example the literature
surveys by Häkkinen and Nuutinen 2007 and Reunanen et al. 2006). For
example Haynes and Price (2004) found that the most important factors that
affect productivity of work include the quality of indoor conditions, workspace
structure, comfort of work spaces, flexibility, and interaction and distur-
bances. Similar aspects affect work satisfaction: possibilities for undisturbed
work and spontaneous interaction, comfort, ergonomics, space for storing
the needed equipments and documents, possibilities for chatting and good
spaces for break; accessibility to needed technology, indoor conditions and
possibilities to adjust (Olson 2002, Veitch et al. 2003 and Charles and Veitch
2002). With regard to workspace structure, there is a general opinion that in-
dividual working rooms and individual workstations create satisfaction, while
lack of those can be compensated with help of good architectural design and
high quality ICT (Voordt 2004).
3.1.3 Processes

Different kinds of methods and standards have been developed for the management of user needs especially in terms of minimum performance levels and technical requirements. The major purpose of legislation in this field is to ensure the health and safety issues of buildings. However, many buildings are still suffering from failures and weaknesses and there is a potential for improvements. This shows that good usability cannot be ensured with help of minimum levels stated by building codes, but a better understanding is needed to improve the understanding of usability (Nylåna 2005).

Case studies have also shown (for example Häkkinen et al. 2007) that in spite of careful preparation there may be significant problems in understanding and identifying the user needs. Systematics that support requirement setting and identifying user needs in terms of functional performance and consistence with the strategic working models are missing. The existing methods mainly support subsequent assessment of user satisfaction.

The workplace concept represents the convergence of facilities management, information technology and human resources. The responsibilities of facility managers extend beyond operating issues to the more fundamental goals of providing high-performing and sustainable workplaces. Accordingly, the performance measurement paradigm must also be shifted from measuring facilities to measuring workplaces, using models and measures that recognize the importance and interdependence of facilities, information technology and human resources (Kaczmarczyk and Murtough 2002).

Space planning is the process of optimizing the layout of a building to suit a business's needs; ideally this is done in the context of the business plan and facility management plan (Muir 2003). Conceptually the process is simple; the needs of the business and those of the employees are gathered, analysed and translated into a space plan through a design process. The success or a failure of the space planning solution can be assessed using various indicators and methods. Different kinds of user satisfaction survey instruments exist. These link user satisfaction and self-assessed productivity to the environmental factors of thermal, lighting, acoustic and spatial comfort and privacy and other issues (Wilkinson and Leifert 2003). The outlines of these kinds of surveys can also be made use of in the process of understanding user needs.

The premise is that especially the following three types of methods can be used to support the understanding of users’ needs: 1) outlining functional and social performance, 2) interviews, and 3) visualisation tools. Structured outlines of functional and social performance support owners and users to express their needs. Also visualisation tools should be developed and made use of in the process of requirement management. The nature of user activities and the practical meaning of the stated strategic goals of an organisation should be understood in the early stages of project. At present, the building process lacks systematic for identification and understanding user needs from the view point of

- the consistence of workspaces with user's strategy, activities and desired ways of working,
- suitability for daily user needs and activities,
- special requirements based on specific characteristics of work,
- user's tolerance with regard to risks of non-conformity,
- compatibility with desired imago.

Section 2 introduces definitions given for usability, serviceability and building performance. We lack detailed outlining which could be made use of when investigating user needs. However, there are approaches which offer a good
starting point. For example, there are building-level tools for requirement setting for building performance; these include the Finnish tool EcoProP (Huovila 2005). These methods and tools should be further developed to support the identification of space and activity specific needs. At present, the main headings of the EcoProP tool are as follows:

- Conformity: Location, Spaces, Services
- Performance: Safety, Indoor conditions, Accessibility, Adaptability; Usability; Comfort.

Usability is not divided into subheadings. REKOS (Häkkinen et al. 2002) project defined that the usability is about building spaces and their relations, ability to orientate, and the easiness to use the spaces. The connections of different kinds of spaces are essential from the view point of usability, for example the location of kitchen spaces with regard to meeting rooms, and location of corridors with regard to office rooms. The easiness to use the spaces is also important. This may depend for example on the possibilities to adjust indoor conditions, easiness to clean and operate spaces, and easiness to maintain and repair spaces. Flexibility or adaptability might also be seen as one part of usability. REKOS defined flexibility with regard to residential buildings and divided the term into the following sub headings: Usability of spaces for different kinds of use purposes (from the view point of electricity, ICT and other installations); Flexibility with regard to furnishing (ability to place furniture variedly); Ability to make changes in the image of spaces; Ability to make changes in the dimensions of spaces. Correspondingly, we can define that in addition to connections of different kinds of spaces, also the standard of installations, image, and furnishing options are of importance.

In an early design phase, the architect typically visualises various design concepts by hand sketching, or by making draft layouts and illustrations with an image processing or design tool. The visualisation is needed in order to negotiate and decide over aesthetical, functional, and technical issues. The process includes typically several iterations, which eventually converge to an optimal or widely accepted solution. An ideal support tool might be a system combining the ease of hand sketching with the accuracy and realism of a computer based system. In principle, architectural 3D models would work fine in visualisation purposes for the requirements capture. However, in spite of the obvious progress that has been made, the current design tools are not easy enough to be used for real-time conceptual visualisation and requirements capture.

Some advances to this direction have been reported in literature. A notable work is reported in Oh et al. (2005). There the starting point for the 3D design is a 2D layout, in which an interface is provided to extrude and edit (resize, move, rotate or remove) 3D space structures. Another approach is to enable compilation of a conceptual design from a set of 3D primitive objects (basic forms), as e.g. in Virtual Lego (Oh 2004).

In principle, a specific description language could be developed, based e.g. on the use of a set of basic geometric patterns and graphs. The 3D models are specific text files, nowadays typically variants of XML. Independent whether the input is in textual, graphical or model based, the result needs to be converted into textual format. This needs a specific language convention to be used including a well defined vocabulary (semantics). By using specific semantics, connections and associations between spatial objects and various captured parameters, the design data can be made and stored into a database for further use. A problem is that language and its semantics depend on the user and on the purpose of use. The importance and priority of the requirements also vary and are many times both difficult to measure or
quantify, and controversial with each other. The system should therefore support optimisation of the captured set of requirements according to a chosen set of cost functions (price, space, distance, functionality, etc.).

In addition to the drafting for visualisation properties, the system should also support the storage and follow-up of the captured requirements in order to avoid the known problem of gradually drifting away from the original user requirements during various design and implementation phases.

A novel possibility - especially useful for 3D visualisation in existing buildings or environments - is the use of Augmented Reality, which enables visualisation of virtual objects in physical environment. An example of an AR tool for renovation visualisation is described by Pinto et al. (2007). Augmented Reality, or more generally Mixed Reality, means computer visualisation which combines physical scenes with virtual objects. This option is particularly applicable for showing designed 3D structures in existing buildings and environments. A useful functionality in 3D visualisation is the possibility to position an animated human avatar to give realism, as well as an indication of the real scale of the 3D environment. This avatar can also be animated, and made to move according to physical rules (among other things this requires the so called collision detection between the avatar and its 3D environment). Animation is commonly used in computer games where even the human behaviour can be modelled. A corresponding example in Mixed Reality is to place a motioning real human into 3D environment, e.g. an architect to walk inside the 3D building model, explaining his/her reasoning behind specific architectural choices.

An example of an AR based tool for architectural visualisation is the Augmented Scale Model by VTT. AR_ScaleModel enables Mixed Reality collaboration with an architectural scale model, augmented on a conference table. The user interface is based on a virtual pop-up menu, and enables functionalities like cutting planes, rotation, scaling, and moving (navigation).

3.1.4 International view and position of Finland
Workplace processes have been taken use in large knowledge work companies in order to ensure efficient use of spaces, satisfaction and productivity. Significant owners and actors in the field of real estate like GSA in the US seek improvements with help of integrated workplace processes. On the basis of the information provided by the NWW web page (NWW, 2010) it seems that countries active in this area are the UK and the USA. At present there are 20 consultant companies in Finland which offer services for workplace processes. Senate Properties actively applies the process in both new construction projects and refurbishment projects.

Capturing user needs can be seen as one part of workplace processes. However, we are in early stages in developing any kinds of methods, concepts and tools in order to support understanding and identification of user needs and interpreting these are performance requirements.
3.1.5 Summary
Functional and social performance is an important element of sustainable building and construction; thus we need methods that enable the capturing of user needs and the management of functional and social performance. It is doubtful whether the overall functional and social performance could or should be quantified in general terms, because the suitability for planned use depends on subjective views. However, improved consideration and management of functional and social performance is possible by developing methods for identification and understanding user needs. The premise is that especially the development of structured outlines for functional and social performance and visualisation tools would support understanding and consideration of user needs.

3.2 References


CIB (2010). International council for research and innovation building and construction (CIB). www.cibworld.nl


ISO 9001:2000 Quality management systems -- Requirements


3.3 Building Performance and Value Creation

Pekka Huovila, VTT

3.3.1 Definitions

*Performance* is a qualitative level of a critical property at any point of time considered (ISO 15686) and behaviour in service for a specified use.

3.3.2 Objectives

The main objective for building performance metrics is to support the successful delivery and maintenance of built assets over their life span. It means that constructed facilities meet the needs of their present and future stakeholders in an optimal way. In this case the primary stakeholders are users of buildings, their owners and the society.

3.3.3 Processes

The following figure illustrates Building Information Models in different phases of the life cycle of buildings. Separate models are used here to illustrate different perspectives, e.g.

- the requirement model describing the desired performance in use based on the operation model
- the design model expressing the estimated performance based on proposed technical solutions that meet user requirements
- the production model reflecting the constructed building and its technical systems installed based on the design model
- the commissioning model that is handed over to customers
- the operation model where the performance in use will be finally validated by customers and which experiences hopefully form a basis for learning how the requirements for buildings in the future should be set (in new construction or refurbishment).

![Figure 15. The Life cycle performance models of buildings.](image)

In the process, the performance requirements of end products (buildings) should be set so that their meeting end user needs can be validated. If the objectives are described in a form of technical solutions (designs or products) without documenting the desired performance, there’s a risk that any change in design during the construction process may lead to compromising user needs.
3.3.4 International view
There aren't any international standards describing the behaviour of buildings in use in a way that could be taken as such as a building performance model. However, different approaches towards that objective have been evoked nationally and also internationally during the past decades.

ISO6241 Performance Standards for Buildings (ISO, 1984) contains information about user requirements. The European Commission Construction Products Directive (EC, 1989) determines six essential requirements at a general level. CIB has produced so called Master Lists in different decades that include performance classifications (CIB, 1964, 1972, 1983, 1993). CIB has even produced a Compendium of performance based building models providing a framework for performance classification. In addition to those international and European structured lists, national examples could be taken from the different countries. In the US, ASTM serviceability standards contain performance parameters and ASHRAE commissioning guidelines include user need listings.

Examples of User requirement lists are given in Tables 1 and 2 from ISO6241 and ASTM (serviceability) standards. An example of the CIB Compendium Performance in use classification is given in Table 3. That includes, in addition to building performance and cost and environmental performance, headings for construction process and operation.

<table>
<thead>
<tr>
<th>Stability</th>
<th>Fire safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety in use</td>
<td>Tightness</td>
</tr>
<tr>
<td>Hygrothermal</td>
<td>Air purity</td>
</tr>
<tr>
<td>Acoustical</td>
<td>Visual</td>
</tr>
<tr>
<td>Tactile</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Requirements for the suitability of spaces for specific use</td>
<td>Durability</td>
</tr>
<tr>
<td>Economic.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 User requirements (ISO, 1984).

<table>
<thead>
<tr>
<th>Support for office work</th>
<th>Meeting and group effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound and visual environment</td>
<td>Typical office information technology</td>
</tr>
<tr>
<td>Change and churn by occupants</td>
<td>Layout and building features</td>
</tr>
<tr>
<td>Protection of occupant assets</td>
<td>Facility protection</td>
</tr>
<tr>
<td>Work outside normal hours or conditions</td>
<td>Image to public and occupants</td>
</tr>
<tr>
<td>Amenity to attract and retain staff</td>
<td>Special facilities and technologies</td>
</tr>
<tr>
<td>Location, access and wayfinding.</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Serviceability (ASTM, 2000).
The issue of meeting client requirements cannot be solved without knowing what the requirements are, or without capturing the needs behind the expressed or unexpressed requirements. Arto Kiviniemi (2005) did some empirical studies in his PhD work at Stanford to find out how the requirements can be traced in the building process. The replies were "it would be very laborious task to go through the meeting minutes trying to find out the requirements for any specific space or building element" or "the only documents where this could be found are the meeting minutes, but they don’t cover all issues". In other words, the requirements are not often documented in a way they could be useful for a requirement model. Instead, technical solutions are documented and their conformity is assessed instead of comparing the original user needs or performance requirements.

Meeting client requirements by delivering the desired output (value, performance) at accepted input (cost, environmental and other impacts) can be expressed in an efficiency formula. Cost efficient construction means delivering buildings of desired quality (performance) at accepted (whole life) cost.
Eco-efficient construction is defined in a similar way. The Japanese building rating tool (Casbee) has developed the building environmental efficiency approach as shown below.

Figure 16. The numerator (performance, value, quality) aspects and the denominators (impacts to monetary and nature’s economy).

Lützkendorf et al. (2005) surveyed performance tools, standards, checklists and sets of instruments. The following figure shows in which areas those tools can be best applied. It is stated that those instruments have often been developed for a specific use at first, with more functions and applications pursued later.
Their study described the applicability of different tools, such as LCC, LCA, EcoProP or Legep.

### 3.3.5 In Finland

In Finland, VTT’s EcoProP tool, including a database based on VTT ProP® classification, is one of the few examples of (systematic performance) requirement management tools for buildings.
The indoor conditions in Finland are supported by the FiSIAQ Indoor climate indicators as shown in the following table.

<table>
<thead>
<tr>
<th>Thermal conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Room temperature (Winter/Summer) [°C]</td>
</tr>
<tr>
<td>2. Temporary deviation from set value [°C]</td>
</tr>
<tr>
<td>3. Vertical temperature difference [°C]</td>
</tr>
<tr>
<td>4. Air velocity (Winter/Summer) [m/s]</td>
</tr>
<tr>
<td>5. Relative humidity [%]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indoor air quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Radon [Bq/m3]</td>
</tr>
<tr>
<td>7. Carbon dioxide [ppm]</td>
</tr>
<tr>
<td>8. Carbon dioxide [mg/m3]</td>
</tr>
<tr>
<td>9. Ammonia and amines [μg/m3]</td>
</tr>
<tr>
<td>10. Formaldehyde [μg/m3]</td>
</tr>
<tr>
<td>11. Volatile organic compounds [μg/m3]</td>
</tr>
<tr>
<td>12. Carbon monoxide [mg/m3]</td>
</tr>
<tr>
<td>13. Ozone [μg/m3]</td>
</tr>
<tr>
<td>14. Odor intensity (intensity scale)</td>
</tr>
<tr>
<td>15. Mass concentration of airborne particulate Matter [μg/m3]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acoustic conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Noise level of heating and air handling equipment [dB] (offices/kitchens/living rooms and bedrooms).</td>
</tr>
</tbody>
</table>

Table 4 Indoor climate (FiSIAQ, 2001).
3.4 References and recommended reading


CIB. *Compendium of Building Performance Models*. Performance Based Building (pebbu).


3.5 Life-Cycle Commissioning Processes

_Satu Paiho and Veijo Nykänen, VTT_

### 3.5.1 Definitions

**Continuous CommissioningSM** (CCSM) is an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits for existing commercial and institutional buildings and central plant facilities. (Liu et al. 2002)

**Commissioning** (Cx). Building commissioning, often abbreviated as “Cx,” is a systematic quality assurance process that spans the entire design and construction process, helping ensure that the new building’s performance meets owner expectations. (Haasl & Heinemeier 2006a)

**Life-Cycle Commissioning** (LcCx) is a systematic building life-cycle process for assuring that new buildings and their system performances meet owner expectations and user needs, and existing buildings operate, function and are maintained optimally according to owner expectations and user needs. (Paiho et al. 2007)

**Retrocommissioning** (RCx) is a systematic method for investigating how and why an existing building’s systems are operated and maintained, and identifying ways to improve overall building performance. (Haasl & Heinemeier 2006b)

### 3.5.2 Objectives

A commissioning (Cx) process should be launched as early as in the programming phase to check that owner’s and users’ needs and requirements are clearly defined and documented, and that indoor and energy performance requirements are included to owner’s program. In addition, it should be audited that design solutions and installation outputs meet given requirements, and verified that the building satisfy given indoor and energy requirements in use. Cx should also be included as a part of routine facility management process over the building life cycle. (Nykänen et al. 2007)

- Cx activities include the following goals (Nykänen et al. 2007):
  - To provide safety, healthy and comfortable spaces for living and business
  - To improve design quality by more effective feedback
  - To assure that all building services systems are compatible with each other
  - To improve energy efficiency of buildings and building systems
  - To decrease operation costs
  - To improve operation and maintenance personnel introductory briefing and training
  - To improve documentation during the building life-cycle
  - To meet customer needs and expectations and satisfy customer requirements
The main objectives for the life-cycle commissioning are buildings and communities that perform optimally. The issues that function towards these objectives can be divided in four main sectors, namely (Figure 19):

- Systematics and processes
- Information and knowledge management
- Exploitation of knowledge
- Implementation strategies

Figure 19. The overall framework of issues dealing with LoCx (Paiho et al. 2007).

3.5.3 Processes
In Figure 20, there is the outline chart of the Cx process (Nykänen et al. 2007). Visier (2004) and ASHRAE (1996) presented the Cx processes which were the starting points for the development of this Finnish Cx process. The attached checkpoints “diamonds” link the Cx activities to the building process phases in general. At the beginning of a construction project, goals are established and the owner’s and users’ needs are determined. Then, the system requirements are set with the help of design procedures. Thirdly, the goals are implemented and performance is verified in the elaboration and construction phases. Finally, indoor climate and energy consumption is managed with new building automation and online reporting systems.

