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CREDIT Performance Indicator Framework - A proposal based on studies of building cases, regulations, standards and research in seven Nordic and Baltic countries. CREDIT Report 3.

Bertelsen, Niels Haldor; Frandsen, Anne Kathrine; Haugbølle, Kim; Huovila, Pekka; Hansson, Bengt; Karud, Ole Jørgen

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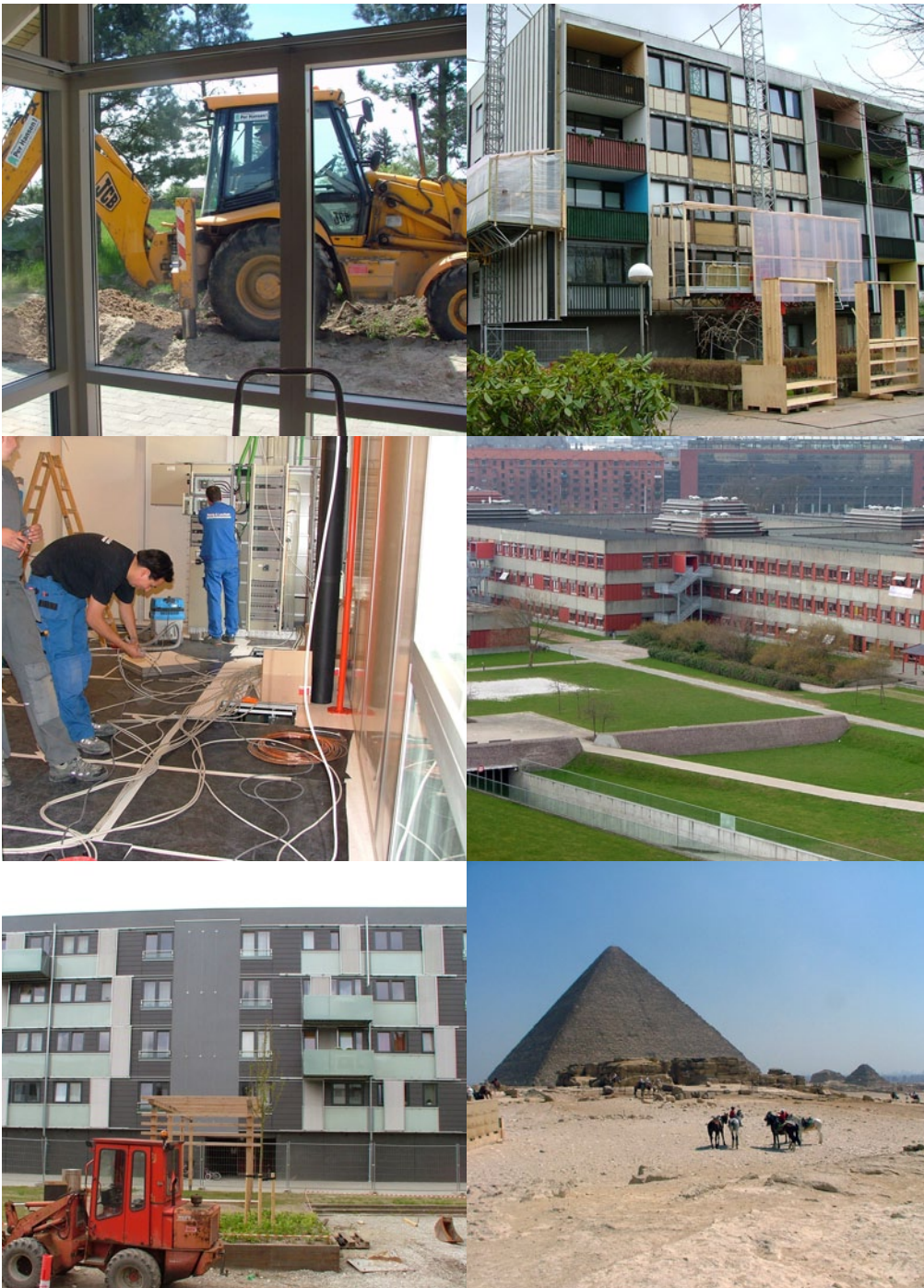
LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

CREDIT Performance Indicator Framework

A proposal based on studies of building cases, regulations, standards and research in seven Nordic and Baltic countries

CREDIT Report 3



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Niels Haldor Bertelsen
Anne Kathrine Frandsen
Kim Haugbølle
Pekka Huovila
Bengt Hansson
Ole Jørgen Karud



Danish Building Research Institute
AALBORG UNIVERSITY

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Dr. Neergaards Vej 15, DK-2970 Hørsholm
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Preface

This report summarises the work undertaken in CREDIT leading to a proposal of CREDIT performance indicator framework, a part of the Nordic/Baltic project *CREDIT: Construction and Real Estate – Developing Indicators for Transparency*. The report presents the objectives and the research model for CREDIT followed by a presentation of the approach and general structure of the framework, a specification of the indicators and the CREDIT indicators in relation to the CREDIT case studies, standards and research and the national building regulations.

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).

Danish Building Research Institute, Aalborg University
Department of Construction and Health
August 2010

Niels-Jørgen Aagaard
Research director

Summary

This CREDIT Report 3 'CREDIT Performance Indicator Framework' presents a framework of building costs, performance and impact indicators. The framework is an endeavor to map and communicate many and differing approaches and perspectives on building and real estate in one model. The general and specific objectives of the research on the performance indicator framework were to:

- Improve transparent value creation in both construction and real estate.
- Develop an international performance classification framework focusing on the first step needed by the Nordic and Baltic countries.
- Provide recommendations for international key indicators for buildings.
- Focus on performance demands and requirements to buildings to satisfy the end-user needs and functions of the building rather than to follow a prescriptive approach.
- Distinguish between the demand and the supply perspective in the construction and facility management process.
- Secure that the needed performance information is available throughout the life cycle of the building.

The performance indicator framework developed in CREDIT is a 'gross' inventory of indicators relevant in relation to building and real estate in the seven Nordic and Baltic countries: Denmark, Finland, Iceland, Norway, Sweden, Estonia and Lithuania. The content of the report is based on CREDIT Report 1, State of the Art, the findings in 28 CREDIT case studies as well as on input from national building regulations and standards on selected research topics. The performance indicator framework was developed concurrently with the case studies and experience with assessment tools, enterprises, buildings and international benchmarking reported in CREDIT Reports 2, 4 and 5.

Performance indicators in seven independent facets

A simple and understandable structure of indicators in seven independent facets was developed in CREDIT. They range from hard-core measurable indicators to soft, qualitative and hardly measurable indicators. The first facet included costs and price through the life cycle of the building. The five next facets addressed performance of location, building, building parts, facility management and process. They all included objective measurable performance indicators and indicators that addressed less measurable properties as well as the users' experience and feelings. The final facet focused on the impact of the building on the external environment, social life and economy.

- 1 Costs, price and life cycle economy (LCE)
- 2 Location, plot, region and country
- 3 Building performance and indoor environment
- 4 Building part and product performance
- 5 Facility performance in operation and use
- 6 Process performance in design and construction
- 7 Impact environmentally, socially and economically

These 7 facets were divided into sub-facets, which in turn were divided into sub-facets covering a total of 187 indicators.

The performance indicator framework encompassed two different ways of looking at the building, depending on which relation you have to it:

- The building viewed from within as the occupier or owner of the building
- The building viewed from without as the surrounding society

Because of its inclusive character, the CREDIT performance indicator framework could work as a tool to improve the performance of buildings as well as the cooperation between the parties in the construction and real estate sectors.

Product and process performance indicators

User's experience and feelings are important and therefore they were included in five of the seven facets: location, building performance, building parts performance, facility management, and process performance. This was done with the intent to focus on values as well as end-user needs rather than prices, costs and standard of execution and equipment.

In the study it was also important to get a better understanding of how the built environment could create value for the users and thereby increase the outcome of activities housed in the building. One focus was therefore the assessing of indicators that were directly linked to the building or the perception of it. It turned out to be the main topic in the performance indicator framework presented in the report. A second focus was the assessing of indicators and how we link the productivity of the enterprises involved and the different processes in construction and real estate. The report presents process indicators to support the primary focus in the building sector today. The third focus of the study was to change the focus from the building as an expense to how it could be a social and economic advantage for the business and the activities in the building in use. It appears in the CREDIT performance indicator framework as a new approach in several facets and levels, and it might be a new positive way to push the development forwards in the future.

Performance indicators and the phases of the buildings life cycle

The CREDIT Indicators have three different purposes depending on where and when in the building process they are addressed. In the initial phases they serve as specifications or requirements in the briefing and programming phases. During design and construction phase they serve as guidelines for the design and how to compare qualities and properties of building and component in order to comply with the requirements. After completion, they serve as tools to assess the performance, quality or economic potential of the finished building as a delivery to facility management and the users of the building. It is important that these three purposes in the practical application of the CREDIT performance indicator framework are carefully interlinked and information is reused to improve the process performance.

Key performance indicators

The CREDIT case studies showed that a few indicators turned up in all cases or in relation to all building types and therefore could be common key performance indicators in CREDIT. These few common key indicators were of a basic character namely: location, building type, size/area and price/-costs. Otherwise the indicators varied primarily depending on the purpose of the assessment and on the user or recipient of the assessment. There did not seem to be a strong linkage between particular indicators and specific building types. Therefore CREDIT recommended that several sets of key performance indicators should be defined, reflecting the needs of specific user/recipients (end-user, client, authorities, contractors, consultants) of the assessments as well as sets that reflect the needs linked to particular phases in the life cycle of the building.

With the interests and needs of the building owner/client in mind, CREDIT proposes a set of 10 key indicators with indicators from all facets of the classification framework and on various levels of facets. Other proposals could be prepared in the future as alternatives.

Readiness of the performance indicators

The various indicators described in the report were at very different stages concerning their readiness for inclusion in national or cross-boarder benchmarking. Some of the indicators were already being applied in national benchmarking, international certification schemes in many or all the countries in CREDIT and they were covered by international standards. This included many but not all the indicators on indoor climate, energy efficiency, environmental impact and facility management. To use these indicators in cross-boarder benchmarking, would require translation and harmonisation.