Figure 20. The commissioning process.
Different kinds of tools and systematic methods are required in each phase of the commissioning process. These methods and tools include but are not limited to the following ones:

- **Cx systematics**: Cx team and agent, Cx process (from design to maintenance), Cx plan, economics, benefits, Cx metrics, persistence of Cx benefits, embedded Cx, integration of design, and project partners' common objectives.

- **Cx methods**: Fault detection and diagnosis, diagnostic performance monitoring, benchmarking, automated Cx (utilizing data models, BEMS etc.), trend analysis, manual Cx, measures for different equipment/systems/buildings/communities, audits, NIALM (Non-Intrusive Appliance Load Monitoring), functional tests, automated tool and supply management, logistics management, etc.

- **Cx guidelines and tools**: Guidelines, procedures, reporting frames, protocols, standardized tools, checklists, assessment information, documentation, real-time maintenance support.

- **Information and knowledge management**: ICT based tools for data transfer, from buildings to databases, from databases to analysis, user interaction.

- **Calculation & simulation**: Energy, exergy, emissions, life-cycle analyses, building performance (thermal comfort, illumination, noise, indoor air pollutants, acoustics etc.), networks, control, and operation & maintenance.

- **Data warehouses**: Databases for building information, material and product database, information on previously commissioned buildings, cost-benefit analyses, best-practice analyses, load profiles, references, case examples, etc. Decision support: Combining calculations and measurements, verifications, visualisation, performance analyses of equipment, systems, buildings, building blocks and communities, and design management.

As shown in Figure 21, lots of data is collected and monitored in existing buildings. The key questions are: for whom, from where and for what purpose the data is collected. Also the key performance indicators must be defined based on these questions.

![Figure 21. Overview of building performance evaluation (Deru & Torcellini 2005).](image)
3.5.4 International view
The United States is a leading country in building commissioning. As distinct from routine operations and maintenance, the particular power of commissioning is in looking at systems-level problems, e.g., interactions between control systems and HVAC equipment (Mills et al. 2004). The scope of commissioning can span all aspects of buildings, including space performance, security, safety, structural integrity, indoor environmental quality, and energy performance.

Building commissioning procedures have been developed in several countries for example within an Annex of the IEA Implementing Agreement Energy Conservation in Buildings and Community systems, Annex 40, “Commissioning of Building HVAC Systems for Improved Energy Performance”.

Impacts and benefits
Mills et al. (2004) performed a ‘meta-analysis’ analyzing commissioning results from 224 buildings across 21 states, representing 2.8 million square metre of commissioned floor area (73 percent in existing buildings and 27 percent in new construction). For existing buildings, they found median commissioning costs of $2.91/m², whole-building energy savings of 15 percent, and payback times of 0.7 years. For new construction, median commissioning costs were $10.76/m² (0.6 percent of total construction costs), yielding a median payback time of 4.8 years (excluding quantified non-energy impacts).

In the meta-analysis (Mills et al. 2004), the most cost-effective results occurred among energy-intensive facilities such as hospitals and laboratories. Less cost-effective results are most frequent in smaller buildings. The projects identify 3,500 deficiencies (11 per building, 85 projects reporting) among existing buildings and 3,305 (28 per building, 34 projects reporting) among new construction. HVAC systems present the most problems, particularly within air-distribution systems. The most common correctional measures focus on operations and control.

New-construction commissioning is more strongly driven by non-energy objectives such as overall building performance, thermal comfort, and indoor air quality, whereas existing-building commissioning is more strongly driven by energy savings objectives (Mills et al. 2004). Several non-energy impacts were reported for both cases (Figure 22).
Commissioning guides

In the United States, several commissioning guidelines or manuals exist. In the following text, some examples of the commissioning guides are given.

Haasl & Heinemeier (2006a) & (2006b) have written commissioning guides for new and existing buildings which describe the building (retro)commissioning process, and are mainly written for building owners, managers, and operators. They answer the following questions:

- What is building (retro)commissioning and why should I implement the process?
- What are the benefits and costs of (retro)commissioning?
- How do I hire a (retro)commissioning lead and integrate them into my existing team?
- What happens during the (retro)commissioning process and how does it relate to design and construction?
- How will the (retro)commissioning process ensure efficient operations at my facility over the long term?
- How do I get started with (retro)commissioning?

Liu et al. (2002) present a Continuous CommissioningSM (CCSM) guidebook which include several CC measures and examples for different systems (air-handling units, water/steam distribution, central chiller plants, central heating plants, thermal storage systems). The guidebook also includes documentation on optimum building performance.

The Building Commissioning Guide (2005) GSA provides the overall framework and process for building commissioning from project planning through tenant occupancy, keys to success within each step and the ways that each team member supports the process of commissioning. While recognizing that every project is unique and that the required activities will vary on every project, this Guide provides recommendations, minimum requirements and best practices based upon industry guidance and GSA experience.
3.5.5 In Finland

Nowadays in Finland, building commissioning is not yet a standard procedure during the building life-cycle. Most often it is only used during building hand-over in new buildings, and sometimes as a separate measure in existing buildings. (Nykänen et al. 2007)

Paiho et al. (2007) developed a roadmap for LcCx-related issues in Finland (Figure 23). The roadmap includes main drivers, potential markets, main technologies utilized, and headline products and solutions.

Figure 23. The roadmap of LcCx-related issues in Finland (Paiho et al. 2007).

Pietiläinen et al. (2007) developed a general guidebook for commissioning and launched a Finnish term “Toimivuuden Varmistaminen” (ToVa) for commissioning (Cx). In the guidebook general procedures for ToVa activities are described covering the whole life cycle of the building. ToVa means clear definition, capturing and documentation of end user requirements and their compliance assessment and verification in all the phases from design through realisation to the operation and use. In the guidebook special focus has been put on the indoor air quality and energy efficiency. The guidebook includes general instructions for the assessment and verification of Indoor Air Quality and energy efficiency but it gives also checklists to be used in different phases of building process. Organisation and responsibilities of ToVa-activities as well as methods to be used in different phases have been discussed in guidebook.

3.5.6 Summary

The old commissioning concept was confined only to hand-over phase in building process. The modern building commissioning is a quality management process from owner and user requirements across design and construction process. The building commissioning also consists of beneficial methods and procedures to manage the life cycle of a building.

Modern buildings consist of numerous systems, which are usually designed and constructed separately. One of the main goals in the Cx process is to integrate these systems to work well together and to achieve comfortable spaces and energy efficiency. Cx methods can also be applied to user services.
References


3.7 Benchmarking

Jorma Pietiläinen, Janne Peltonen, Timo Kauppinen and Teemu Vesanen, VTT

3.7.1 Definition

Benchmarking is defined as "a process used in management and particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice, usually within their own sector. This then allows organizations to develop plans on how to adopt such best practice, usually with the aim of increasing some aspect of performance. Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to challenge their practices.

3.7.2 Objectives

Benchmarking is a powerful management tool because it overcomes "paradigm blindness." Paradigm Blindness can be summed up as the mode of thinking, "The way we do it is the best because this is the way we've always done it." Benchmarking opens organizations to new methods, ideas and tools to improve their effectiveness. It helps crack through resistance to change by demonstrating other methods of solving problems than the one currently employed, and demonstrating that they work, because they are being used by others. Benchmarking, originally invented as a formal process by Rank Xerox, is usually carried out by individual companies. Sometimes it may be carried out collaboratively by groups of companies (e.g., subsidiaries of a multinational in different countries). One example is that of the Dutch municipally-owned water supply companies, which have carried out a voluntary collaborative benchmarking process since 1997 through their industry association.

3.7.3 Processes and Procedures

There is no single benchmarking process that has been universally adopted. The wide appeal and acceptance of benchmarking has led to various benchmarking methodologies emerging. The most prominent methodology is the 12 stage methodology by Robert Camp (who wrote the first book on benchmarking in 1989).


The following is an example of a typical shorter version of the methodology:

1. Identify your problem areas - Because benchmarking can be applied to any business process or function, a range of research techniques may be required. They include: informal conversations with customers, employees, or suppliers; exploratory research techniques such as focus groups; or in-depth marketing research, quantitative research, surveys, questionnaires, reengineering analysis, process mapping, quality control variance reports, or financial ratio analysis. Before embarking on comparison with other organisations it essential that you know your own organisation's function, process; baselining performance provides a point against which improvement effort can be measured.
2. Identify other industries that have similar processes - For instance if one were interested in improving handoffs in addiction treatment s/he would try to identify other fields that also have handoff challenges. These could include air traffic control, cell phone switching between towers, transfer of patients from surgery to recovery rooms.

3. Identify organizations that are leaders in these areas - Look for the very best in any industry and in any country. Consult customers, suppliers, financial analysts, trade associations, and magazines to determine which companies are worthy of study.

4. Survey companies for measures and practices - Companies target specific business processes using detailed surveys of measures and practices used to identify business process alternatives and leading companies. Surveys are typically masked to protect confidential data by neutral associations and consultants.

5. Visit the "best practice" companies to identify leading edge practices - Companies typically agree to mutually exchange information beneficial to all parties in a benchmarking group and share the results within the group.

6. Implement new and improved business practices - Take the leading edge practices and develop implementation plans which include identification of specific opportunities, funding the project and selling the ideas to the organization for the purpose of gaining demonstrated value from the process.

3.7.4 Technical benchmarking or Product Benchmarking

The technique initially used to compare existing corporate strategies with a view to achieving the best possible performance in new situations (see above), has recently been extended to the comparison of technical products. This process is usually referred to as "Technical Benchmarking" or "Product Benchmarking". Its use is particularly well developed within the automotive industry ("Automotive Benchmarking"), where it is vital to design products that match precise user expectations, at minimum possible cost, by applying the best technologies available worldwide. Many data are obtained by fully disassembling existing cars and their systems. Such analyses were initially carried out in-house by carmakers and their suppliers. However, as they are expensive, they are increasingly outsourced to companies specialised in this area. Indeed, outsourcing has enabled a drastic decrease in costs for each company (by cost sharing) and the development of very efficient tools (standards, software). Mavel (http://www.mavel.com) is the worldwide leader of such analyses.

Types of Benchmarking

– Process benchmarking - the initiating firm focuses its observation and investigation of business processes with a goal of identifying and observing the best practices from one or more benchmark firms. Activity analysis will be required where the objective is to benchmark cost and efficiency; increasingly applied to back-office processes where outsourcing may be a consideration.

– Financial benchmarking - performing a financial analysis and comparing the results in an effort to assess your overall competitiveness.

– Performance benchmarking - allows the initiator firm to assess their competitive position by comparing products and services with those of target firms.

– Product benchmarking - the process of designing new products or upgrades to current ones. This process can sometimes involve reverse engineering which is taking apart competitors products to find strengths and weaknesses.
– Strategic benchmarking - involves observing how others compete. This type is usually not industry specific meaning it is best to look at other industries.

– Functional benchmarking - a company will focus its benchmarking on a single function in order to improve the operation of that particular function. Complex functions such as Human Resources, Finance and Accounting and Information and Communication Technology are unlikely to be directly comparable in cost and efficiency terms and may need to be disaggregated into processes to make valid comparison.

3.7.5 Defining and measuring energy performance in buildings

Energy performance in buildings can mean many different things. Energy intensity, or energy use per unit of floor area, is one common measure of building energy performance. The U.S. Environmental Protection Agency (EPA) ENERGY STAR building program, with its Portfolio Manager rating system, measures and compares building energy performance through adjusted energy intensity. However, energy intensity must be balanced against other performance criteria and project requirements, for example, a building with no lights, air-conditioning or mechanical ventilation will have extremely low energy intensity, but will not adequately serve the needs of building occupants. Building energy performance can also be measured as compared to a threshold, usually with respect to an energy code or standard. While this is the most common metric used for new building energy performance, a building that has been designed to perform at a significant reduction below the energy code may not compare well to a similar building where performance is measured by energy intensity. (Hinge et al. 2008)

Many earlier codes and rating schemes did not take process energy into consideration, defined in ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings, as “energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building.” For example, many design teams will gather energy performance data for energy-efficient buildings by comparing only the systems that the design team controls such as envelope insulation value, percentage glazing, solar shading, chiller and boiler efficiency, fan and pump motor efficiency, installed lighting power density, and system selections. This excludes the process energy elements, some of the biggest end users in new buildings, such as server rooms, lab equipment, cooking or restaurant equipment, security systems, building control systems, fire safety systems, computers, printers, copiers and some plug loads. Many of these excluded loads operate 24/7; so while an energy savings calculation will state significant energy savings, the real energy use of a new building may be much higher. These details need to be considered when setting goals and reporting both projected and actual energy performance.

A common basis for reporting building energy use and comparison of energy performance is available in a new standard from ASHRAE. ANSI/ASHRAE Standard 105-2007, Standard Methods of Measuring, Expressing and Comparing Building Energy Performance provides a method of energy performance comparison that can be used for any building, proposed or existing, and allows different methods of energy analysis to be compared. The guidance in the standard progresses from energy use index (total annual energy use per square foot) to other indexes, such as energy use per hospital bed, and then to performance comparison frameworks. (ASHRAE 2008)
3.7.6 International view (examples of benchmarking schemes)

In the wake of quality assurance, benchmarking and key performance indicators have been emphasised as an effective strategy to improve productivity, stimulate innovation and improve customer satisfaction (McGeorge et al. 2002). Since the seminal work of Camp (1989) on benchmarking, the last decade has seen much work done to establish key performance indicators for the performance of both buildings and companies within the construction and real estate cluster. Three international trends can be identified within the construction and real estate cluster (Haugbølle & Hansen 2006):

– First, studies have been conducted within a range of subjects like facility management (Massheder & Finch 1998; McDougall & Hinks 2000; Haugbølle & Hansen 2005) and the performance of contractors (Xiao & Proverb 2002; Palaneeswaran & Kumaraswamy 2000).

– Second, several models for benchmarking has been developed within the construction and real estate cluster e.g. to predict construction times (Chan & Chan 2004; Kaka 1999, Li et al. 2001; Sommerville & Robertson 2000).

– Third, a number of benchmarking schemes have been implemented around the world (Bakens et al. 2004; Beatham et al 2004).

In the Nordic countries, a multiplicity of approaches has been implemented but with respect to benchmarking and key performance indicators, a number of challenges remain to be addressed. First, on a strategic management level we need to reflect on some of the institutional settings in which benchmarking schemes operate as pointed out by Garnell & Pickrell (2000) and Bresnen & Marshall (2001). Thus, the design of benchmarking schemes must take into account how benchmarking is linked to the interplay between politics and markets. Analytically, we can distinguish between public and private modes of organisation, and between profit and non-profit modes of organisation.

Existing benchmarking approaches and tools (some examples in pictures below) will be investigated and the current status in participating countries will be examined. Information about used indicators and experiences gained in Europe, USA and Asia will be collected and reported. Task will be carried out in collaboration with other WP’s.
3.7.7 Benchmarking schemes in Finland

e3Portal - Benchmarking service for energy performance of buildings – e3portal.vtt.fi

At Technical Research Centre of Finland an internet-based information service for municipal building owners - called e3Portal - has been developed (e3Portal 2008). Municipalities act as content provider by updating continuously the consumption figures and other information to the data warehouse of the portal. Building operators and other users can access the service over internet using only the standard web-browser. Via benchmarking local actors can be motivated and best practice information can be disseminated. In addition to the up to date information on energy management, energy auditing, saving technologies etc. also tools for energy calculations, monitoring and benchmarking are available.

The manager of a building for example can easily compare the energy consumption of his own building with the similar ones in the whole country. When planning improvements and designing saving concepts top ten lists of saving measures found in hundreds of energy audits in similar buildings can be reported from portal data warehouse. Environmental load from building energy usage can be visualised and the real effects of local saving policies can be analysed. Information about successful saving measures and their real impacts can be delivered among municipalities. Portal supports in a new way the networking and best practice dissemination on local level but can be easily used in international collaboration as well.

Starting point for the portal is that municipalities are not only “passive” users of the portal but they act as content provider of portal as well. Municipalities can upload the energy consumption etc. data of their buildings to the central database of portal via this interface. Data can be based either yearly or monthly consumptions depending on the availability and monitoring practices on local level. At VTT consumption figures are checked before publishing in portal in order to find the failures in data.
The e3Portal includes following services,
- energy management,
- energy targeting,
- energy monitoring,
- energy consumption,
- energy audits,
- implementation and financing,
- clearing house,
- e3Portal toolbox,
- help and contacts.

The e3Portal tool box makes it possible to report and analyse detailed and identified information of buildings. The manager or caretaker of a building for example can easily compare the energy consumption of his building with the similar ones in the whole country. Here there is an example of these kind of benchmarking reports. In this case the energy consumption for heating is almost double as high as the average in "control group". Electricity is used much less than in other similar buildings and the water consumption is increasing rapidly above the average of similar principal schools found in portals data warehouse.

**PRINCIPAL SCHOOL, Performance rating based on specific consumption**

![Graphs showing energy consumption and water consumption for heating, electricity, and water](image-url)

Figure 26. An output example of e3Portal benchmarking tool
KTI, the Institute for Real Estate Economics
KTI is an independent service company and research organisation providing information, analysis and research services for the Finnish real estate industry (KTI 2008).

– KTI offers benchmarking services as
– KTI index and portfolio benchmarking,
– rental benchmarking,
– operating cost benchmarking,
– customer satisfaction benchmarking.

The KTI index measures returns on direct investments on property (standing investments). The total market value of the property portfolios in the index is over EUR 17 billion that is approximately 60 % of the value of the holdings of the financial institutions and property companies. The dataset of KTI index gives current information not only on returns but also for example on yields, rental values and occupancy rate.

KTI collects annually cross-section data on Finnish rents of commercial premises. Since 1990, KTI has gathered information about rents of retail-, office- and industrial premises. In autumn 2004, KTI’s database on rents consisted of approximately 26 000 contracts compiled from over 50 cities. The database provides: information about new and valid contracts in different areas, information about the real estate rental market, and possibility to compare prerequisite and contents of the contracts.

The purpose of KTI’s operational cost benchmarking service is to provide a tool that improves the effectiveness of managing operational and facilities costs in individual properties and portfolios. Participating companies receive detailed performance information about their properties which is compared to similar properties. They also receive information about operational costs in other types of properties. Total Costs of operations are divided into 14 smaller categories according to a Finnish book-keeping law in a following way: administration, maintenance, roadways, parking and grounds, cleaning, heating, water and wastewater, electricity, disposal, insurance, rental expenses, taxes, other expenses, repairs / replacements, and renew expenses / capital improvements.

TOTAL RETURNS 2006 - BY SECTOR

![Diagram](image)

Figure 27. Example of KTI index.

Promain – Pro Management Intelligence Service
Promain is an internet based benchmarking service, where the performance of your own building can be compared to other similar type of buildings in the same industrial branch by using visual graphic presentations. Promain also
includes VTT’s yearly company specific analysis report and information bulletin for property business sector. Over fifteen years, Promain company and VTT have jointly done energy use and real estate management cost and consumption benchmarking with other companies. At the moment, the service includes printing houses, spas and health clubs. (Promain 2008)

The purpose of the following example reports is comparison with other facilities of the same industrial branch. Blue colour indicates the facility in question, green/red colour indicates median or average values in the group, red colour = upper quartile, blue colour = lower quartile.
Figure 28. Example reports on operation weather corrected heating costs / cubic content.

3.7.8 Summary

Performance based building has become a main target area for developments in real estate and construction sector some ten years ago, when changes in the approach towards client – provider relationship were redefined by the World Trade Organization (WTO). The Agreement on Tariffs and Trade was signed in 1997 with the statement “Whenever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or descriptive characteristics.” This made it necessary to initiate a development and standardization effort to describe the target performance rather than the structural solution, and led to development of the CIB Proactive Programme for Performance Based Building Codes and Standards (Foliente, G.C., Leicester, R.H., Pham, L. 1998). In the following years, a lot of effort has been targeted into the practical issues involved.

All procurement/acquisition processes can be either Prescriptive or Performance Based (or a combination of these); and some, such as Design-Build, Private Finance Initiative (PFI), and Public Private Partnership (PPP) are particularly well suited to be Performance Based. In the US government, performance-based contracting is mandatory (The USA Federal Acquisition Regulations, US Government 2000). In Europe, there are many initiatives, both at the national and at the Union level, such as the Construction Product Directive to promote the same end.
In the wake of quality assurance systems in construction, benchmarking and key performance indicators have been emphasised as an effective strategy to improve productivity, stimulate innovation and to motivate for better operation and maintenance. During the last decade much work has been done to establish key performance indicators for the performance of both buildings and companies within the construction and real estate cluster. Three trends can be identified in relation to benchmarking schemes and key performance indicators internationally:

- First, studies have been conducted within a wide range of subjects like facility management and the performance of contractors.
- Second, several models for benchmarking has been developed within the construction and real estate cluster e.g. to predict construction times (Chan & Chan)
- Third, a number of benchmarking schemes have been implemented around the world (Bakens et al. 2004). Benchmarking activities that have been targeted to performance related issues are mostly concerned about sustainability and in particular energy. Many schemes for the energy efficiency evaluation of buildings have been set up.

Examples of such include LEED and ENERGY STAR in USA and similar attempts e.g. in UK like Energy performance in the Government's Civil estate. In the last one the information is intended to assist in the reduction of energy consumption, by helping energy managers to set their own energy benchmarks against which the actual energy performance of a particular building or site can be compared and offering suggestions for the improvement of energy performance. The LEED Green Building Rating System is the national benchmark for high performance green buildings (http://www.usgbc.org/), and ENERGY STAR partnership offers a proven energy management strategy that helps in measuring current energy performance, setting goals, tracking savings, and rewarding improvements (http://www.energystar.gov/). Energy Smart Tool is an online performance-based building energy benchmarking tool developed by the Energy Sustainability Unit (ESU), Department of Building, School of Design and Environment, National University of Singapore, supported by European Union through the EU-ASEAN Energy Facility, and National Environment Agency of Singapore and Jurong Town Corporation Singapore. The main objective of the Energy Smart Tool is to provide comprehensive, reliable and accurate benchmarks of energy consumption and efficiency in buildings. This tool is intended to be a starting point in assessing building energy use and saving potential. It provides the user with a direct comparison of his building energy performance among the total cohort of similar facilities, which can help to identify the position of your facility, and to set energy and efficiency targets.

A second major group of benchmarking techniques and tools is aimed at post occupancy evaluations, usually concerning user satisfaction, in particular in terms of indoor climate. As the indoor climate is highly related to energy issues (mostly trough HVAC and illumination), this kind of benchmarking actually is connected to energy issues.

Though there are several existing benchmarking schemes the utilisation of benchmarking is still rather limited however. Especially in among European countries reliable and coherent data on the performance of buildings is difficult to find. That’s why there is lot of potential for the development and Nordic countries can more easily act as forerunners because of the similarities in climate and cultural circumstances as well as building traditions.
4 State of the art in Sweden

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The aim of the Swedish contribution to the CREDIT project is to develop a project related performance management and assessment tool that: identify and capture end-user requirements, measure and verify the compliance to performance criteria throughout the life-cycle of a building. This state-of-the-art presents a review from an international, national and real estate organisation perspective on how this may be fulfilled.

4.1 International Review of Methods and Tools

The process of capturing the needs and requirements of the end-users in construction projects can be structured in a process model to ease the view of the purposes and goals for each step.

4.1.1 The carpenter model

The international literature review is structured after a model, created by the Swedish team, called the carpenter, see Figure 29.

![Figure 29. The carpenter model.](image)

The model consists of three main parts: before the project, during the project and after the project.

Before the project starts there is need for a needs analysis in which the client and/or the end-user/s analyse their situation and needs, which should lead to a decision to either keep it the way it is, relocate the organisations to an existing space or they conclude that a rebuild or a new-build is needed.
And it is the latest two that is in focus for this project. This needs analysis is or should be the input to the project.

During the project assessment and verification it is needed to measure more than once to be able to compare with other projects. It is therefore important to define proper milestones during the project where assessment and verification should be taken place. We have identified five potential milestones:

- Project initiation/needs analysis
- After brief
- After detailed design
- After construction phase
- During Facilities management (FM)/occupancy

The reason we put the FM inside the project box is because it is often the client that is managing the FM part.

After the project an evaluation of the outcome is necessary. The evaluation should verify if the needs analysis captured the actual needs for the particular project. It should also bring feedback to the participants so lessons can be learned from this project to future ones for improving, for example, briefing, assessment and cooperation.

4.1.2 General Remarks of the Found Methods and Tools

A review of methods and tools for capturing end-users requirements or bring value for them shows that there exists a number of tools and methods for parts, but only few of them attempts to cover the whole process: from needs analysis to evaluation of the building in use. The methods are primarily focusing on the early and/or the late phases. Most methods stress an increased communication both within the sub-phase that the method is targeting for, but as well between different sub-phases of the project. The improved communication is necessary for a number of reason, for example, is the briefing concerned to be a problem area (Barrett et al., 1996) and that there often exists stereotype images among the actors that hinders effective collaboration in the construction process (Loosemore and Tan Chin, 2000). By improving the communication and the social processes of the work practice, the goal fulfilment and the professional skills can be improved (Zika-Viktorsson et al., 2003). Even though there are a number of tools and methods in the early and the late phases, a study in UK showed that the construction industry in general put little resources into the pre-project and the post-project stages and little evaluation of previous project at all. So, there exists an unwillingness to use maps and methods partly because the benefits of using them are not seen among the participants (Lawson et al., 2003).

4.1.3 Methods and tools incorporated in the carpenter model

The found methods and tools are presented according to the milestones in the carpenter model as a means of providing an accessible overview of them. Some of the methods/tools are managing the specific phase in the construction project and some are evaluating that specific phase. Some of the methods/tools can be used in more than one milestone, but the description of the method/tool is only done first time mentioned.

Managing the strategic briefing phase

Initiating the project

Gray and Huges (2001) divide the initiating phase in three main parts: getting started, the statement of needs and the business case. Every part involves meetings with end-users and ends with a review of what is decided. The needs set in the initiating phase are not considered to be totally fixed and can be changed in the functional brief of scheme design. It is, however,
necessary to conduct a risk analysis of the changes (Gray and Hughes, 2001).

Strategic needs analysis
Strategic needs analysis (SNA) attempts to understand the context from the stakeholders’ perspective to find a strategic approach for the project. The most critical factor for a successful SNA is the involvement, interest and commitment by the clients (Smith et al., 2003). The methodology of SNA is workshop-based and influenced by strategic management and problem solving approaches (Smith et al., 2008).

Soft system methodology
Soft system methodology seeks to produce relevant models of the world that support the discussions when trying to understand the reality that the project is meeting. The method is, for example, helpful in the strategic briefing to better understand the end-users organisation and business processes (Green and Simister, 1999).

Expert choice
Expert choice is a software program, developed by a mathematician called Saaty, to be used in the strategic briefing process. The method can contribute to the process of finding an appropriate strategy that supports the client’s business. The software program analyse different alternatives and support an understand of the strategies underlying objectives (Smith et al., 1998).

Problem Seeking
In the initial phases is the Problem Seeking method helpful as it provides advises of how to conduct workshops and interviews. The method consists of analyses in five steps: goal, fact, concept, needs and problem (Peña and Parshall, 2001).

Value management
Value management attempts to increase the ability to satisfy the stakeholders during the whole project (Andersson et al., 2006). This is conducted by calculating the customer value (Setijono and Dahlgard Jens, 2007) and finding a balance between cost and quality of the functions in order to create added-value. Value can be regarded as the relation between subjective and economic parameters (Andersson et al., 2006).

Project management
Project management is the application of knowledge, skills tools and techniques in different activities in order to reach the goals of the project in such a way that the processes delivers optimal for the customers. Project management consists of a number of supporting processes, for example, scope, time, cost, human resources management, to ensure the deliver of the project (PMI, 2004).

Quality management
SS-ISO 8402 states that quality management includes all the activities within the management function that determine the quality policy, objectives, responsibility and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system (ISO, 1994).

Design quality indicator
Design quality indicator (DQI) is based on three main elements: a conceptual framework, a data-gathering tool, and a weighting mechanism. Those three elements attempt to capture the value creation of the design in relation to the different needs of the occupants in the building. The work should in-
volve, for example, the client, the designers, the end-users and the producers (Cole-Colander, 2003; Gann et al., 2003). One of the main thoughts, when creating the tool, was to make it usable by anyone of the stakeholders and in any phase of the buildings life-cycle: conception, design, construction and in-use (Gann et al., 2003).

Building performance evaluation
The goal with building performance evaluation is to improve the quality of every decision taking during the life-cycle of a building: the concept is directed to all types of buildings. The building performance concept can be explained as: the set up of performance criteria, exercise performance measures and then compare the criteria with the outcome of the measuring (Preiser and Vischer, 2005b).

Evaluating the strategic briefing phase
Initiating the project

Design quality indicator

Building performance evaluation

Balance scorecard and design performance measurement
A survey of the use of design performance measurements in the consulting engineering sector in UK, showed that the organisations focused on costs-based indicators in projects. It was found that there was a need to go beyond these cost-based indicators to improve work and learn. A balanced design performance scorecard was developed with six key performance areas: client needs, integrating the project into design aims, project design processes, external design processes, profitability and efficiency of projects, learning and innovation. The purpose was to fit the design performance with the business strategy but more research is needed before it becomes a complete tool (Torbett et al., 2001).

Behaviour-performance outcome paradigm
The method studies the relation between the goal level and the performance through an evaluation of project outcome (Liu and Walker, 1998). The paradigm can be useful in the project procurement, from conception phase to occupancy phase, for example, when examine occupant's satisfaction of a building; to understand how people make decisions within an organisation; how faults affect on the behaviour and are handled in the project (Liu, 2003).

Managing the functional briefing phase
Functional briefing
The statement of needs and business objectives are transformed into a functional brief document that precisely defines the client’s requirements. The functional brief is not dynamic: changes are not to be considered after the brief has been established, estimated and agreed (Gray and Hughes, 2001).

Dynamic briefing
The dynamic briefing process take-off from the fact that customers’ needs and requirements are changing through the project process and that the briefing process is complex and dynamic and ongoing through the whole project (London et al., 2005). In the dynamic brief development there is, however, a need to identify specific points through the project where brief activities can be evaluated to receive performance feedback (Othman et al., 2005).

Concurrent Engineering
The Concurrent Engineering (CE) is a cross-scientific method for coopera-
tion and efficiency by looking at both organisation goals and individual evolvements (Norell, 1992). CE uses a mix of strategies with the purpose to reduce lead times, product costs, improve business efficiency and satisfy customers/clients (Kamara et al., 2001).

**BriefBuilder**
The BriefBuilder® was developed in the Netherlands and is a web-based planning tool with the aim of improving the communication and performance of the brief. The system can also be used for testing construction solutions against the brief statement, to manage changes during the project and to increase the knowledge by re-using information from earlier projects (van Ree et al., 2006).

**BriefMaker**
BriefMakerTM is a software tool that attempts to automate the brief design in the work of developing clear statements of the client’s requirements. The tool consists of a three step procedure: concept validation, core solution and full solution. The three step approach makes it possible for stakeholders to make remarks three times before proceeding. The system is under evolution (Hansen and Vanegas, 2003).

**Quality Function Deployment**
Quality function deployment (QFD) has been used in the construction industry when designing flats and houses. In Sweden it was used in the construction company when planning apartments on the basis of customer wants and needs (Gustafsson, 1995). ‘House of quality’ is a useful tool for analysis of the customer needs and technical requirements and to increase communication with the customers (Delgado-Hernandez et al., 2007).

**EcoProp**
EcoProp is a software tool developed in Finland that supports the requirements process of a buildings performance and conformity in the briefing process. The tool can as well provide an estimation of the building’s life-cycle costs (Huovila and Porkka, 2008).

**Integral client brief**
Integral Client Brief (ICB) is a briefing toolkit that link-up databases, expert systems and intranet. The purpose is to achieve an integrated process from project initiation to occupancy with the purpose of, for example, increase the customer satisfaction. The method encourage strategic discussions of the local planning by focusing on organisation and people (Malmqvist and Ryd, 2006).

**Teknisk Standard (Technical standard)**
Technical standard (TS) is developed by public real-estate organisations in Sweden with the purpose of helping the client to do ‘right’ from the start and to increase the stakeholders’ responsibility taking in the project. TS uses a database called PTS that helps the client to manage the construction process with key data for a ‘standard’ building (Malmqvist and Ryd, 2006).

**Design quality indicator**

**Value management**

**Project management**

**Quality management**
Evaluating the functional briefing phase

Balance scorecard and design performance measurement

Behaviour-performance outcome paradigm

Building performance evaluation

Managing the design phase

Design Management and Collaborative Design
The two methods aims at improving the product, the processes and the collaboration between the actors through advanced managerial and technical practices (Ahire and Dreyfus, 2000). It is argued by the advocators that a socio-psychological approach would most likely be able to manage the sensitivities of designers through a creative, learning and reflective collaboration (Sebastian, 2005).

Participatory design
In the participatory design approaches are designing regarded to be a social process. The users and architects are interacting in workshops with the aim of understanding the users’ real needs (Luck, 2003). The project briefing process is, from this perspective, regarded to be a consultative method that uses interviews, steering group meetings to bring a voice to the end-user to create accessible design. The focus is on user satisfaction and post-occupancy evaluation (Luck et al., 2001).

Design quality indicator

Building performance evaluation

Value management

Project management

Quality management

Evaluating the design phase

IPA (Intentions Practices and Aspiration) model
IPA model evaluates the design phase and is a model that emphasis on learning from past experiences. The evaluation concerns the intension, practice and aspiration of how the design proceeded or should have proceeded from three perspectives: the product, the process and the performance. Every perspective is further analysed from three time perspectives: pre-project, project and post-project. The method is based on questionnaires (Lawson et al., 2003).

Building performance evaluation

Balance scorecard and design performance measurement

Behaviour-performance outcome paradigm

Early supplier involvement and early contractor involvement
These two indicators are not directly concerning the end-user involvement but indirectly they bring benefits for the end-users by encourage the project to conduct a better design from the start by involving participants with different kinds of knowledge (Ugwu and Haupt, 2007).

Managing the construction phase

Value management
Contractor Quality Performance

Contractor Quality Performance (CQP) measures what is delivered to the clients (owners and end-users) and the corporate culture within the company with CQP indicators. The goal is to achieve total client satisfaction with the quality of the product and the services (Yasamis et al., 2002).

KPIs from Construction Excellence

Construction Products Association in partnership with Construction Excellence have created a programme of KPIs called Construction Products Industry that is a part of the Construction Industry KPIs. The focus of the KPI programme is on customer satisfaction, people and environment. ‘People’ includes employees and customers and are further divided into four categories: builders’ merchants, main contractors, specialist contractors and clients, designers and end-users (Construction Products Association, 2005).

Design quality indicator

Managing the FM/occupancy phase

Value management

Project management

Building performance evaluation

Quality management

Evaluating the FM/occupancy phase

Post occupancy evaluation

Post-occupancy evaluation (POE) is a systematic process that can be used to evaluate the building performance in use from three perspectives: technical, functional and behavioural (Preiser et al., 1988). The method is systematic but also a dynamic and evolving process with the focus of the requirements and needs of the buildings occupants (Preiser, 2002). The methodology often uses three or four different investigate methods together to broaden the perspective of the studied object (Bechtel, 1996).