Other groups of indicator were not quite as readily applicable in benchmarking let alone in cross boarder benchmarking. This included areas like process performance and life cycle costing, both of which were covered by international standards. In these areas the barrier was the differences in the charts of accounts, making up of amounts and sizes both on national as well as international level.

A third group consisted of indicators that were possible to distinguish only in two classes, compliance with building regulations or not. This group included such areas as accessibility, construction safety and fire safety. The reason why they were not applicable right now differs.

A fourth group consisted of indicators of a relative character. This included indicators addressing usability, architectural or aesthetic quality and cultural heritage. Some of these indicators were included in international standards, but were not defined in acknowledgement of the relative character of these issues that either depends on building function or on cultural or national values.

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 is an introduction to the following chapters with a description of the purpose of this CREDIT Report 3 and the research method applied in the study leading to CREDIT performance indicator framework.

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 Byggeforsk, 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.

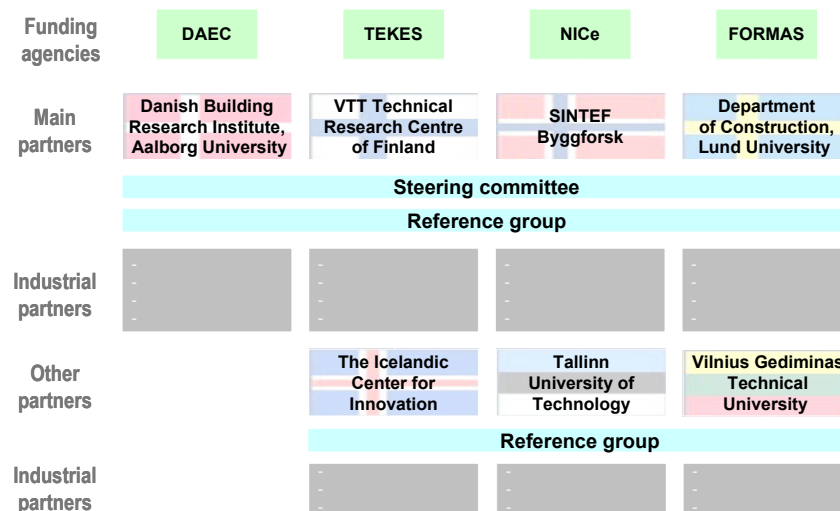
The project was managed by a steering committee chaired by the project owner, the project coordinator was secretary and each of the four main partners had two seats. The steering committee saw to the overall coordination and operation of the project, and was responsible for making the decisions necessary 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 sectors.

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)
Deliverables: Stimulus paper, draft report and final report (D5) on State-of-the-Art. CREDIT Report 1.
- 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 2.
- WP5: National case studies. (Responsible: VTT/FI)
Deliverables: Stimulus paper, draft report and final report (D7) on case studies and buildings. CREDIT Report 3.
- WP6: International benchmarking. (Responsible: VTT/FI)
Deliverables: Stimulus paper, draft report and final report (D8) on sector, national and international benchmarking. CREDIT Report 4.
- 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 respon-

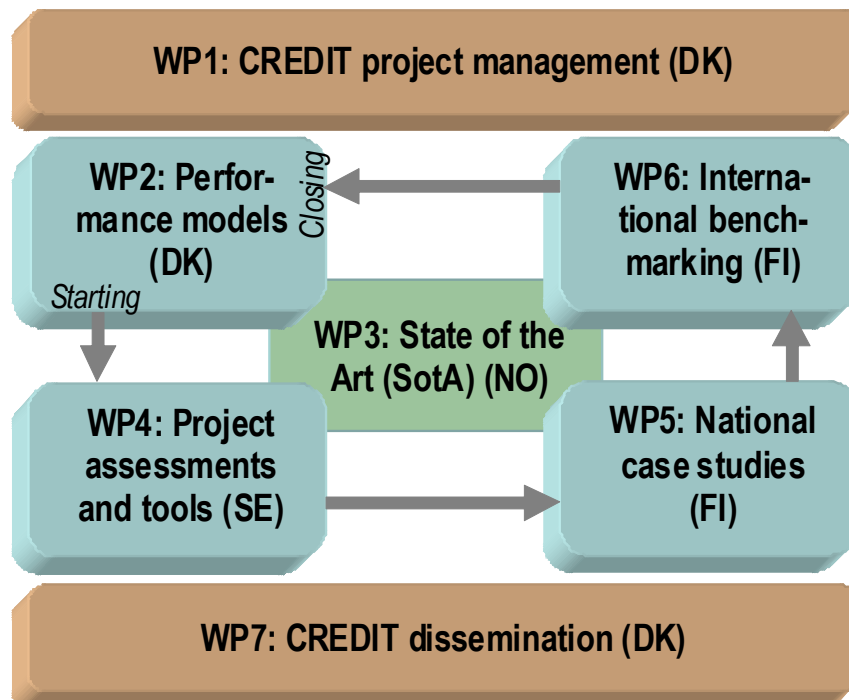
sible authorities. Each meeting package (MP) focused on a specific work package (WP) and consisted of a one-day project meeting, a half-day user workshop, a reference group meeting and a steering committee meeting.