Probe

Feedback is often regarded as a key factor to improve building performance. Unfortunately, feedback is rarely common and much is confidential in construction projects. Probe is an initiative in the UK to improve the openness, provide feedback to building service engineers and provide specific information on factors for success and areas need to be improved (Cohen et al., 2001). The feedback is directed directly to the designers and their clients (Preiser and Vischer, 2005a).
Satisfied customer index
There exist different standard satisfied customer indexes across the world, for example, the American, the European and the Swedish. Their procedures differs a bit but their main purposes is to receive knowledge about how the customer values the delivered services/product of the company (Cessel and Strand, 1999-12-21).

Customer perceived value
Customer perceived value (CPV) can be used to predict customer behaviour and loyalty. The tool analysis what an offer gives a customer (in terms of costs and benefits) compared with the alternatives on the market. The focus is on needs and values for the customer and weights every category’s relative importance (Swaddling and Miller, 2002).

The gap model
The gap model analyses why there exist customer dissatisfaction. This is conducted by studying the different stages in the delivery process to find gaps where the delivery did not succeed in fulfilling the needs and wants of the customers (Bergman and Klefsjö, 2003).

Quality of professional life
Quality of professional life (QPL) measures the satisfaction with the circumstances of job: salary, organisation, facilities, work-mates, patient etc. (Gene-Badia et al., 2007). This can be an important factor to measure in order understand if it is the physical environment that is the problem or if it is an organisational problem.

Housing quality indicators
Housing quality indicators (HQI) focus on the links between the project and the local environment by analysing aspects such as physical sustainability, overcrowding, housing services, extra amenity, tenure, safety, accessibility, and housing price (Hall and Meng, 2006).

Building research establishment environmental assessment method (BREEAM)
The objective of the BREEAM method is to survey how the building affects the environment. It attempts to reduce the environmental impact of the built environment by encouraging best environmental practice in building design, operation, management and maintenance (Holmes and Hudson, 2002).

Building performance indicator
Building performance indicator (BPI) measures building performance from different aspects of its condition. The outcome can be used in the evaluation process of a building and to provide benchmark measurements (Shohet, 2003).

Design quality indicator

Building performance evaluation

Balance scorecard and design performance measurement

Behaviour-performance outcome paradigm

4.2 Review of Swedish real estate organisations

During the winter/spring of 2008 interviews were held with 12 representatives from the real estate organisations (e.g. the clients) and they were then
invited to a workshop. The focus of the interviews and the workshops was: how they evaluate their cooperation with their end-users and how they work to satisfy them. The clients represent housing companies, schools and offices and healthcare facilities. Three workshops were conducted: one for each type of real estates and each workshop lasted for two hours.

4.2.1 Interviews
From the interviews appeared that most of the organisations are measuring satisfied customer index (SCI). The purpose of the measuring was: to improve their work; to be attractive on the market; to be aware of “Quick fixes” and to gain inputs to future projects.

Most of the SCI measurements do not allow the customers to rank the importance of the statements they are taking a stand for. This makes it impossible for the real estate organisation to know if they are asking about or fixing things that really matters to the end-users: the SCI is most commonly measuring what is delivered not what is wanted. Another general problem was the difficulties in knowing how to transform the achieved information into something valuable for their customers. Many of the organisations were able to conduct quick fixes after the measurements and some of the organisations had plans to increase the communication with their customers to better understand their needs.

Feedback from the measurements was presented in intern papers, letters, meeting with the end-users and early meetings of new projects.

4.2.2 Workshops
Even though the real estate organisations that participated in the workshops are quite divers: some are private and some are public and their end-users and taskmaster differs, many of their problems were similar. Some of the subjects that were discussed are presented below and this section ends with some final remarks that appeared during the workshops with the real estate organisations.

Communicating
Many of the clients (the representatives of the real estate organisations) found it hard to communicate in a constructive way with the end-users. The end-users were, by some participants, regarded as conservative when it came to space planning. In a few cases were, however, the client’s opinions about optimal space solutions so strong that they could be regarded as conservative in their thinking. This indicates that not only the end-users should be regarded as conservative: it is much a question of taking and giving. This highlights the importance of an increased communication as a means of better understand the end-users in their complex surrounding. Clients, from the hospital and healthcare real estates, used a facility planner, with experience of working in hospital, as an interpreter between the end-users and the client. The companies regarded this organisational setting to be very successful. Clients, without a facility planner, expressed needs of either having an external person, with pedagogical skills, to ease the communication with the end-users or letting the architect be the link between the client and the end-users.

Manage the constantly changing market
At a project level it was found difficult to make the new technology fit in the existing, inflexible, buildings. The end-users were regarded to be positive when it came to new technology but conservative of space planning and rooms. The clients expressed the need of finding flexible space solutions as the needs in the end-users organisation often changes: concerning both
their activities and the number of members. For project success a flexible space solution was, therefore, ranked high among the clients.

External changes, for example, the economical situation in the society, political decisions and trends are aspects that were considered difficult to manage in the real estate organisations.

It was also found difficult to make the decision process objective. The individuals’ subjective opinions were often regarded to influence the decisions making in the projects to a too large degree. The subjective opinions of the individual were not regarded to reflect the best solution of either the organisation as a whole or the organisation in a longer term perspective.

The clients experienced that successful projects with satisfied end-users often was the result of a successful process of finding space solutions that supported the end-users’ workflows.

Finding solutions for contradictive needs and requirements
The clients that represented public companies found it difficult to know how to weigh strategic business, political and technical requirements in order to bring value for the end-users, employees and taxpayers. In other words: how to find the optimal solution when your service is only covering one part of the whole, how can you cooperate with the whole organisation to find a better solution and thereby achieve more satisfied customers?

The clients found it hard to know how the end-user valued different value-adding parameters. For example, how much are the customers willing to pay for a view over sea, or an oak tree floor? In the same time tended too many choices make the customer incapacitated. Another aspect to manage is that the end-users and the clients often have different time perspectives of the built environment. This was considered complicating the process of achieving satisfied customers as well.

But even though the real estate organisations’ end-users have different needs, the problems of getting the project and requirement processes to work were found to be almost the same.

Requirements for a new tool
Most of the real estate organisations experience that they are quite good at managing the construction project: they have routines for procurement and project meetings. What they find more difficult is the early statement of needs and the evaluation of the projects. The clients found it difficult to transfer the received information into something value-adding. It was considered hard to manage the process of asking, implementing and evaluating. The clients’ interests in common are tools/methods that are capable of:

- Comparing parameters against each other according to what brings the most value for the end-user
- Find more flexible solutions for long term commitment concerning telecommunication and environment/energy
- Increase the communication with the end-users to better understand their wants and needs
- Manage value changes on the market
- Perform a better needs analysis
- Better KPIs and evaluation parameters
- Manage the information from the evaluations
- Benchmarking tools on a project level, but not on a national or an international level.
**Untapped knowledge within the real estate organisations**

When potential tenants registered their interest to cue for an apartment, in one of the housing companies, they were offered to fill in a questionnaire on the website of the company. The information was then gathered in a database and includes information about the tenants on a personal level (age and civil status) as well as space-related wants, for example, a balcony or a garden, washing machine in the apartment, close to a park or the city and so forth. This information was not used, but the housing company was planning to try to use it in upcoming projects to increase the understanding of the needs/requirements from different groups of end-users.

One of the real estate organisations has, for one and a half years, been conducting project and space measurements on a regular basis as well evaluation reports of old projects. The comparisons towards the functional requirements are though not satisfactorily conducted. The client expressed a need to improve the analyses of the information as a means of learning how to improve the project processes and find better solutions in future projects.

### 4.3 Methods and Tools in Use in Sweden today

In Sweden there are no nationally coordinated benchmarking models concerning the fulfilment of end-user requirements and value creation in use today. There are some national evaluation schemes in use measuring sector change, project effectiveness etc. Moreover, there are some real estate and facilities management companies that use post occupancy evaluations and satisfied customer index to measure end-user satisfaction in general and to some extent in relation to how new or refurbishment projects fulfill their requirements. This section describes three national/regional schemes and three examples of how real estate and facilities management companies work, or do not work. Today, there exist no developed indicators in neither of the schemes. The second and the third scheme (FIA and BQR) and their attempts to develop new indicators will be further described.

#### 4.3.1 National / regional schemes

**Utmärkt bygge (Excellent construction)**

A number of issues, problems, concerning the construction process and the result delivered surfaced during the housing exhibition Bo01 in Malmö. As the situations that surfaced during the housing exhibition were discussed, the Construction Council came to the conclusion that many of the problems causing the situations were well known. There was also a general agreement that there were solutions but that it had been difficult to get them in place into the construction industry. The industry members of the board expressed a fear of that the nation-wide initiatives would find it hard to find their way down to the people actually working in the industry in any better way than earlier attempts. They decided to try something new. They felt that the initiatives to change and what needs to be changed should come from the actors in the industry. It was decided to create a forum, the Construction Process Forum (Byggarcessforum).

The aim of the forum as it initially was defined was to develop the construction and the real estate management process, increase the profitability across the supply-chain, increase the human value among the actors of the construction process, and increase the image of construction. The action plan that was developed through out the forum ended up as a program, in-
spired to some extent of the Considerate Contractors Scheme\(^7\), with the aim of improving the efficiency of the construction process and of improving the image of the construction industry. Construction projects are linked to program either by the client or the main contractor. By linking the projects to the program they bind themselves to obey the rules of the scheme. The client or the main contractor binds themselves to:

- demand from the other actors in the project to follow the rules of the program for an improved construction process,
- post sign at the sight telling that the project is linked to program and how the general public can get in touch with site management,
- cooperate with advisors of the program, and
- take part in the evaluation of the program

According to the plan of action, and subsequently the program, increased efficiency of the construction and improved image of the construction industry is reached through improving the following areas (Utmärkt Bygge, 2007):

- cooperation,
- design and planning before construction starts,
- project and site management,
- knowledge building and feedback,
- consideration
- respect for the environment
- good working conditions, and
- considerate neighbour.

This developed into the program Utmärkt Bygge. In the program a tool has been developed to enable participating projects to benchmark how well they do compared to other projects that are participating (Utmärkt Bygge, 2007)

FIA

Different initiatives to improve the construction industries competitiveness have been introduced in a number of European countries, for example Constructing Excellence (the UK)(Constructing Excellence, 2006), PSI Bouw (Holland) (PSI Bouw, 2006) and Utmärkt Samhällsbyggande (Sweden) (Byggkommittén, 2007). In Sweden, apart from the larger Utmärkt Samhällsbyggande a more focused program aimed at improving the competitiveness of the civil engineering part of construction, FIA (Renewal within the civil engineering sector), was launched in December 2003. The aim of FIA is that the year 2010 their vision should be fulfilled, the vision states (FIA, 2006):

The civil engineering part of construction is and is perceived as, an important and respected society provider, whom, together, in an innovative and learning process and in a cost efficient manner develops the road and rail infrastructure to fulfil the demands of society and end-customers. The industry has compared with today’s situation substantially increased their efficiency and lowered the frequency of faults. (Free translation from Swedish)

To achieve this five aims have been defined (FIA, 2006):

- Increased efficiency delivering increased quality at lower cost with increased profit margins. (Efficiency)

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\(^7\) Considerate Contractors Scheme is an UK initiative with the aim of improving the image of the construction industry, see www.ccscheme.com
- Better teamwork and increased cooperation between the parties of the industry (Cooperation)
- Better incentives for R&D and development of competencies. (R&D)
- More efficient dissemination of existing knowledge and competence (Knowledge transfer)
- Recruitment of new personnel made easier by the more positive image of the industry. (Image)

From these aims several different research and development projects have been and will be initiated by FIA to achieve these aims. FIA saw a need to monitor how the civil engineering sector develops, in order to effectively plan and implement development projects. As a result, the Division of Construction Management, Lund University was commissioned by FIA to create a tool, a questionnaire, with the aim to measure the change in the Swedish civil engineering part of construction in regards to the five aims that FIA has identified.

The construction of the survey was undertaken with two main requirements from FIA. Firstly, the survey was limited to just cover the internal aspects of civil engineering projects in the design and implementation phases. Focus should be on the relationships and activities of client, the contractor and the designer, which gives that the primary focus of the survey is on the aims of efficiency and cooperation. Consequently, due to this requirement the survey will be focused on project operations, much in line with Taskinen and Smeds (Taskinen and Smeds, 1999). Further, the activities made during the long and complex planning process where much of the external communication with those affected by the project is not considered. The effect of this is that the aspect of image is only moderately considered in this survey. Additional evaluations will thus have to be made to cover how the image of the civil engineering sector is improved.

Secondly, the survey was required to be as easy as possible to answer by the respondents. One effect of this was that the number of question was to be as few as possible. The challenge was thus to find a balance between the numbers of questions required to sufficiently cover the aims and limitations of the study and at the same time have a limited number of questions to ensure a survey that was easy enough to answer. This resulted in a survey construction in close cooperation with representative of the civil engineering sector (FIA) and the research community (Construction Management, Lund University). Every proposed question was discussed and approved, or disregarded, in consensus. This process resulted in a survey that was easy enough for the respondents to answer without compromising the scientific aspects of the study.

The final survey consists of factual questions about the projects and questions where the respondents shall grade assertions about the project on a 10 graded scale from very bad to very good. The assertions and how they relate to the five goals is presented in table 1 (very strong, strong, weak or none). There was also an open question added that addressed the issue of key factors for the outcome of the project. This question gives a qualitative explanation of aspects covered in other questions. The measurements constructed from the factual questions will be adapted to the five goals laid out by FIA to evaluate how the Swedish civil engineering sector will develop in accordance to these goals (Widén et al., 2006).

BQR
As a response to an increasing interest in the Swedish construction sector to measure performance the Swedish Council for Construction Excellence (BQR), Chalmers Univeristy of Technology and Swedish Institute for Quality...
teamed up to develop a cross sectoral tool (Josephson and Lindström, 2007). The aim is to create (Nordström, 2005):

“A tool for performance measuring, enabling, from a clients perspective, risk identification, avoiding cost for mistakes as well as steering towards increased quality and effectiveness in building and civil engineering projects” (Nordström, 2005:25)

From a wide search 250 different key factors that had been used as different performance indicators were identified. Nine factors were singled out (Josephson and Lindström, 2007):

– Organisation
– Leadership
– Motivation
– Project goals
– Time
– Cost
– Customer satisfaction
– Productivity
– Learning development and improvements

Different aspects are measured at three different times of the project process (1) before the actual project start as some kind of risk management, (2) during the project to allow for adjustment during execution and (3) after the project are finished for future use. Small project may choose to only do it before and after or only after (Josephson and Lindström, 2007).

There are some fundamental characteristics set up for the tool (Josephson and Lindström, 2007):

– Easy to collect data
– Easy to manage
– Quick feedback
– Involve many
– Produce usable results

The tool is not completely ready yet. It has been tested and evaluated during 2007.

4.4 Conclusions

The literature review showed that there are a number of different methods for managing end-users that could be used for parts, but that there are very few that attempts to cover the whole process. Most methods exist in the early and in the late phases. The reason why there are more methods in the early phases can be that these phases are concerned to be problematic. Even though a lot of guides and methods have been published, little improvements have been seen on the market (Barrett et al., 1999). Barrett et al (1999) concludes that there is a need for making the brief takers interested in the methods and overcome their reliance on experience. And that raises questions like: are the methods to complicated and theoretical to be practically used or is it only a resistance against a changed way of working?

One commonality of the tools is that almost all seek to increase the communication between the stakeholders in the project by meetings and interviews.
Many of the methods are built on quite complex systems of data gathering and analysis systems that require knowledge and practice to manage.

Another difficulty that many of the methods are trying to, in different ways, understand end-users real needs and requirements of a building. It becomes obvious when reading about these methods that there are difficulties in understanding issues of subjective nature. Some voices tries to measure subjective aspects while others turn down any of these attempts.

A different question raised is if the process is regarded dynamic or static. Barrett et al. (1999) conclude that if creativity is stifle by too much emphasis on rational decision making, it can undermine the ability of understand and effectively address the problems in briefing (Barrett et al., 1999). Is this the reason why designers are afraid that the project management (PM) is not compatible with the creative process: that it will stifle the creativity? Does it really stifle creativity or is it again fear of changed way of working? How much freedom or sensitiveness for different circumstances usually exists within PM? How does the dynamic brief really work during construction?

Othman et al (2004) states that changes often have negative impact on project cost, time and quality. But their study showed that the changes lead to that the brief better met the client’s expectations and enhances the project performance. One more divergent opinion is if the focus should be on the individuals experience and need of the building or if the focus should be on an organisational level. Does different building requires different approaches and if so, can a tool be that flexible in managing different situations?

In the CREDIT project indicators for measuring and benchmark is the primary focus. In the early phases not many methods seeks to measure the outcome of the phase. The measuring between the brief and design performance often concern the process or product few concern the design quality aspects such as satisfaction, innovation or aesthetic appearance. The reason for this can be that it is concerned to be difficult to discuss subjective matters or find the problems to difficult to solve when a project organisation includes many consulting organisations (Lee Hansen and Vanegas, 2003). DQI attempts to measure the design quality but is criticised for not being a good measuring tool and only focusing on the product (Markus, 2003).

This raises questions like is it possible to measure the outcome of the early phases? If it is possible: is it relevant? As an attempt to answer the last question is that the early phases are often regarded as the most critical phases (as mentioned earlier) and should thereby be measured to, in some way, ensure the future success of the project. If you don’t measure it is hard to know if you become better or if you full fill end-user requirements. The providers often think the early phases take are to time and cost consuming. The users and architects often have the opposite point of view. Is it possible to make subjective aspects objective? Or is it other things that should be measured? Maybe the measurement should assure that the process have reflected on all important issues? That all end-users were involved in a democratic order? That set goal where obtained? If set goals where relevant in order to what really was needed?

In construction phase the situation is quite the opposite the early phases. Here we have a lack of method of how to involve end-user but several on how to measure different aspects. The most important in the construction phase is that stakeholders affected of the construction are held informed about the construction and that every member is aware of the end-users so that every change is done with the end-users in mind.
In occupancy/FM the balance between methods for involving end-users and measure is better than in other phases.

But it raises questions like: if the measurement methods in construction and occupancy/FM are satisfied? Are they measuring relevant aspects in the view of receiving satisfied end-user?

The methods that attempt to cover the whole process are not very well tested in reality. But the thought of BPE is in line with the CREDIT project. Normally the building is evaluated first when occupied. BPE however attempts to improve the quality of every decision taken during the whole life-cycle of the building by evaluating the outcome of every phase (Vischer, 2008). Vischer (2008) discuss the different initiatives of briefing and managing the process from the user perspective and conclude that:

“Some of these initiatives are technical, some are cost-oriented, and some are humanistic—but all point in the same direction: change. It is inevitable that as more knowledge accumulates and is disseminated, and as momentum gathers to change traditional building processes and recognise the complexity of modern and future construction, that optimising the quality of the built environment which people occupy will become a major goal of construction” (Vischer, 2008, p 163)

Many of the methods are criticised for not bring any guidance for how to act upon the result/outcome from the method. There is, thereby, a need for improving the usability of the methods and tools from both a micro and a macro point of view to improve the whole building process, before the quality of the built environment can be optimised.

In the review of Swedish real estate organisations appeared that almost none of the methods and tools discovered in the literature review were in use or the awareness of their existents was very low. The organisations in generally measures SCI but some of the organisations had difficulties in creating value of the outcome. During workshops it became clear that it was considered difficult to communicate with the end-users, to adapt to a constant changing market and to make decisions in an environment with contradictory needs and requirements. In Sweden there are no nationally coordinated benchmarking models on the fulfilment of end-user requirement and value creation today. There are some national evaluation schemes in use measuring sector change, project effectiveness etc. and some real estate and facilities management companies use post occupancy evaluations and satisfied customer index to measure end-user satisfaction in general and to some extent in relation to how new or refurbishment project fulfil their requirements. Examples of these schemes are Excellent Construction, FIA and BQR.

4.5 References


5 State of the art in Denmark

Anne Kathrine Frandsen, Niels Haldor Bertelsen, Kim Haugbølle, SBi

Introduction
The aim in the Danish State of the Art report is primarily to give an overview of the evaluation and benchmarking systems that is either working in the building sector, or has been tried in pilot projects.

Secondarily it will try to point out examples of benchmarking or labeling systems in areas in the vicinity of the building sector such as the real estate business, construction material industry that could be useful to study, as well as building projects appropriate to study with the objective of CREDIT in mind.

But before getting to the examples a model, developed through a series of pilot projects done by SBi, for understanding the building process and the values of both the building and the building process will be introduced.

Methodology
The Danish part of the State of the art report is based on three sources:

- Interviews with representatives for the different parties in the building process (clients, architects, contractors, public authorities, and developers of benchmarking schemes), all experienced with evaluation or benchmarking of the building process or the final building.
- Interviews with researchers covering a large range of relevant issues relating the build environment. Issues such as daylight, lighting, air quality, ventilation, acoustics, energy, accessibility, and more qualitative issues like environmental questions/sustainability, functional and social demands to schools and educational buildings, housing and commercial buildings.
- Lastly it is based on studies of literature on benchmarking systems that are in use in Denmark, and reports and documentations of Danish pilot studies of evaluation and benchmarking.

5.1 Requirements for performance in the building regulations

In Denmark, requirements for the basic performance of buildings is defined in the building law and the health and safety work act and is specified in building regulations. On top of that are the requirements for the specific building case, specified in the brief for the building. If the requirements for the building are in conflict with the building regulations it is possible in some cases to apply the authorities for a dispensation.

The building regulations (BR 08) include building performance specifications concerning:

- The regulations of the building in relations to the location
- The lay-out of the building including accessibility lay-out of dwellings, toilets and so on.
- Constructions
- Fire regulations
- Indoor climate
- Energy consumption
- Installations

In order to obtain building permission, the application material has to show how the planned building will meet the requirements. Before the occupation of the new building is allowed, the authorities give an occupancy permit. If the finished building is not in accordance the building permission, and does not meet the performance requirements, the occupancy permit cannot be given. The authorities can in the building permission require that the energy consumption, air tightness, acoustic climate and humidity in the finished building is measured before an occupancy permit is given.

The building regulations refer to a range of standards and guidelines that give specifications, recommendations for the right layout and execution or key measurements. Naming a few:
DS 490:2007 Sound classification of dwellings with four classes of acoustic quality.
DS 3028, Accessibility for everyone,
DS/EN 81-70/A1:2005, DS/CWA 45546-1:2004, DS 105.2 and DS 105 all concerning the accessibility of buildings, public places and recreational areas
DS 447 and DS 428 Execution and fire protection of ventilation systems.
DS/EN/CR 1752 Ventilation of buildings - planning criteria for indoor climate
DS 700 on artificial lighting in work rooms

SBI-anvisning 216 - Guideline to the building regulations BR 08, covering the same themes as the BR 08.
SBI-anvisning 218: Sound conditions in buildings for teaching and day care – requirements and recommendations.

5.2 Experiences from Danish Pilot Studies of Benchmarking

In the 1980s different reports and analyses from organisations and national authorities put focus on the weak productivity development in the construction sector compared with other sectors. In 1993 The Ministry of Trade and Business Affairs published an economic trade analysis on the construction and housing (Erhvervsfremmestyrelsen, 1993). To improve the productivity it was proposed that the following initiatives must be initiated: Project Renovation, Products and Processes in Construction and Project House.

All three initiatives have been completed. In Project Renovation a large number of development projects (around 100) (Bertelsen, 2001) demonstrated on different building parts and types of old buildings how renovation and renewal can be improved. Several of the projects included benchmarking and productivity e.g. ‘Quality in project control’ (Kvalitet i projektstyring, Bertelsen, 2003). In Products and Processes in Construction four consortia competed on efficiency and quality improvements in planning and construction of a number of non-profit housing projects at different locations in Denmark (Erhvervsfremmestyrelsen, 2001).
In Project House ten different working groups with more than 200 participants from all corners of the sector analysed literature, models and experiences, and as a result they have presented a large number of proposals to improve productivity in different areas. Working group 10 has, for example, a proposal on key figures, performance indicators and benchmarking of productivity (Metoder til kvalitetssikring af alment boligbyggeri, Bertelsen, N.H., 2001 (Methods of evaluating the Quality of Non-profit Housing Construction).

5.1.1 Evaluation of Standard and Quality

In relation with the development program Process and Product Development the Danish Building Research Institute (SBI) in 2000 got the assignment of developing a methodology to evaluate standard and quality of public housing.

The development of the methodology was based on the experiences from the earlier pilot evaluation done by SBI, Methods of evaluating the Quality of Non-profit Housing Construction (in Danish: Metoder til kvalitetssikring af alment boligbyggeri) (Bertelsen, N.H., et al., 2001).

The methodology addressed a comprehensive assessment of six themes targeting the parties in the construction sector: Architecture, building technology, indoor air quality, environmental impacts, life cycle costs, user satisfaction (By&Bolig, 2000).

It was tested by independent evaluators on 17 development projects build as public housing within a comparable economic budget. The generation of data was based on participatory observation and documentary evidence.

The conclusion of the project was that generally, the methodology can be used for comprehensive assessments of standard and quality. However, in order to use the methodology to a larger extent, it needs to be tested on several building types, and subsequent adjustments. (Erfaringer med evaluering af standard og kvalitet, Haugbølle, K., Beim, A., Eriksen L., 2003)

5.1.2 Key Figure System for Residential Housing

This was followed up in 2005 by a proposal for how to incorporate evaluations of quality and standard of residential housing in the key figures system for residential housing that already existed in Byggeskadefonden (Building Damage Fund) evaluation of not-profit Housing and BOSSINF (see further description in Benchmarking in Denmark), Nøgletalsystem for boligbyggelser, Bertelsen, N.H., et. al. 2005 (Key Figure System for Residential Housing).

The proposal addressed assessments of both:
- sizes and price (the area of the houses, the price pr. square meter, the costs of the craftsmen, the consultants, differences between planned and spend expenses)
- standard and quality of the building (of the technical solutions, the properties and their execution, evaluation of the residents)
- the course of the planning and building process (frequency of accidents, collaboration, defects, spend time consumption and planned time consumption).

This in order to create insight in the relationship between price and quality, find best practices and incorporate assessments of the process and of the competences of collaborators in the understanding of quality.
5.1.3  Block model
The Block model is a data structure for buildings. It is developed parallel to
the former mentioned projects and on the basis of the experience that was
gained among others from these projects.

The central idea in the block model is a common block structure for the main
building parts that are used in all the different phases of the life cycle of the
building, and that are in common for all building types, directly related to the
building classification system SfB.

In the block structure the building is divided in six main objects with several
subordinate objects.

1. Buildings and construction (foundation, walls, floors, stairs, elevators,
   roof, balconies and other exterior fittings).
2. Rooms and fittings
3. Installations in the buildings (wiring, heating, water pipes and drainage,
   ventilation etc.)
4. The building area (the site, connections, planting, roads, passages and
   other pavements).
5. Common activities (taxes, building administration, design, the construc-
   tion site, construction management, insurance and financing)
6. Fixtures and furnishing of the rooms

It has been tried on renovation of buildings, and construction of social hous-
ing projects, university buildings and schools. It has been used to compare
the price per sqm., the total economy of the building, levels of quality and dif-
ferent user values.

5.1.4  Basismodel
Basismodel is a data model developed by SBi that can read data in different
CAD systems and convert it to a simple model that dynamically can be modi-
fied to all phases in the construction process. E.g. to a digital tendering, the
tasks, amounts, properties, the specification of the product and the execu-
tion and a 3D model are interconnected.

What is interesting in relation to benchmarking is the structure of the model
and how the interconnection of all the different data on a project (the organi-
sation of the project, the geometry of the project, the properties of the ob-
jects and the different tasks to be executed related to the project) is handled
through a classification - the project key.
(http://www.sbi.dk/byggeprocessen/basismodel)

5.3  Benchmarking in Denmark

5.3.1  Real Estate
In 1976 The Building and Dwelling Register (BBR) was established with data
on property in the whole Country, since 2001 the Danish Enterprise and
Construction Authority has been the in charge of the BBR, together with
Kommune Holding and Kommunernes Landsforening.

The information in the register comes from the owners of the property and
dwellings themselves. It contains information on 1.6 million properties, 3.8
million buildings and 2.7 million dwelling and commercial units on floorage,
location, use, ownership, installations, building materials etc. Only some of the data is publicly available.

Another organisation in relation to real estate is Inspection of Houses (Huseftersyn) (www.hesyn.dk) that covers private housing which the owner occupies alone. The condition of the house is assessed and described by an appointed consultant, and potential damages is classified in three classes. The inspection is carried out in connection with a sale, and is available for the potential buyer of a house.

A parallel organisation that supplements the Inspection of Houses, emerged in 1997 with the task of giving all buildings, not only private houses, a label for consume of energy (www.femsek.dk), see under "Energy consumption".

5.3.2 Construction
In relation to National Agency for Enterprise and Construction (EBST) there are several organisations with activities on evaluation and benchmarking of certain building types:

The Danish Building Defects Fund (Byggeskadefonden) (www.bsf.dk) covers publicly financed new non-profitable housing and houses for youths, the elderly and housing co-operatives.

The Building Defects Fund on Renewed Buildings (Byggeskadefonden vedrørende Bygningsfornyelse) (www.bvb.dk) covers publicly financed building renewals.

Both foundations were founded in 1986 as a part of a quality reform with new regulation on quality assurance, which had the purpose of reducing the amount of defects in construction. Both funds do a 1-year and 5-year inspections with the help of appointed consultants, registering defects. The data from the inspections is accessible for the public.

The Danish Enterprise and Construction Authority (EBST) has value making by improving the competition means in the sector and a reduction of cost in comparison with the international level as goals in their policy. Politically, development of digital construction is emphasised, as well as partnering, public-private co-operation, the public owners as leaders in change in the sector and evaluation of contractors’ activities. In most cases the different initiatives are based on the proposals presented in the report ‘The future for the building sector – from tradition to innovation’ (Byggeriets fremtid – fra tradition til innovation) (www.ebst.dk) (Erhvervsfremmestyrelsen, 2000). The objective is to improve productivity and quality, which is a national problem compared with the international level. In practise the focus is mainly on cost reduction and large-scale construction and evaluation of construction companies to expose any the problems.

Byggeriets Evaluerings Center
In line with the policy presented above a new organisation - the Benchmarking Centre for the Danish Construction Sector (Byggeriets Evaluerings Center) (www.byggeevaluering.dk) was established in 2001. The centre is a private organisation funded by the building sector and supported by EBST.

Since 1st. July 2005 Danish construction companies/contractors have had to present KPIs for previous projects if they wish to undertake construction projects for the Danish State. These KPIs include:

- Customer satisfaction,
- Defects,
- Compliance with time schedule
- Health and safety at the workplace.

New rules with effect from 1st. of May 2008 demands KPIs for architects and engineering firms if they wish to undertake projects for the Danish State, including evaluations from the client on:

- Economy,
- Time,
- Communication and cooperation,
- The functional and aesthetic quality of the building
- The general quality of the produced project material.

The Key Figures on the different companies are directed at the owners/clients as a tool when choosing the consultants or contractors for a coming building project.

But some of the key figures are generalized. These are accessible for the public, and can serve as indicators for the whole construction sector. The managing director participates in the Danish reference group, and SBi has access to the indicators that lies behind the actual key figures.

**BOSSINF**

Since 1992 information on all publicly funded social housing projects in Denmark has been registered in BOSSINF. BOSSINF is an electronically based report, management and information system for every stage in the administration of public funding for social housing projects that is run by the Ministry for Social Welfare (Velfærdsministeriet).

The main purpose of the information system is to monitor the building costs of social housing projects.

It is mandatory for every non-profit housing association and every local authority to use BOSSINF at three specific stages of a social housing project, at the application for public support, at the competitive tendering when the building license is given, and at completion of the building project. BOSSINF contains for instance information about the location of the (planned) buildings, the name of the housing association and the person representing the building owner, the involved partners in the project, the cost of the main building parts, the cost of other expenditures, the size of the buildings and the apartments, whether it is a new building project or a renovation of existing buildings, the type of tender and the duration of the project (planned and realised).

The Ministry of Social Welfare issues an annual report on key performance indicators related to e.g. building types, building costs and geographical location, which allows the government to monitor the overall development of building costs and the social housing companies to benchmark their individual building projects against other social housing projects.

New rules have demanded key figures on every publicly funded social housing project since March 2007 including evaluation of the performance of both the construction companies and the architects and engineering firms. This means that the information the construction client report in the BOSSINF system, is supplemented with indicators on quality and defects, health and safety at the workplace, efficiency, level of prices, changes of prices during the construction, and user satisfaction. The evaluator is the Benchmarking Centre for the Danish Construction Sector (Byggeriets Evaluerings Center). The key figures will be published on The Danish Building Defects Fund (Byggeskadefonden) webpage (www.bsf.dk).
Indoor climate labelling of dwellings

Indoor climate labelling of dwellings is a relatively new initiative, a collaborate scheme by the Danish Technological Institute and Danish Society for Indoor climate. The assessment of the air in the dwellings is based on chemical analyses of the air in the most important rooms of the house. In the laboratory the concentration of the different chemical substances is compared with the substance's threshold value for smell and irritants. Additionally a sensorical assessment is made in the laboratory of air from the dwelling collected in big bags.

5.3.3 Facility Management

The Ministry of Social Welfare

Like the annual report on key performance indicators on construction costs the Ministry of Social Welfare publishes annually key performance indicators on facility management of social housing in Denmark on the basis of the accounts they receives from all the Danish social housing companies. This includes numbers on 400,000 dwellings, 20 % of all housing in Denmark, built during the last 100 years.


DFM-Key

The association Danish Facility Management – key (DFM-key) was established in 1996 by facility managers, construction firms, consulting engineers and suppliers for public organisations and institutions. DFM-key is a non-profit organisation. The activities of DFM-key are financed by member subscription. The purpose of the association is to establish a common set of benchmarks in and between companies and facilities in order to support management decisions and increase competitiveness.

DFM-key collects key performance indicators within five main categories: Fixed expenditures, operation, maintenance, consumption, and cleaning. Each of the five main categories is divided into a number of more detailed sub-categories. Key performance indicators are collected from close to 440 facilities representing about 3.9 million sqm. The key performance indicators are in principle applicable to all types of facilities and have developed into a de facto national standard that is also being used in relation to social housing. The majority of facilities included in the benchmarking scheme are, however, administrative facilities.

Once a year detailed key performance indicators are published in reports distributed among members only, based on data delivered by each member. Only a few generalised key performance indicators are accessible for the public. These include average costs for e.g. operation and maintenance per m². Therefore, the prime incentive for membership is the access to detailed facility management data and the possibility of comparing and discussing your performance with other members.

Today DFM-key has 55 members and has reached a position as the leading operator on key performance indicators for facility management in Denmark. The results of the association, including definitions on types of areas and an account plan for operation activities, is regarded in Denmark as a de facto standard in this area.

The association Danish Facility Management – key is engaged in Nordic co-operation with the objective developing a Nordic standard for benchmarking Facility Management. (www.dfm-key.dk).
5.3.4 Resource consume

Water consumption

Energy consumption calculation formula
At SBI a calculation formula has been developed for the prediction of the electricity consumption of a household in Denmark, ([http://www.sbi.dk/miljø-og-energi/livsstil-og-adferd/husholdningers-elforbrug-hvem-bruger-hvor-meget-til-hvad-og-hvorfor](http://www.sbi.dk/miljø-og-energi/livsstil-og-adferd/husholdningers-elforbrug-hvem-bruger-hvor-meget-til-hvad-og-hvorfor)).