The seven CREDIT meeting packages alternated between the participating countries:

- 1 Helsinki, Finland, 24-25 January 2008: Kick off and end-user values.
- 2 Oslo, Norway, 29-30 May 2008: WP2 Performance models and WP3 State-of-the-Art.
- 3 Lund, Sweden. 8-9 October 2008: WP4 Project assessment methods and tools.
- 4 Vilnius, Lithuania, 19-20 January 2009: WP5 National case studies.
- 5 Reykjavik, Iceland, 8-9 June 2009: WP6 International benchmarking.
- 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.



1.4 CREDIT reports, deliverables and eRoom

The work of each of the main work packages (WP3, WP4, WP5, WP6 and WP2) 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 enterprises; building projects and real estate; and national and international benchmarking. 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 2, 4 and 5.

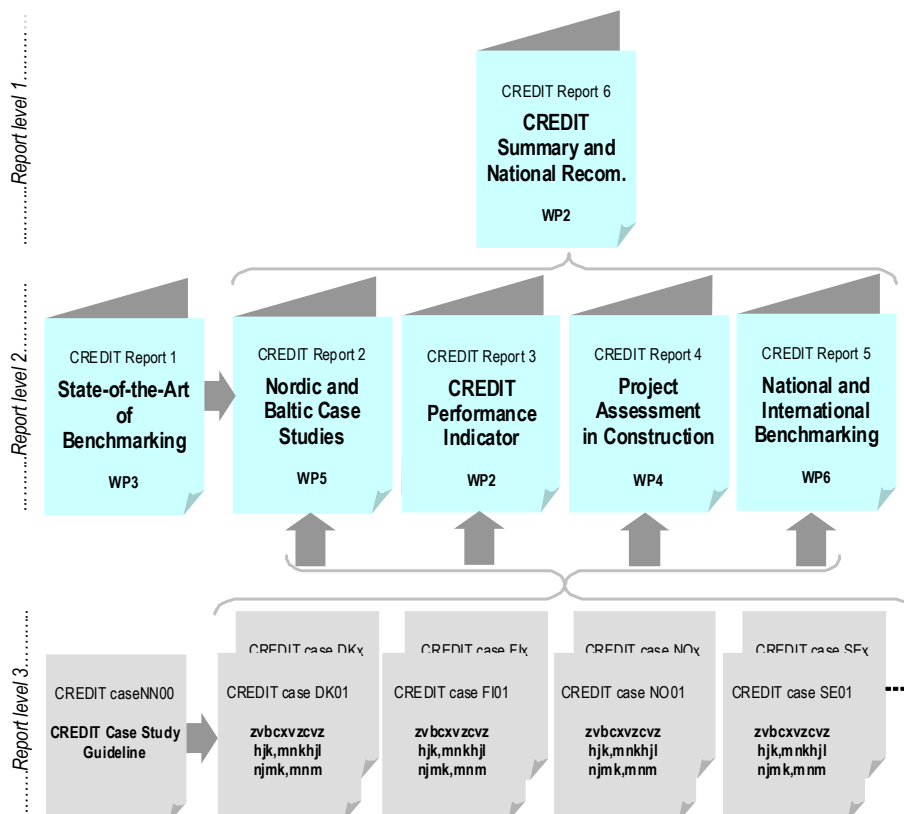
CREDIT Report 3 describes the CREDIT performance indicator framework as a result of 'WP2 Performance models', and the indicators are relation to national regulations; international standards and research; and:

- Report 2 Nordic and Baltic Case Studies
- Report 4. Project Assessment and Enterprises.
- Report 5 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, in CREDIT Report 6 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 CREDIT Report 3 and research methods

In this section is first described the background and recommendations from CREDIT Report 1 State-of-the-Art to the research in performance indicators. Based on that is the objectives and tasks for the CREDIT Report 3 Performance Indicator Framework formulated and described in the second part of this section. This set the scene for how to specify the research method and the design of the work, which is described in the third part of this section. In the last part is given a short introduction to how to read the report.

Recommendations and findings in State-of-the-Art

CREDIT Report 1 State-of-the-Art is a common background for the study in Work Packages 2, 4, 5 and 6, and therefore also an introduction to the research behind CREDIT Report 3 CREDIT performance indicator framework. In the State-of-the-Art report is recommended to divide the research in Work Package 2 Performance models in three:

- First how to organise the research work in the different activities in CREDIT project
- Secondly how to study performance indicators and propose a common CREDIT framework
- Third how to report a common conclusion from all the different activities in one manageable summary report.

This CREDIT Report 3 Performance Indicator Framework is the result of the research on the second item, and in the State-of-the-Art report is stated several specific recommendations on this second item.

The CREDIT Report 1 State-of-the-Art points to the need for defining who the end-users are and which of these groups CREDIT needs to focus on. The specific areas of importance to different groups of end-users such as occupants, workers, facilities management personnel and owners of buildings are not easy to extract from the existing contributions. Identifying and explicitly stating the areas of importance to the end-user groups would help to establish a common focus. This means that a performance indicator framework must reflect a conception the user's specific area of interest.

Most of the material identified in the State-of-the-art report, both evaluation and benchmarking systems and literature, was 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 and operating the building.