Energy consumption labelling
The energy consumption labelling is run by the common secretariat for inspection and labelling systems. An appointed consultant gives the label and classifies the building on the basis of the planning and construction material, or with older buildings inspection of the house and registration of the consumption. In order to get an occupancy permit for a new building the building has have a energy consumption label.

5.3.5 Accessibility

The A-label for accessibility
The association ‘Good access for everyone’ (God adgang for alle) has made a labelling system for accessibility ([www.godadgang.dk/dk/a-maerket/a-maerket.asp](http://www.godadgang.dk/dk/a-maerket/a-maerket.asp)). This voluntary labelling system is made for existing buildings and places etc. Therefore the requests reflect the conditions that have to be fulfilled if a user with a particular disability should be able to use the place. For every one of the seven disability categories there is a set of requirements in relation to the physical accessibility.

The requirements are developed in collaboration with the different disability organisations and the involved professional association.

They are based on the Danish standards on accessibility (DS 3028, Accessibility for all (Tilgængelighed for alle), DS-handbook 105, ‘Outdoor areas for all’ (Udearealer for alle) and the handbooks from the Danish Road Directorate, ‘Circulation areas for all’ (Færdselsarealer for alle) and Handbook in accessibility (Håndbog i tilgængelighed).

5.3.6 Product classification

DVC - Danish Window Certification
The Danish Window Certification (Dansk Vindues Certificering DVC) is an impartial control system that ensures that the certified products are in accordance with the technical specifications of the window industry and a series of European testing and classification standards.

DIM - Danish Indoor Climate Labelling
Danish Indoor Climate Labelling (DIM) is a voluntary labelling system for building products on their impact on the indoor climate. DIM is common for Norway and Denmark.

The objective of the DIM is to improve the indoor climate in building by giving the manufacturing companies a tool to develop products that are better for the indoor climate, give the users a tool to choose the product that are best for the indoor climate and give everybody an understanding on the building products impact in the indoor climate.

The DIM declare:
Degasification, emitting of particles, and there has to be instructions about handling the product in relation to transport, storage, fitting, cleaning, and maintenance.
CE labelling of insulation quality
The insulation value of insulation materials is labelled when there is a pro-
duct standard on the material in question, a standard the manufacturer can
contribute to. The CE labelling is not a label of quality but only a description
of the properties of the material.

DUKO – Roofing underlay classification
DUKO – Roofing underlay classification (Dansk Undertags Klassifikation) is
a voluntary classification system driven by the Danish Construction Agency,
The Danish Building Defects Fund, The Danish Building Defects Fund on
renewed buildings and BYG – ERFA (Building experience Fund). In the sys-
tem there are four different classes of application that depends on what roof
the roofing underlay is built into.

MK certification of building materials
MK certification is given to materials that comply with requirements of the
Danish Building regulations for example for wet rooms. The certification is
done by ETA – Denmark that is part of Danish Standards certification. ETA –
Denmark can decide whether the certification can be given on the basis of
existing tests, or on the basis of tests done by a Danish test institute ap-
proved by ETA – Denmark.

Conclusions
How a building project meets the requirements described in the building
regulations is assessed by the authorities in order to grant a building permis-
sion. Likewise it is assessed whether the finished building is in accordance
with the building permission before the occupancy permit I given. And in
some instances the authorities can require that some performance param-
eters are measured, before giving the occupancy permit.
So in relation to the requirements for the basic building performance that are
described in the building regulations there is a evaluation system that follow
the building project through the building process.
The labelling systems for building products make that market more transpar-
ent and make it thereby easier to meet the many different requirements in-
cluded in the building regulations or in the brief of the specific building.
But the focus of these requirements to the building performance is primarily
on the technical or environmental aspects of the building and in lesser de-
gree on the functional, social aspects, and does not include the aesthetical
aspects.

In the above mentioned actual benchmarking systems, the general picture is
that the assessments are made in the last part of the building process, after
the completion of the building and till users occupies the building. This also
includes the pilot studies done by the Danish Building Research Institute.
With exception of BOSSINF (where estimation on price and amounts are in-
cluded in the applications for public support in the early stages of the build-
ing process) there are no examples of a system where the assessments are
done from the start of the building process and follow the project through
briefing, design, construction till the users occupy the executed building.

The intension with the Block Model pilot project are to develop an index of
prices based on experience form former building projects, to be used in the
initial phases of a project, to give the client and the consultants an idea of
the consequences concerning the price of different choices of design and
material. In this way the block model could cover both the initial and final
phases of the building process, but the concept has not been developed that
far yet.
In most of the actual benchmarking systems information on both values/qualities of the building and the course of the building process are included. On the building it is primarily quantities/area and price of the building and the durability that are assessed, only the KPI’s on the consultants from The Benchmarking Centre for the Danish Construction Sector include values of the building like usability, energy consume, and indoor climate.

When it comes to the building process it is primarily the time consumption and the relation between planned and spend time that are assessed along with amount of defects in the execution and accidents on the site.

In the pilot studies done by the Danish Building Research Institute it is primarily the performance of the building that is assessed, not only price and quantity but also usability, durability, energy consume, indoor climate and aesthetic of the design. Here it is the assessment of the building process that is lacking, with an exception in Key Figure System for Residential Housing (NBB), where figures on time consumption (planned and spend), defects and accidents and the course of cooperation are included.

One can conclude that there is lacking experience with evaluations that follow the building project through all the phases. Likewise there is a lack of experience with evaluations with assessments of many different performance indicators of both the planning and building process and the building itself.

Generally the information generated in the evaluations address the needs of the owners/clients or the investors. But some of the information is also relevant for the rest of the actors in the sector, either as benchmarks useful for comparing the performance ones own firm with other players on the field (BEC, BSF) or as a general knowledge relevant and accessible for all in the sector (BSF).

There is an absence of evaluation of end users needs and the project and the building compliance of the end users needs in the Danish examples. The end users assessment of the building performance is only addressed in some of the pilot projects (NNB, Evaluation of Standard and Quality Methods of evaluating the Quality of Non-profit Housing Construction):

Among the representatives from the different parties in the construction sector in Denmark (The Danish Reference Group) there was agreement that the benchmarking systems in use in Denmark generally are weak when it comes to the assessments of quality. And it is difficult to gain knowledge and experience from the key figures on the causes to low productivity or defects. Never the less it is here that the interest of the National Agency for Enterprise and Construction (EBST) is lying. Is it possible to find the reason why the price of the construction of social housing is 30 % higher and office buildings 15-20 % higher in Denmark than in other countries that are comparable? That is a key issue for EBST. They would like CREDIT to focus on assessments of performance indicators from the whole building process, and an adjustment of key figure systems so it is possible to make comparisons internationally.

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Appendix

<table>
<thead>
<tr>
<th>Phase</th>
<th>Briefing</th>
<th>Designing</th>
<th>Construction</th>
<th>Facility Management</th>
<th>Use</th>
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</table>

Possible point of assessment

Benchmarking systems
- BEC – contractors
- BEC – consultants
- BSF
- BOSSINF
- Ministry of social welfare
- DMF – key
- DST
- FEMSEK
- HESYN
- BBR

Pilot Projects
- Methods for evaluation of social housing
- Evaluation of standard and quality
- NNB (key figures for social housing)
- Block Model

<table>
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<tr>
<th>Benchmarking systems</th>
<th>Systems benchmarking new construction</th>
<th>Systems benchmarking existing buildings</th>
<th>Pilot projects done by the Danish building research institute</th>
<th>Evaluation of standard and quality</th>
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</thead>
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<td>BEC contractors</td>
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<td>Communication</td>
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(x) indicates a point of assessment.
6 State of the art in Iceland

Björn Marteinsson, Innovation Center Iceland

6.1 Benchmarking and Performance Indicators in Iceland

6.1.1 Introduction
The Icelandic market is very small and there is little tradition for sharing data between companies as all actors are in one way or another in a direct competition. Benchmarking as a way of measuring efficiency or quality of results is little used so far, but there is a trend for an increased interest in these matters.

Information that can be used for benchmarking on a national scale is by tradition mainly regarding energy use and the built amount of new buildings.

The subject “benchmarking and performance indicators” was taken up for discussion with different actors on the market;

Consults:
- Batterið architects, Sigurður Harðarson
- Gláma/Kím, Árni Kjartansson
- Efla engineers, Eva Ingvadóttir

Contractors and associations:
- Samtök iðnaðarins (The Federation of Icelandic Industries), Árni Jóhan
- Ístak contractor, Kolbeinn Kolbeinsson
- [Fasti (Icelandic Facility Management Association), Óli Jón Hertervig; has not been accessible]

Building owners
- Félagsbústaðir, Þórarinn Magnússon

The following text is partly based on discussion with the above mentioned persons.

6.1.2 Quality insurance in the construction industry in Iceland
In a report by a committee nominated by The Ministry of Environment the following items of interest are mentioned (Valdimar K. Jónsson et al, 1998);

- Poor descriptions result in that it may be difficult to see at the start what the buyer expects regarding quality.
- Inspection and quality control is hampered by poorly defined quality requirements.
- Diffuse and ill defined descriptions generally tend to result in that the cheaper choice is taken instead of quality.
- Better descriptions of quality of materials and components are badly needed.
It is pointed out that the situation results in that the building cost has undue effect on what is built and how, and the effect of initial quality on maintenance and total cost is not evaluated enough.

The situation can be said to be more or less the same now, 10 years later. Performance indicators have not been described or defined, and this is negatively affecting work on quality insurance in the construction market.

### 6.1.3 Data collection and information as to date

The term “benchmarking”, in its limited use in Iceland, is sometimes used for two different aspects;

a- A comparison of values for different objects in the scope of studying what can be done better and thus aiming for improvement in performance.

b- Following-up of eventual changes in performance, e.g. comparison between objects, or inter-comparison of each object, to find out changes to better or the worse (mainly as indicators of faults).

Based on discussions with actors on the market it may be stated that benchmarking in the first mentioned aspect is so far very little used in Iceland. There are though some examples of this use in pilot projects- in these studies no specific models or methods are used; the data is gathered the hard way from the companies and so far there is no automatic registration of “interesting” data.

- “Félagsbústaðir”, a housing company owned by Reykjavík municipality; a study of maintenance cost for eleven houses of different building periods over a five years period (Björn Marteinsson, 2006). The distribution of the cost on different aspects is considerable, but the period studied so far to limited to show if there is a systematic difference between houses.

- “Fasteign” a housing company owned by some municipalities and financial companies; A comparative study of various performance aspects of five “kinder gartens” (Óli Þór Magnússon, 2008). In the study the operational cost of five childrens day-care homes is studied over a two years time period. The staff of the homes was also asked to evaluate different performance aspects of the homes. The study shows some clear differences between homes, both in operational cost and satisfaction of staff and other users. This pilot study has shown some interesting results and it seems to be the case that at least two systematic design faults have been found.

- A case study of owner satisfaction of homes in two municipalities; Reykjavik and Akureyri (Björn Marteinsson, 2008). The study shows that performance satisfaction regarding function of homes and environment is partly dependent on age of the homes but location is also important. It is also very clear that older homes have usually been refurbished to some extent, which may explain the general satisfaction of owners.

Information that can be used in comparison of buildings, benchmarking, is located in various databases, which may or may not be accessed by the researcher or even the general public. Generally it can be stated that the best databases of interest are regarding energy use of buildings, but in practice this data is not always accessible for studies as it is considered as a violation of personal integrity to give information on use of e.g. heating energy for a specific building (if privately owned).

Comparison, or inter-comparison of objects is rather frequent in evaluation of energy use of distribution nets (in whole or parts) to estimate changes in en-
ergy losses (e.g. in Reykjavik municipality) and also in evaluation of energy performances of buildings (e.g. the above mentioned “Félagsbústaðir”).

Following is a list of the more interesting actors and database owners;

Orkustofnun, (The Energy Authority, http://www.orkustofnun.is). This is a government institute responsible to the Ministry of Industry. Orkustofnun is the official specialist on energy production and imports and make estimates of energy use in future. On their home page information about energy production in Iceland can be found and estimates of future needs for energy in various fields.

Orkusetur (http://www.orkusetur.is). Orkusetur is an information center for energy application and use, linked to the governmental institute; Orkustofnun. Information regarding changes the last 15 years in use of electricity, hot water and oil per capita is easily accessible.

Hagstofan (Statistics Iceland, http://www.hagstofa.is/). Statistics Iceland is the National Statistical Institute of Iceland and was founded in 1914. Statistics Iceland collects information regarding both economical and social statistics, and yearly. The information on buildings is though limited to homes (not service or public buildings) and consists of yearly built amount (number of apartments, total amount in m3, apartment size statistics; number of rooms). Statistics Iceland also publishes every three months a New Building Cost Index which is based on calculation models for very well defined types of buildings and actual market cost for labour and materials.

Fasteignamat ríkisins (Icelandic Property Registry, http://www.fasteignamat.is). All buildings and homes have a specific registration number. Estimated building cost and current tax value for any building in Iceland can be accessed from this home page (official information that can be accessed by anyone). Based on these figures an annual Selling Cost Index of buildings is calculated, based on location of buildings.

Figure 30 Domestic use of electricity; MWh/person.

They also give information that can be used to estimate the energy requirements for heating of a home, given location and size.
6.2 References:


7 State of the art in Lithuania

Arturas Kaklauskas, VGTU

7.1 Customer Requirements, Needs and Satisfaction / Emotions

Various interested parties (clients, users, architects, designers, utilities engineers, economists, contractors, maintenance engineers, building material manufacturers, suppliers, contractors, financing institutions, local government, state and state institutions) are involved in the life cycle of a building, trying to satisfy their requirements and needs and affecting its efficiency. The above requirements and needs embrace the expected cost of a building, maintenance costs, living space, number of floors as well as the requirements to its architecture, aesthetics, comfortability, functionality, proportions, materials, sound insulation of partition walls, taxes and allowances, interest rates, etc. Besides, the built environment, its ecology, sound level and local infrastructure are also taken into consideration. This list may be continued.

The problem is how to define an efficient building life cycle when a lot of various parties are involved; the alternative project versions come to hundreds thousand and the efficiency changes with the alterations in the environment conditions and the constituent parts of the process in question. Moreover, the realization of some objectives seems more rational from the economic perspective thought from the other perspectives they have various significance. Therefore, it is considered that the efficiency of a building life cycle depends on the rationality of its stages as well as on the ability to satisfy the needs of the interested parties and the rational character of environment conditions.

The entire building life cycle process should be planned and executed with consideration of the goals aspired to by the participating interested parties and the micro and macro environmental levels. In order to realize the above purposes an original Model of an Integrated Analysis of a Building’s Life Cycle was developed by the authors to enable users and the parties involved in the project to analyze a building’s life cycle, as well as to be able to see its micro and macro environments as one integrated entity. To achieve the above-mentioned aims new multiple criteria analysis methods and a Multiple Criteria Decision Support System for Building’s Life Cycle were developed (Zavadskas, Kaklauskas et al., 2005).

Formalized presentation of the above research shows how changes in the micro and macro environment and the extent to which the goals pursued by various interested parties are satisfied cause corresponding changes in the value and utility degree of a building life cycle. With this in mind, it is possible to solve the problem of optimization concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of building life cycle versions allowing find an optimal combination of customer requirements and needs pursued and finances available.

Web-based Biometric Mouse Intelligent (WBMI) System was developed by VGTU for measuring and analysis of user’s emotions and labour productivity
with a biometric mouse. The research included development of the WBMI System, which works in the background and is able to assess user's emotional state and labour productivity during work with a computer. The system captures information about user’s emotional state and labour productivity using three main biometric techniques: physiological (skin conductance, amplitude of hand tremble, skin temperature), psychological (e-self-reports) and behavioural/motor-behavioural (mouse pressure, speed of mouse pointer movement, acceleration of mouse pointer movement, scroll wheel turns, right- and left-click frequency). The system extracts physiological and motor-behavioural parameters from mouse actions and palm characteristics, and the user fills in the psychological (e-self-reports) data, which can be used to analyse correlations with user’s emotional state and labour productivity (Zavadskas, Kalauskas et al., 2008).

The data-gathering tool can be improved by using different biometrics technologies. For example, Layered Voice Analysis (LVA) technologies can analyze different layers within the voice, using multiple parameters to analyze each speech segment. LVA can detect various cognitive states, such as whether your subject is excited, confused, stressed, concentrating, anticipating your responses, or unwillingly sharing information. The technology also can provide an in-depth view of the subject's range of emotions.

7.2 Utility Degree and Market Value Model

Significance \( Q_j \) of real estate \( a_j \) indicates satisfaction degree of demands and goals pursued by the interested parties - the greater is the \( Q_j \) the higher is the efficiency of the real estate. In this case, the significance \( Q_{\text{max}} \) of the most efficient real estate will always be the highest. The significances of all remaining real estate are lower as compared with the most efficient one. This means that total demands and goals of interested parties will be satisfied to a smaller extent than it would be in case of the best real estate. The utility degree of real estate is directly associated with quantitative and conceptual indicators related to it. If one real estate is characterized by the best comfortability, aesthetics, price indices, while the other shows better maintenance and facilities management characteristics, both having obtained the same significance values as a result of multiple criteria evaluation, this means that their utility degree is also the same. With the increase (decrease) of the significance of a real estate analyzed, its degree of utility also increases (decreases). The utility degree of real estate is determined by comparing the real estate analysed with the most efficient real estate. In this case, all the utility degree values related to the real estate analyzed will be ranged from 0\% to 100\%. This will facilitate visual assessment of real estate efficiency (Kaklauskas, 1999).

The utility degrees of the real estate considered as well as the market value of real estate being valuated are determined in seven stages. Solving the problem of determining the market value \( x_{11-R} \) of real estate \( a_i \) being valuated, which would make it equally competitive on the market compared with the real estate \( (a_2 - a_n) \) already sold, a particular method of defining the utility degree and market value of a real estate was suggested. This was based on a complex analysis of all the benefits and drawbacks of the real estate considered. According to this method the real estate utility degree and the market value of a real estate being estimated are directly proportional to the system of the criteria adequately describing them and the values and weights of these criteria (Kaklauskas, 1999).
7.3 Lithuania Review

In Lithuania, VGTU has been involved in several Framework 5 and 6 projects (e.g. PeBBu, Brita-in-Pubs, INTELCITIES) collecting and developing performance indicator systems and performance assessment in the brief process. VGTU has also developed intelligent, voice stress analysis and IRIS recognition systems for multiple criteria analysis of building life cycle process as follows: Building's Refurbishment Knowledge and Device Based Decision Support System; Multiple Criteria Decision Support Web-Based System for Facilities Management; Cooperative Integrated Web-based Negotiation Decision Support System for Real Estate; Multiple Criteria Decision Support On-Line System for Construction Products; Sustainable Development Analysis Web-Based System; Building Life Cycle Decision Support System; Buildings’ Multivariant Design and Multiple Criteria Analysis Decision Support System; Web-Based Biometric Mouse Intelligent System for Analysis of Emotional State and Labour Productivity; Voice Stress Analyser Decision Support System for e-Examination; Web-based Biometric Mouse Decision Support System; Innovation Multiple Criteria Decision Support Web-Based System; Multiple Criteria On-Line International Trade Decision Support System; Intelligent Library and Tutoring System; Voice Stress Analysis System; IRIS Recognition System; Ethical Multiple Criteria Decision Support Web-Based System; Loan Analysis Decision Support System; Foundations Analysis Decision Support System.

In cooperation with their partners, an author of the article has created the Construction Technology Platform of the Republic of Lithuania. The Platform considers the current situation in Lithuania, the vision of the European Construction Technology Platform (ECTP) until 2030, growing society needs, cohesive construction requirements and the directives of Lisbon Strategy. While creating the part on Information and Communication Technology in Construction within the Platform, global experience was analysed thoroughly as well. In order to implement advance information and communication technologies in construction area, hereinafter the following five main trends of its implementation are analyzed in the Platform:

- Transformation of sector of construction and real estate.
- Construction materials, equipment and machines.
- Construction process.
- Built environment and its management.
- Training, education, experience adoption.

7.3.1 Cooperative Integrated Web-Based Negotiation and Decision Support System for Contractor and Buyer (NDSS)

NDSS can use best practice, explicit and tacit knowledge. For example, a buyer performing a multi-criteria analysis of all real estate alternatives selects the objects for starting the negotiations. For that purpose he/she marks (ticks a box with a mouse) the desirable negotiation objects. A negotiations e-mail are created by the Letter Writing Subsystem and sent to all real estate sellers after the selection of the desired objects is made and then Send is clicked. During negotiations the buyer and the seller with the help of NDSS may perform real calculations (the utility degree, market value and purchase priorities) of the real estate. These calculations are performed on the basis of characteristics describing the real estate's alternatives obtained during negotiations (explicit and tacit criteria system, criteria values and weights). According to the results received, the final comparative table is then developed. Following on from the developed final comparative table the multiple criteria analysis and selection of the best real estate buying version is carried out by using NDSS.
There are two main categories of rules and procedures in the Expert Subsystem:

- Development of suggestions as to what brokers to use and for what reasons further negotiation should be carried out. With the help of the DSS-RE having determined the sequence of priority, the degree of utility and the market value of the real estate, the rules of the expert’s subsystem suggests what brokers to use and for what reasons further negotiation should be carried out.

- Composition of comprehensively reasoned negotiation e-mail for each of the selected brokers. By using information inherited from the previous DSS-RE calculations and predefined rules and procedures, the expert’s subsystem composes of negotiation e-mail for each of the selected brokers, where it reasonably suggests that the price of the real estate should be decreased. The e-mail includes references to the calculations performed by DSS-RE.

7.3.2 Experiences from Lithuanian pilot studies: Building refurbishment multiple criteria decision support system

Building refurbishment involves a number of stakeholders pursuing various goals. This leads to various approaches of the above parties to decision making in this field. In order to thoroughly analyze the alternatives available and obtain an efficient compromise solution it is often necessary to define them on the basis of economic, qualitative, legal, social, technical, technological and other type of information. Basing oneself on possessed above information and the Building refurbishment multiple criteria decision support system it is possible to perform multiple criteria analysis of refurbishment projects components (walls, windows, roof, floors, volumetric planning, engineering services, etc.) and select the most efficient versions. After this, the received compatible and rational components of a refurbishment are joined up into projects. Having performed multiple criteria analysis of projects made up in such a way, one can select the most efficient ones. Strong and weak sides of investigated projects are also given an analysis. Facts of why and by what degree one version is better than the other are also established. All this is done basing oneself on conceptual and quantitative information (Zvadskas, Kaklauskas et al., 2006).

7.3.3 Real Estate’s Market Value and a Pollution and Health Effect Analysis

Certain groups of patients included in this study are those such as asthmatics, a topic patients, patients with emphysema and bronchitis, heart and stroke patients, people with diabetes, pregnant women, and the elderly and children who are especially sensitive to the health effects of outdoor air toxicants. It is estimated that about 20% of the USA’s population suffers from asthma, emphysema, bronchitis, diabetes or cardiovascular diseases and are thus especially susceptible to outdoor air pollution (American Lung Association, 2005). Much research, digital maps and standards on the health effects (respiratory effects, cardiovascular effects, cancer, reproductive and developmental effects, neurological effects, mortality, infection and other health effects) of outdoor air pollution, a premise’s microclimate, and real estate valuation, has been published in the last decade. The above-mentioned and other problems are related to a built environment’s air pollution, the premise’s microclimate, health effects, and real estate market value, etc. However, a Real Estate’s Market Value, Pollution and Health Effects Analysis Decision Support System (RE-MVPHE-DSS) can analyse the above factors in an integrated way. RE-MVPHE-DSS consists of the following subsystems: market value analysis, air and noise pollution, premise’s microclimate,
health effects, voice stress analysis, complex determination of the weights of
the criteria, cooperative decision making and multiple user (Zavadskas, Kak-
lauskas et al., 2007).

7.4 Benchmarking in VGTU, Lithuania

Benchmarking: a structured approach for identifying the best practices from
industry and government, and comparing and adapting them to the organiza-
tion's operations. Such an approach is aimed at identifying more efficient
and effective processes for achieving intended results, and suggesting ambig-
uous goals for program output, product/service quality, and process im-
provement [4].

Examples of benchmarking include Web-Based Decision Support System for
Real Estate Transaction. The real estate transaction process can be divided
into five stages: listing, searching, evaluation, negotiation, and execution. At
present moment the developed System allows performance of functions as
follows: listing, search of real estate, finding out of alternatives and making
of comparative tables, alternatives multiple criteria analysis stage, e-
negotiation, the after-purchase evaluation stage. A customer may perform a
search of alternatives from databases of different brokers. It is possible
since the forms of data submission are standardized in a specific level.
Such standardization creates the conditions to use the special intelligent
agents performing search of the required real estate in various databases,
and gathering information about them. Customers specify requirements and
constraints and the system queries the information of a specific real estate
from a number of online brokers. The system performs the tedious, time-
consuming, and repetitive tasks of searching databases, retrieving and filter-
ing information, and delivering it back to the user. Results of search of a
specific real estate are submitted in tables, which may include direct links to
a Web page of brokers. By submission such a display, the multiple criteria
comparisons can become more effectively supported. While going through
the purchasing decision process a customer must examine a large number
of alternatives, each of which is surrounded by considerable amount of in-
formation (economic, quality (architectural, aesthetic, comfort), infrastruc-
tural, legal, technological, and other factors). Following on the gathered
information the multiple criteria analysis are being carried out. Capabilities
to use the System in alternatives multiple criteria analysis stage are:
– Real estate valuation from various aspects (i.e. determination of market
value, value in use, and investment value).
– Multiple criteria analysis of alternatives and selection of most efficient
ones.
– Valuation of factors affecting the value of real estate (for example, valua-
tion of real estate location, real estate and depreciation).
– The after-purchase evaluation stage. A customer evaluates the usefulness
of the real estate in the after-purchase evaluation stage.

By using System the buyer (broker) determines the initial priority, utility de-
gree and market value of the analyzed real estate’s alternatives. A buyer
performing a multi-criteria analysis of all real estate alternatives selects the
objects for starting the e-negotiations. During e-negotiations the buyer and
the seller with the help of System may perform real calculations (the utility
degree, market value and purchase priorities) of the real estate and select
the best real estate buying version. Also the System can provide recom-
mendations to a real estate broker. The System accumulates information
about the popularity of real estate alternatives that are placed into the data-
bases. The popularity is determined on the basis of the number of customers
analyzing a certain object and on the basis of the time-spent watching. A seller is offering to reduce or increase the value of the real estate being sold on the basis of such information; other pieces of advice also are provided (Kaklauskas et al., 2005). Such an approach is aimed at identifying more efficient and effective real estate transaction process and suggesting ambitious goals for the transaction process improvement.

To develop and analyze thousands of building’s life cycle alternative variants based on dozens of criteria, each having specific values and weight would hardly be possible without the use of intelligent systems. To achieve the above aims, a Multiple Criteria Decision Support System for Building’s Life Cycle was created. Complex databases of a building life cycle and its stages were developed providing a comprehensive assessment of alternative versions from economic, technical, infrastructural, qualitative, technological, legislative and other perspectives. Based on the above complex databases, the developed System can make until 100,000 building’s life cycle alternative versions, performing their multiple criteria analysis, determining utility degree and selecting most beneficial variant without human interference (Kaklauskas, 1999; Zavadskas et al., 2005).

Multiple criteria decision support on-line system for construction developed by VGTU allows the performance of the following functions:

1. Search of construction products. A consumer may perform a search of alternatives from catalogues of different suppliers and producers. This is possible since the forms of data submitted are standardized into specific levels. Such standardization creates conditions to use special intelligent agents who perform a search of the required construction products from various catalogues, and gather information about the products. One or several regions may limit such search.

2. Finding out alternatives and making comparative tables. Consumers specify requirements and constraints and the System queries the information of specific construction products from a number of online vendors and returns a price-list and other characteristics that best meets the consumer’s desire. The System performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information, and delivering the information back to the user. Results of a search of specific construction products are submitted in tables, which may include direct links to a Web page of a supplier or producer. By submission such a display, of the multiple criteria comparisons can become more effectively supported. The results of the search of a concrete construction product are often provided in one table where one can sometimes find direct links to the Web page of the supplier or manufacturer.

3. Evaluation stages of alternatives (i.e. multiple criteria analysis of alternatives and selection of most efficient ones). While going through the purchasing decision process a customer must examine a large number of alternatives, each of which is surrounded by a considerable amount of information (price, discounts given, thermal insulation, sound insulation, rate of harm to human health of the products, aesthetic, weight, technical specifications, physical and moral longevity). Following on from the gathered information the priority and utility degree of alternatives is then calculated. The utility degree is directly proportional to the relative effect of the values and weights of the criteria considered on the efficiency of the alternative. It helps consumers to decide what product best fits their requirements.

4. The after-purchase evaluation stage. A consumer evaluates the usefulness of the product in the after-purchase evaluation stage, etc.
7.4.1 Validity
Validity is a term that describes how well a test, or a test item, measures what it claims to measure, accurately predicts a behavior, or accurately contributes to decision making about the presence or absence of a characteristic. Validity is the degree to which information being used is appropriate, meaningful, and useful. Reliability is the degree to which the information being used is accurate, stable, and consistent.

Reliability and validity of different built environment qualitative indicators (end user needs, qualitative building performance indicators, qualitative value creation, etc.) can be increased by using biometrics technologies. For example, in order to increase the efficiency and quality of e-learning studies, a Voice Stress Analyser Decision Support System for e-Examination (VSA-DSS-E) was developed at Vilnius Gediminas Technical University (VGTU). VGTU have developed a voice stress database, which contains students’ answers that are given during an examination, and a specific algorithm, which is the core of the VSA-DSS-E and which can evaluate a student's knowledge by giving a precise mark after a psychological test, which is performed prior to the examination (Kaklauskas et al., 2008).

7.5 References

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8 www.gt-cybersource.org/Record.aspx
9 www.montgomerycollege.edu/outcomes/glossary.htm
10 www.montgomerycollege.edu/outcomes/glossary.htm

8 State of the art in Estonia

Roode Liias, Tallinn University of Technology

8.1 Dwelling stock in Estonia: set of criteria for assessment

8.1.1 State of the Art Paper

Data used in this report is based on publicly available statistical data and common knowledge collected from different official sources.

The national housing stock of Estonia consists of dwellings inherited from different eras; the largest of which as for influence has been the Soviet period (basically since 1945 until 1991). Though the publicly built stock of this period was developed according to strict rules and standards, it was performed and maintained on low level of quality. At the same time the housing stock developed during the booming times of the property market at the very beginning of the 21st century where developed not following any norms rather than only the requirements set by speculative clients. Accordingly, performance of the works does not meet the general understanding about fair construction.

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1919</td>
<td>60 030</td>
<td>9.41</td>
</tr>
<tr>
<td>1919-1945</td>
<td>90 850</td>
<td>14.24</td>
</tr>
<tr>
<td>1946-1960</td>
<td>65 700</td>
<td>10.29</td>
</tr>
<tr>
<td>1961-1970</td>
<td>125 880</td>
<td>19.72</td>
</tr>
<tr>
<td>1981-1990</td>
<td>125 110</td>
<td>19.60</td>
</tr>
<tr>
<td>1991-1995</td>
<td>17 960</td>
<td>2.81</td>
</tr>
<tr>
<td>From 1996</td>
<td>7 400</td>
<td>1.16</td>
</tr>
<tr>
<td>Unfinished</td>
<td>8 370</td>
<td>1.31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>638 180</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5 Distribution of dwellings by year of construction. Source: Statistics Estonia 2007

During the last decade of years – the construction and property markets have been undergoing several changes. These changes still do not have major influence on the general statistical data about the stock. The fully stagnated construction market of the beginning of the 90ies started to develop due to massive privatisations in the sector. The construction and property market made dramatically rapid increase during the first 5 years of the 21st century, but has fully slowed down by today (year 2008) due to general and international financial crises.

On these rather different stages the changes have been very clearly towards market-driven ones when in parallel dwellings with luxurious and rubbish quality for quite high costs was provided. Changes of the legislation and ownership structure, joining the EU and the financial market have very rapidly changed the environment for the actors of the housing sector. Currently, there is no, and there has been no any nationally coordinated benchmarking models to be used for the built environment, incl. housing. There is the legis-
lation available stating the minimal requirements to be followed when designing dwellings and a reasonable number of national standards (EVS) to be followed, but still they are not used as an effective instrument for managing the sector. Only introducing the EU energy-saving directive and the consequent national guideline documents may hopefully create the preconditions still for one-factor (energy-efficiency) benchmarking.

In 2007, 96 per cent of the housing stock was in private hands and 4 per cent was owned by the public sector (25 per cent of the public sector housing stock was owned by the state and 75 per cent by local governments). Ca 85 per cent of households has their own residential space and about 15 per cent are the tenants. Most of the privately rented dwellings are held by small owners, which renders the sector difficult to control for tax purposes and the state lacks an adequate overview of the sector.

Generally saying – liberal market and private sector initiatives are governing the sector, though the national housing strategy sets its national system for politically fair benchmarking.

8.1.2 Background data

According to the 2000 Population and Housing Census there were 617 400 dwellings in Estonia, the current statistics estimated that on 1 January 2007 there were 638 200 dwelling units in Estonia, with most of them (96 per cent) in private ownership. There are more dwellings than households in Estonia – in 2006 the estimated number of households was 573 400, the average household had 2.3 members. In 2000 the respective figure was 575 300, thus the number of households has decreased by two thousand over six years. Every third household was located in Tallinn or in the surrounding of it, in Harju County. 65.7 per cent of dwellings are located in the cities and towns and 34.3 per cent in the countryside. 10 per cent of all households live in farmhouses, 19.5 per cent in single-family dwellings and terraced houses and 70.5 per cent in apartment buildings.

As at the first half of 2007, 91.8 per cent of the dwellings were permanently inhabited. The total floor area of inhabited dwellings was 38 760 000 m² and the average floor area per capita was 28.9 m². Two-room apartments make up the biggest number of dwellings, i.e. 229 860 apartments or 36 per cent of the total. As regards the supply of housing space Estonia ranks among the relatively well stocked European countries.

The Estonian National Housing Development Plan for 2008-2013 constitutes a strategic basis for developing the housing sector. The principal aims in the field of housing are ensuring access to suitable and affordable housing for the population of Estonia, achieving high quality and sustainable housing stock and building diversified residential areas which are developing in a balanced and sustainable manner.

When following the liberal market principles introducing them to housing, the duty of the state is to create the general framework/conditions for the housing market (i.e. through legislation, institutional arrangements and support measures) to be followed by the residents. Based on these requirements the owners of the units have to make their decisions as to resolving their individual housing problems and for the associations involved in the housing sector to further develop the field. The role of the national Government is also stated as continuing the activities when improving the legislation concerning access to housing services, the conditions ensuring the quality of housing, the milieu value, energy conservation possibilities and security of housing.
Pursuant to the Constitution and Local Government Organisation Act the task of organising housing and utility services on its administrative territory rests with the local government. The tasks of individuals in the field of housing include performance of the obligations placed on them and management, maintenance and improvement of dwellings in their ownership or use, as well as in the surrounding living environment in conformity with legislation and good practice in the community.

The objectives in the housing sector for the years 2008-2013 are:
- to create access to housing for all inhabitants of Estonia
- to improve high quality, energy efficient and sustainable housing stock
- to ensure diversified residential areas developing in a balanced and sustainable manner

Clearly, when introducing any schemes for benchmarking in the sector the KPI should depict listed above aim and sub-aims.

The main objectives as for the dwelling stock arise from the need to extend the life-time of the existing dwellings. For this primarily, by not allowing the apartment buildings to fall into disrepair because of poor maintenance and repairs, to increase the energy efficiency of dwellings, to improve the quality of the living environment, to raise residents' awareness about housing maintenance and to broaden the financing possibilities of social target groups for housing.