CREDIT Report 1 State-of-the-Art points to the reasonable in using a performance approach rather than a prescriptive approach when defining the requirements of new building or the quality of services (Prior and Szigeti, 2003). 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 the demand perspective and the supply perspective. The demand is the performance required of an owner or end-user perspective and includes a description of the needs of the users. The supply perspective on the other hand includes the performance of products and processes in order to deliver the required performance.

This means that a performance indicator framework must encompass both perspectives to ensure that the needed information is available throughout the delivery process.

The objectives and tasks for the research in performance indicators

A primary objective of the work was to present a list of key performance indicators not exceeding a total number of 50-100, applicable in the life cycle of buildings and setting a new international standard widely accepted in the Nordic and Baltic countries. The indicator classification must be developed on the basis of experience gained from the best buildings and enterprises and on the basis of detailed international standard and research knowledge within e.g. economic, facility management, energy, indoor climate and environment.

The first challenge for the work was to create a common performance indicator framework with primary focus on building performance indicators that would encompass the different significant perspectives that various user groups have on buildings and their performance. Preferably the intension was to develop a structure that on one hand contributed to the existing assessment and classification systems already working and on the other hand supported new improvements and how the construction and real estate sectors anticipated to functioning in the future.

The second challenge was to establish and name a set of indicators that covered significant issues relating to the built environment without exceeding 50-100 headings. And furthermore to link these indicators to standards and research knowledge that already existed within these different areas of research. And last to define the classes and values that correspond to specific measures or assessments in relation to the individual indicators.

The third challenge was to select, together with participating companies, a short list of 10 to 20 key performance indicators from the system. Preferably the key performance indicators should present all main categories in the system and be accepted by the majority of the professional players in the construction and real estate sectors.

The purpose of the framework was therefore to form a transparent system to support and encourage improvements and effectiveness in the construction and real estate sectors as well as the quality of buildings in use based on the following questions:

1. How are the indicators applied and expected to be improved in the future in the different parts of the sector in relation to type of building, different locations, phases of the process, different parties and different assessment and management methods?
2. How can indicators be related and combined with the different phases and parties in the process from planning and specification to evaluation of the deliverable of the building and with specific products and building parts to the total building and real estate?
3. How can an international performance indicator framework be consistent now and in the future with the high expectations of researches on one hand and the daily practice in world-class or mainstream enterprises on the other hand?
4. What is the best way to present the indicators for example in a hierarchical system, in a facet system or in a more holistic system like the Internet, or can they eventually be combined in a common international framework, which would at the same time be transparent, robust and dynamic?

Research methods and design

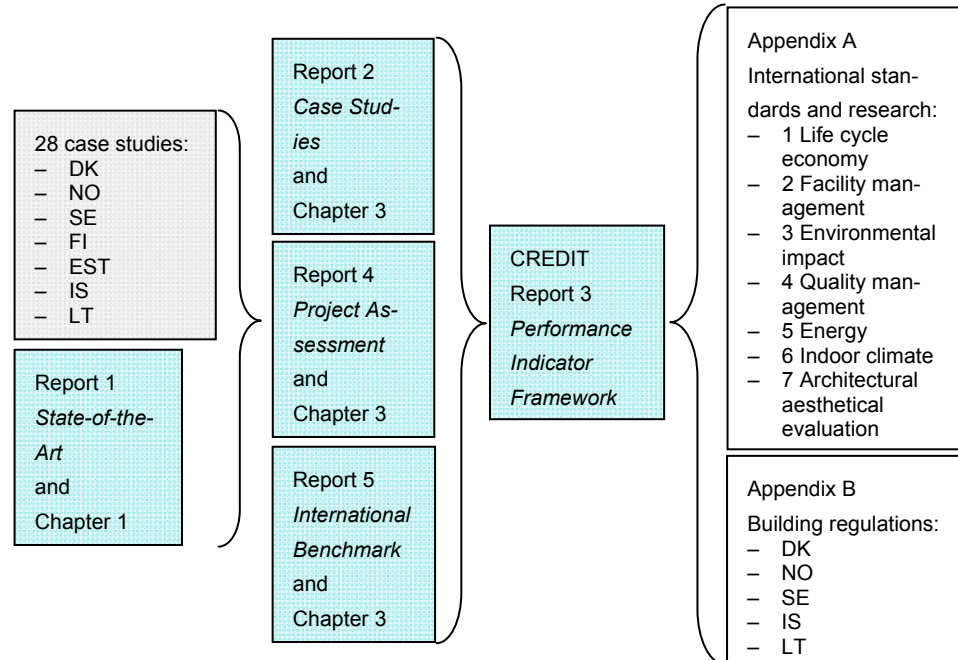
CREDIT performance indicator framework and the CREDIT Report 3 was a result of a process that had been running concurrently with the CREDIT case studies. The first version of a CREDIT performance indicator framework was produced by VTT in relation to the activities in Work Package 5 National case studies, and the following versions of were based on it. In addition the present performance indicator framework and study in the CREDIT Report 3 is based on input from the following six sources:

- Findings from CREDIT Report 1 State-of-the-Art
- Dialogue with researchers and professional organisation
- International research and standardisation work
- Dialogue with the DK CREDIT reference group
- National building regulations in the participating countries in CREDIT
- CREDIT case studies.