Following the above presented statement one will see the necessity of compiling a list of criteria that will depict the current status and the changes that will take place during the agreed time-lag.

*Sustainable development* (as defined in the national housing sector related documents) is a concept for development that meets the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs. In Estonia the following elements comprise sustainable development:
- enhanced quality of life, to be achieved through preserving the Estonian cultural space
- significantly increasing coherence of the society
- maintaining ecological balance

8.1.3 Problems / problem areas for the housing sector

*Housing is not accessible to every resident in Estonia*

Problems related to accessibility of housing have become more topical year-by-year. They concern mostly new households with lower incomes about to enter the housing market. Less competitive groups also face difficulties in accessing housing in the market due to lower income. Purchase prices and rents on the private housing market are not affordable for the majority of such persons and the public sector offers only a very limited number of dwellings.

*Limited number of apartments adapted for person with special needs*

Almost one-third of the disabled require adapted accommodation units for independent coping. Given that disabled persons often belong to lower income groups they need public sector support for the modification of their dwellings.
Deterioration and decreasing quality of the housing stock.
Residential construction volumes of the past decade are considerably lower than the average in 1950-1989 and the houses built half a century ago are gradually reaching the end of their life-time, as prescribed by the applicable standards. Although, there is no direct danger of falling into disrepair the apartment buildings still are in need of reconstruction. Any delay in commencing reconstruction will allow the situation to deteriorate further and result in higher costs in the future.

High energy costs of housing stock.
The issue of energy conservation of the housing stock has come to the limelight with the transposition of the EU directive on the energy performance of buildings. The average energy consumption per square meter is higher in Estonian residential buildings in comparison with the other EU member states (in Estonia ca 250 kWh/m²; in Finland and Sweden this number is below 150 kWh/m²).

Inefficient planning of built environment.
Estonia is currently lacking a comprehensive and established plan on how to combine the technical, social, environmental and economic aspects when designing the living environment and urban space. This has led to chaotic development and has not always been the most efficient.

Problems with awareness among the residents.
The majority of management and maintenance tasks have been placed on the owners of the buildings but they are lacking the required knowledge and professional skills to carry out such tasks. As a result decisions are taken that may not be the best ones for improving the residential buildings and ensuring its sustainability; often materials of poor quality and workers with no professional skills are used.

Given the problems of the Estonian housing sector and in line with the mission and vision of the housing policy the objectives and measures are the following ones.

Accessibility of housing
Objective: To make housing accessible to every resident in Estonia
Measures:
1. Improving access to dwellings
2. Improving possibilities for acquisition of housing
3. Improving housing conditions
4. Ensuring compensation of housing costs to persons with coping difficulties
5. Improving the legal environment and increasing administrative capacity

Housing Stock
Description of the current situation
Objective: To achieve high quality and sustainable housing stock
Measures:
1. Increasing the quality and energy efficiency of the housing stock
2. Increasing awareness to improve the housing stock
3. Mapping the condition of the housing stock
4. Improving the legal environment and increasing administrative capacity

Living Environment
Description of the current situation
Objective: to ensure diversity, and balanced and sustainable development of residential areas
Measures:
1. Improving the quality of the living environment
2. Tidying up apartment building areas
3. Developing urban areas
4. Valuing milieu valuable residential areas
5. Shaping a secure living environment
6. Improving the legal environment and increasing administrative capacity

8.1.4 Condition of the housing stock
Though, Estonia is relatively well stocked with housing as regards the number, but its quality and energy consumption leaves to be desired in comparison with the more developed EU member states. Dwellings in Estonia are smaller, older and in some cases have poorer standard amenities and the share of apartments is dominating, compared to the share of detached (single family) houses. In addition to depreciation of the structures and technical systems of the buildings the supporting infrastructure and utility systems are rapidly becoming obsolete.

8.1.5 National objective
To achieve high quality and sustainable housing stock
Housing stock in Estonia is generally obsolete, depreciated and consumes high amounts of energy. Therefore it is firstly necessary to map the condition of the housing stock and carry out reconstruction of the residential buildings on the basis of the results of the mapping, in order to improve the technical quality of the dwellings.

Satisfaction of the residents with the technical condition and increased energy efficiency of the dwelling in their use should grow for about 20 %. Therefore increasing the quality and energy efficiency of the housing stock is of crucial importance on the national level.

In order to improve the technical condition and increase the energy efficiency of residential buildings the basic structures of many apartment buildings require reasonable reconstruction. It is also important to encourage full renovation solutions for residential buildings and large-scale construction works.

The following benchmarks have been set up on the national level.

<table>
<thead>
<tr>
<th>Criteria/measure</th>
<th>result</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average expected life-time of the housing stock (especially as to the apartment buildings) has increased by</td>
<td>30%</td>
</tr>
<tr>
<td>The share of apartment buildings falling into the highest energy efficiency category will be</td>
<td>10%</td>
</tr>
<tr>
<td>The number of apartment buildings renovated with the help of renovation support</td>
<td>8 000 (increase)</td>
</tr>
<tr>
<td>The share of residential buildings that have undergone energy audits, implemented the recommended measures and reduced their energy consumption</td>
<td>20%</td>
</tr>
<tr>
<td>Technical condition of the different types of apartment buildings has been mapped nationally</td>
<td>95%</td>
</tr>
<tr>
<td>The percentage of expert analyses conducted in the apartment buildings of the target group</td>
<td>50%</td>
</tr>
<tr>
<td>The percentage of energy audits conducted in apartment buildings</td>
<td>30%</td>
</tr>
</tbody>
</table>

Table 6. Goals to be achieved by 2013
8.1.6 Cornerstones for introducing national benchmarking

Since 2003 the construction (or building) act has been introduced where the EU construction product directive based requirements as for different aspects of safety and energy efficiency lay as the cornerstones for all the other acts and decrees to be issued.

Already since 1999 there is the decree issued by the responsible ministry (Ministry of Economic Affairs and Communication) as to the requirements to be followed when designing, developing and building dwelling units. The basic criteria listed in this decree are related to the following aspects:

- this has to be suitable for permanent living
- the space/unit has to be safe for the residents

Both of these criteria cannot be clearly described in numbers and units. They are more like political KPIs one has to follow when developing and managing the housing stock.

To talk about a dwelling unit one has to identify it – there should be a clearly identified and separate entrance. Entrance is not only a door, but also all the equipments one will require when entering the unit – slopes, stairs and the principles for key-cutting.

As for the rooms a living room should be at least 8 m² and the distance between the walls should be not less than 2.4 meters. These requirements may be in place, but in fact nobody can restrict ones development aims when building either smaller premises or these of different size. The following requirement is related to a window – a living room should have at least one window that can be opened for normal ventilation. Also the temperature limit is given – in a living room at least 18 C° should be guaranteed.

In the legislation there is the list of technical requirements as for noise and moisture level; there are the strict requirements as for the fire safety and availability of WC and the provision of cold water. In the electricity safety act there is the set of requirements and obligations the owner is responsible for to be assured; otherwise the premises cannot be used as a dwelling.

Since 2009, January 1st for property transaction the object of transaction should have the energy efficiency sign available. The idea of the requirement is that especially as for the existing housing stock the energy efficiency audit has to be carried out and the results of the audit will be published amongst the basic data about the building.

According to the new legislative act to be issued during the forthcoming month (in December 2008) introducing the energy efficiency sign will start regulating the construction and property market activities. Though the authorities will not start up massive control as to the availability of the signs, the buyer of the property has the right to demand the sign related data to be available and accordingly this will influence the price of the transaction and the choice. Therefore, introducing the principle described above it will start regulating the prices in the market-place, but as the feedback it will start to influence also the property development, especially designing the new-building and reconstruction solutions.

The listed above legislative principles do not stop and constraint the freedom of the property owners when developing especially for their own use – primarily planning requirements are to be followed, but as to the technical solutions there are no criteria that will badly influence private developer’s strategies as for developing new housing stock. In any case, municipal authorities when developing their housing stock have to follow all the requirements ad-
dressed above and to ‘optimise’ the solutions following the budget based cost criteria.

Generally saying, there are the technical requirements listed as for the rooms used as the dwelling units. At the same time there is no social framework related data available as for the residential spaces.

Therefore, when running a fully liberal economic framework on the national level there will be the clear contradiction between the technical and social KPIs for the property sector. Any estate designed for dwellings will require infrastructure to be available – either the possibilities for reliable access or to everyday services. Though these aspects as for influencing the value of the property are well known, the market has been more providers’ (developers’) biased and during the market-boom period (2001-2005) the market-place has been over-produced with properties will relatively low value and quality.

To finalise; Estonia is unique society where the total majority of the housing stock is in private hands. On the national level there are programmes and guidelines and there certain number of instruments that can be enacted to assure sustainability of the housing stock. The goals and sub-goals listed in the programmes are clearly targeted, but implementation of these will require reasonable investments from the individuals – each individual household has to be motivated to follow these goals. For sure, reasonable and adequate investments will increase the value of the property, but too often the value of the property (dwellings!) is speculative and market driven. This is the case of a small and quite polarised market (as Estonia).

Currently there are no public instruments available to assess and manage the quality and value of the dwellings on the national housing market. Therefore, the goals stated nationally will be fulfilled only when the owners of the properties will have the same or similar incentives, but also the availability of resources to cover their own share of the investments required.
9 Discussion and Conclusion

9.1 Scope and Contributions

The purpose of the WP3 State-of-the-art has been:

- Identify and examine a number of existing sets of performance indicators, methods and tools for understanding user needs, requirement management, databases and mandatory reporting.
- Approaches to better benchmarking schemes in the Nordic and Baltic countries, which can compare end-user and client needs, and performance requirement in construction and real estate.

In this work package for the state-of-the-art report, national and international experiences are studied as background for the issues to be dealt with in WP2, WP4, WP5 and WP6.

The report contains a number of models each suited for analyzing different aspects of construction and real estate.

A number of existing sets of performance indicators are identified and examined together with methods and tools for understanding user needs, requirement management, databases, mandatory reporting and approaches to better benchmarking schemes in the Nordic and Baltic countries. Benchmarking that can compare end-user and client needs, and performance requirement on building parts as well as performance measures on real estate in use.

The different participating countries have chosen themes that are of special local interest related to performance indicators and benchmarking, but also subjects and cases that complement each other. The report therefore covers a range of different subjects as well as practices.

9.2 Conclusions and Recommendations

The WP3 State-of-the-art report has raised issues that are basis for recommendations addressing further work in WP2, WP4, WP5 and WP6.

9.2.1 WP2 – Performance Models

The WP3 report points to the need for defining who the end-users are and which of these groups the project needs to focus on in the remaining part of the project. The specific areas of importance to different groups of end-users such as occupants, workers, facilities management personnel, lessors and owners of buildings are not easy from the existing contributions. Identifying and explicitly stating the areas of importance to the end-user groups would also help the project establish a common focus for the next stages and WPs.
The CREDIT project will cover the whole building process (from pre construction / early planning to use or even end-of-life). However, most of the material identified in the State-of-the-art report is on product (the building) rather than on processes. Processes can in this case be the construction process as well as different processes of facilities management / operating the building.

One of the CREDIT project objectives is to select, together with participating companies, a short list of core indicators from the system for pilots. Preferably the core indicators would represent all main categories of the system.

If one of the available models is not suitable, the project should consider creating one model that serves the project’s needs. This CREDIT Indicator Classification System could contribute standardising the use and would also ease communication internally and externally.

In the CREDIT project context, indicators can be used setting objectives for and measuring the performance of a product (or service). They can also be used for monitoring the progress (towards the strategic vision, or performance objectives). Thus, indicators serve both to show the state, and for pointing the trend.

Referred literature in CREDIT report 1 (State of the art) (s. 34, CIB W060 + Prior and Szegeti) points at the reasonable in a performance approach rather than a prescriptive approach when defining the requirements of new building or the quality of services. The prescriptive approach describes the acceptable solution whereas the performance approach describes the performance required of the building in order to serve the use and functions it is meant for.

When applying the performance approach to indicators it is important to distinguish between in the demand perspective and the supply perspective. The demand is the performance required from an owner or end user perspective, and includes a description of the needs of the users. Whereas the supply perspective includes the performance of products and processes in order to deliver the required performance.

This means that an indicator classification must encompass both perspectives to secure that the needed information is available throughout the delivery.

9.2.2 WP4 – Project Assessments and Tools

The aim of WP4 is to develop a project-related performance management and assessment tool that:
- Identify and capture end-user requirements
- Measure and verify the compliance to performance criteria throughout the lifecycle of a building.

Furthermore, WP4 intends to define the concept of value and the related performance indicators for quality of life, productivity, cost, time, amounts and quality.

Project assessment act as the first step in the supply chain for international benchmarking and how performance indicators are collected as part of a building information system.

A comprehensive review of methods and tools for capturing end-users’ requirements or bring value for them is being carried out. Tentative findings
show that a number of methods and tools exist for parts of the process, but only few attempts were found that tried to cover the whole process from needs analysis to evaluation of the building in use.

The literature review showed that there are a number of different methods for managing end users that could be used for parts, but that there are very few that attempts to cover the whole process. Most methods exist in the early and in the late phases. The methods that attempt to cover the whole process are not very well tested in reality.

Commonalities of the methods and tools:
- Seeks to increase the communication between the stakeholders
- Built on quite complex systems of data gathering and analysis systems
- Improve the understanding of the end users real needs and requirements

Differences of the methods and tools:
- If the process is regarded dynamic or static
- If the focus should be on the individuals experience and need of the building or if the focus should be on an organisational level.

Many of the methods are criticised for not bring any guidance for how to act upon the result/outcome from the method. There is, thereby, a need for improving the usability of the methods and tools from both a micro and a macro point of view to improve the whole building process, before the quality of the built environment can be optimised.

In the state of review of Swedish Real Estate Firms appeared that almost none of the methods and tools discovered in the literature review were in use or the awareness of their existents was very low. The firms in generally measures SCI but some of the firms had difficulties in creating value of the outcome. During workshops it became clear that it was considered difficult to communicate with the end users, to adapt to a constant changing market and to make decisions in an environment with contradictory needs and requirements. In Sweden there are no nationally coordinated benchmarking models on the fulfilment of end-user requirement and value creation today. But there are some national evaluation schemes in use measuring sector change, project effectiveness etc. and some real estate and facilities management companies use post occupancy evaluations and satisfied customer index to measure end-user satisfaction in general and to some extent in relation to how new or refurbishment project fulfil their requirements. Examples of these schemes are Excellent Construction, FIA and BQR.

In the Finish state-of-the-art is stated that the interest of the performance based building has increased internationally. It is essential to create buildings that perform both functional and social well which require that the end-users needs requirements are captured. To improve the quality of the buildings performance are several international and national benchmarking systems created. These systems tend to focus on energy consumption and indoor climate aspects which are parts of the end-users needs but do not bring an inclusive picture. The Danish state-of-the-art concludes as well that the evaluation of building performance is primarily conducted from a technical perspective; the functional, social and aesthetical aspects are very rare. The lack of systems that takes a holistic view of, all the phases in, the construction process was found, in the Danish state-of-the-art, as well.
9.2.3 WP5 – National case studies

The purpose of WP5 is to test the tools and key performance indicators in a number of case studies in the Nordic countries with special emphasis on building types like offices, shopping malls, administrative buildings, hospitals, schools, social housing, industrialised building processes and relevant benchmarking tools.

Some questions to the WP5:
- Which cases are suitable for testing the tools?
- What are the organisations’ approaches in the different countries?
- How do the industrial partners capture and codify end-user needs and requirements?
- How do they evaluate the finished project comply to what was expected and how do they approach lessons learned?
- What would they like to improve?
- How can information be linked to building information models?
- How can process performance indicators and parameters be measure continuously throughout the lifecycle of the constructed buildings and real estate?

The WP5 should focus on cases that easily could be linked to an indicator framework, found or developed in the CTEDIT project.

9.2.4 WP6 – International benchmarking

In this work package different national and international benchmarking systems will be analysed, and recommendations will be given of how sector and national indices for performance indicators can be designed and exchanged internationally.

Some benchmarking schemes are mentioned in this State-of-the-art report (e.g. e3Portal). Other measurement initiatives identified in the report can be used for benchmarking in the future even if they are not currently being used for that purpose.

A recommendation to the WP4 is to assess the number of projects, programmes and public authorities that hold data and databases relevant for real estate and construction. The project could look into data available (data that is being collected today) within the construction and real estate industry, and evaluate if they easily be used for benchmarking.

There are few examples from other industries in the documents forming the State-of-the-art report. The CREDIT project could consider taking a closer look into indicators and benchmarking systems applied in other industries.
CREDIT reports

CREDIT reports and CREDIT case study reports are published by Danish Building Research Institute (SBi), Aalborg University, Copenhagen, and all reports are available free of charge in http://www.sbi.dk/byggeprocessen/evaluering/credit-construction-and-real-estate-developing-indicators-for-transparency-1/.

Extracts from the reports may be reproduced but only with reference to source as this example: Karud, O. J. et al. (2010). State-of-the-Art of Benchmarking in Construction and Real Estate. CREDIT Report 1 (SBi 2010:14). Hørsholm: Danish Building Research Institute, Aalborg University.

CREDIT reports


CREDIT case study reports


- CREDIT Case LT01 (2010). *VGTU Laboratory Building.* Kaklauskas, A. SBi 2010:47.

This report describes the state of the art of benchmarking in construction and real estate undertaken as the first part of the Nordic and Baltic project CREDIT: Construction and Real Estate – Developing Indicators for Transparency.

This State-of-the-art report has identified and examined a number of existing sets of performance indicators, methods and tools for understanding user needs, requirement management, databases and mandatory reporting.

The report has also focused on approaches to better benchmarking schemes in the Nordic and Baltic countries that can compare end-user and client needs, and performance requirement on building parts as well as performance measures on real estate in use.

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