Findings from CREDIT Report 1 State-of-the-Art where literature studies of benchmarking and evaluation theory and Nordic and International benchmarking systems were reviewed, formed the basis for the present framework

Researchers and professional organisations with insight in the various themes the framework covered were involved in two ways; they were interviewed two times and asked to give references to relevant international standards or research. On top of that they participated in meetings where the framework categories were discussed and had the opportunity to comment and revise the indicators and the short descriptions of standards and research (Appendix A) related to their field.

Figure 4. Illustration of what input CREDIT Report 3 is based on.



Standardisation work and research on the themes that the performance indicator framework covers were an important basis for the definition and description of the many indicators.

The CREDIT DK reference group discussed the performance indicator framework at two meetings and their comments and proposals resulted in changes and in the definition of it as a common framework.

To make sure that the indicator framework by and large covered the field, the national building regulations in the countries participating in CREDIT were consulted as well as the 28 national CREDIT case studies.

Reading instructions

CREDIT Report 3 consists of 5 main chapters:

- The introduction, Chapter 1, with a brief description of the objectives of the CREDIT project
- Chapter 2 explains the approach and structure of the CREDIT performance indicator framework
- Chapter 3 give an account of the CREDIT case studies, standards and research that relate to building performance and national building regulations in the participating countries in CREDIT that formed the basis of the CREDIT performance indicator framework.
- The indicators in the CREDIT performance indicator framework are specified in Chapter 4
- Finally, in Chapter 7 conclusions are drawn and discussed.

More details on the study of international standards and research and national regulations can be found in Appendix A and B.

2 Indicators and classification principles

In this chapter an account of the approach and general structure of the CREDIT performance indicator framework is given. The view of the building and its performance and the building process that is implicit in the framework is explained in relation to central models developed in CREDIT; CREDIT product model and CREDIT process model and CREDIT carpenter model. In addition it is explained how the indicator framework can be used in different situations and for various purposes according to the objectives described in Chapter 1.

2.1 The approach and general structure

The CREDIT performance indicator framework is an endeavour to map and communicate the many and differing approaches and perspectives on building and real estate in one model or a common framework.

These many perspectives or this gross inventory of indicators relevant in building and real estate is communicated in the CREDIT performance indicator framework as a faceted classification. The classification is made up of seven facets (groups of indicators) that describe independent and mutually exclusive aspects of building. Each facet is sub-divided into four levels.

Five of the main facets in the classification are indicators that reflected different aspects of product and process performance. Additionally two facets are included: A facet reflecting the costs, life cycle costs and price aspects of building, and a facet addressing the impact that the building and facility in use. The first is important for the evaluation of the transparency of construction and real estate, and the second is the impact on the local or global surroundings environmentally, socially or economically.

On the next two levels, indicators gradually reflect more and more detailed facets of the various building indicators. The fourth levels comprise units, classes or values by which the individual indicators are measured.

The main cost, performance and impact indicators in the CREDIT framework consisted of the following seven main facets:

- 1 Costs, price and life cycle economy (LCE)
- 2 Location, plot, region and country (Product performance)
- 3 Building and space performance (Product performance)
- 4 Building part and product performance (Product performance)
- 5 Facility performance in operation and use (Process performance)
- 6 Process performance in design and construction (Process performance)
- 7 Impact environmentally, socially and economically

Each of these seven main facets of indicators is subdivided into three to nine sub-facets of indicators, totalling some 42 indicators. Each of these sub-facets was further subdivided into two to nine sub-facets of indicators ending with 187 indicators included in the classification.

Classification principle

In the first period of the CREDIT project the focus was on how we could develop one common classification system for all Nordic and Baltic countries and performance indicators. Later in the project it got more and more evident, that it was impossible, mainly because the level of experience was so different between the individual subject areas, performance indicators and countries. Therefore, it was decided to aim at a more open and innovative classification system, which could support the improvement of international benchmarking and project assessment in the Nordic and Baltic countries. Classification was therefore changed to a framework, but it still includes a systematisation and organisation of groups or classes of phenomena.

The initial studies indicated the importance of developing a classification or framework fit for the different levels of experience and the digital requirement in new industrialisation and building information models (BIM). It was therefore tested how a faceted classification as opposed to a hierarchical classification could be the foundation in the CREDIT performance indicator framework.

The word classification originates from the Latin word 'classis', which means 'division' or 'part' and the word 'facere' that means 'to do', and basically it means to divide into groups on the basis of certain criteria.

In a faceted classification you distinguish between the various aspects, characteristics or properties of the subject classified. These aspects, characteristics or properties of the subject in question must be clearly defined, mutually exclusive and collectively exhaustive. "Such aspects, characteristics or properties are called facets of a class or a subject" (Taylor, 2006). Whereas, in a hierarchical classification the subject is divided and subdivided into groups where each new group is a sub-species of its parent group; everything that is true of a group is also true of its sub-groups and so on (Kwasnick, 1999). Linné's classification of plants and animals is a classic example of the hierarchical principle.

The application of the faceted classification principle makes it possible to encompass various perspectives of the same subject, which are not internally related but together describe the subject from various angles. In the context of CREDIT, the faceted classification principle facilitated the combination of many user groups and parties with differing views of building and the building process in one classification framework.

The performance indicator classification presented in this report is a conceptual model with the objective of communicating many perspectives on buildings and the building process as well as their internal relation in one common framework. This objective, to present one common framework or model, in some ways collided with the faceted classification principle, e.g. the numbering of the facets and sub-facets.

When applying the performance indicators for international benchmarking and project assessment, CREDIT recommends that a faceted principle is applied. But at the same time that the Nordic and Baltic countries – researchers as well as partners from the construction and real estate industry and the public authorities – are open for changes and new innovative initiatives to improve and expand the CREDIT performance indicator framework.

Conceptual model of building and building performance

A classification of any field of knowledge or group of phenomena reflects a certain understanding of the same field of knowledge or phenomena, and so

does the CREDIT performance indicator framework. The understandings and underlying conceptual models of the classification are explained below.

The conceptual model of product (building) and its performance and the building process inherent in the indicator framework is illustrated in the two sketches in Figures 5 and 6.

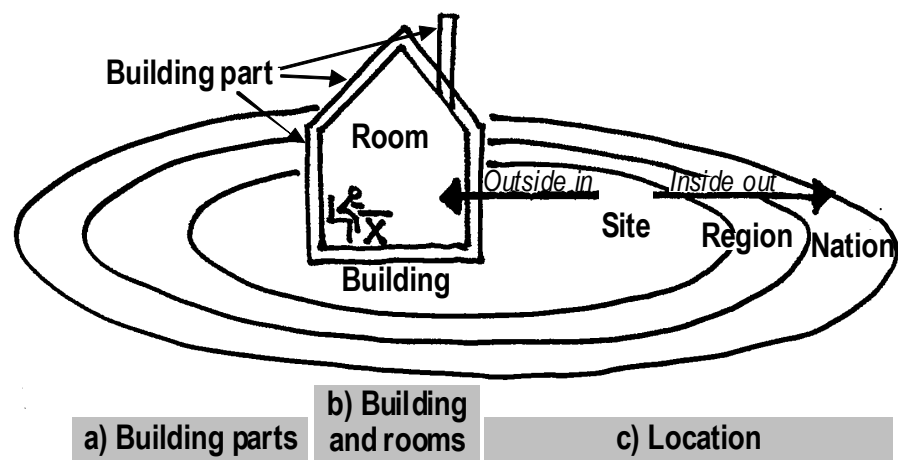
CREDIT product model (figure 5) illustrates two different perspectives on building performance that CREDIT performance indicator framework aimed at encompass: The building seen from the inside and outwards and the building seen from the outside towards the inside.

When seeing the building from the inside, the perspective of the owner or user, the building established a set of conditions for the work, life or business of those who owned or occupied the building; How did the building perform as an architectural space, as an indoor environment, as a construction made of building components or as a facility to operate?

Following that point of view, the building seen from the inside, the surroundings likewise established a set of conditions for the building and for the owner or user of the building; is the building placed in a city or in the countryside and in what country? Is it an area worth preserving or a ghetto? How is this place regarding infrastructure, public transportation and recreational areas etc.?

The performance of the whole building as well as internal spaces and rooms are of special interest for the end-user, the owner and society. In contrast, the construction companies and producers are normally more interested in the construction of building parts (external walls, roofs, heating and ventilation systems) and the manufacturing of components (bricks, concrete, insulation materials, pipes, wires, radiators and fittings).

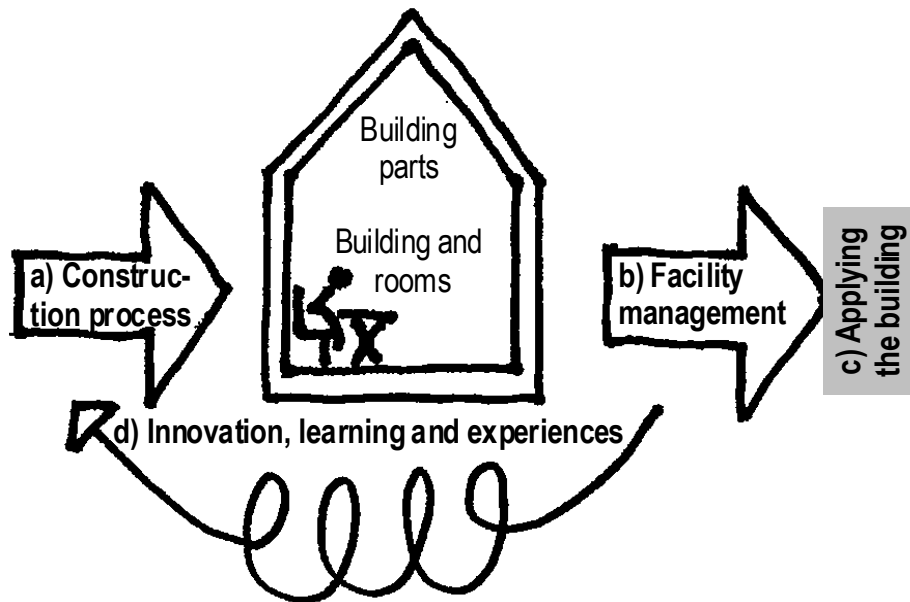
Figure 5. The CREDIT product model illustrates a physical linkage between: Materials, components, systems, building parts, rooms, building and its location in cities, regions and countries. CREDIT looks at the following three selected segments: a) Building parts (Facet 4); b) Building and rooms (Facets 3 and 5); and c) Location (Facets 2 and Facet 7)



The sketch in Figure 5 also illustrates the view of the building seen from the outside and towards the inside, a view that may range from the perspective of the neighbourhood to that of the region or nation. From this perspective it was not only the surroundings that established a set of conditions for the building; the building itself and the use of it had an impact on these condi-

tions. Architecturally and spatially it had an impact on the area closest to it. Socially it could have an impact on the nearby area as well as on a larger scale such as the city. Economically and environmentally it could have an impact on the local area nearby as well as an impact on regional or national level or for that matter on a global level.

Figure 6. The CREDIT process model examines four selected process segments: The design and construction processes on the left hand side of the building in the sketch. The operation of facilities and the use and occupancy of the building on the right hand side of the building in the sketch. The last of the four processes is innovation and learning, and they link the three other processes together.



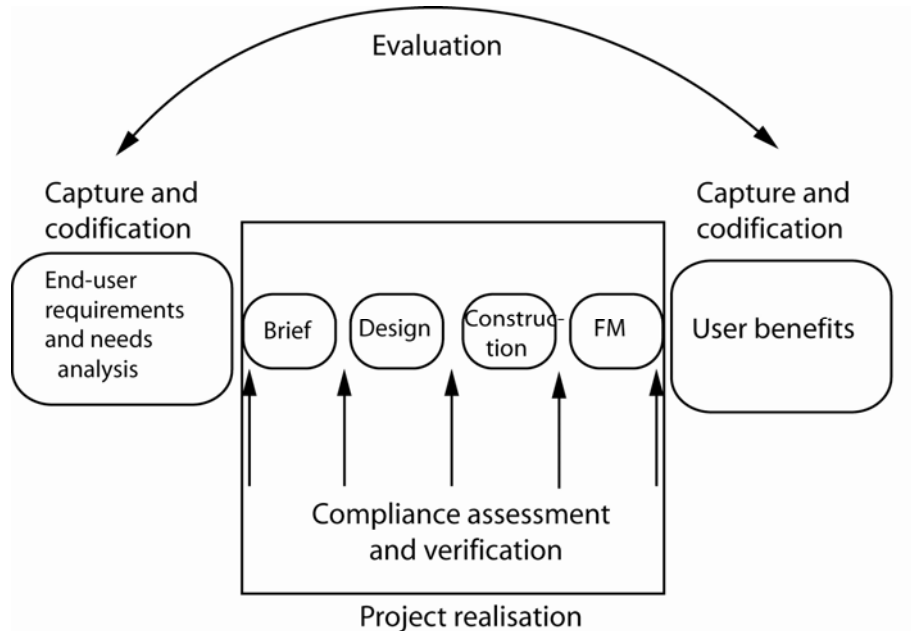
The CREDIT process model (figure 6) is linked to the CREDIT product model. On one hand CREDIT process model described the building design and construction; on the other hand the CREDIT process model included facility management and the use of the building. The last part in the CREDIT process model consisted of lessons learnt on one building project or enterprise and their transformation for use on another project to improve the quality, efficiency and economy of construction and real estate.

The intension with CREDIT performance indicator framework is that it included indicators relevant in all the processes described in the CREDIT process model. The innovation part of the process model indicated that it is important to see the CREDIT performance indicator framework as an important driver for the future improvement of the construction and real estate sector. In addition it would require a dynamic description of a combination of the cost indicators; the performance indicators and the environmental impact indicators, because the indicators would change over time together with the choice of key indicators. Innovation also necessitated the opportunity to compare changes in performance over the short and the long terms, and therefore it was important that the CREDIT performance indicator framework should be robust and comparable back and forth in time.

The CREDIT carpenter model shown in Figure 7 and explained in detail in CREDIT Report 4 is another way of presenting how knowledge and experience from a building process and use phase of a building could be obtained and delivered to future building projects. The CREDIT carpenter model fo-

cused on the sub-processes in the building process where assessments or verification of the compliance could be made.

Figure 7. The CREDIT carpenter model is named after the sketch, which look like the head of a carpenter with ear protector. It presents the building process with a focus on the sub-processes in the building process and the potential assessments made after each sub-process enabling knowledge and experience gained from the building process and the use of the building to be obtained and delivered to future building projects.



The objective of CREDIT performance indicator framework is to include indicators applicable throughout the building process.

- In the initial phases (strategic analysis and briefing) as a basis for the specification of the requirements.
- In design and construction as a basis for verification of compliance with requirements
- Finally in the use phase as a basis for the assessment of the user benefits of the finished building.

Likewise it is the ambition for the CREDIT performance indicator framework that it addressed the issues relevant for the main participants in the building process including:

- Authorities and organisations
- Users (end-users, owners and surrounding society)
- Clients/Facility managers
- Suppliers (consultants, contractors, manufactures)
- Research and development

2.2 Indicators in different situations and for various purposes

In the CREDIT context, indicators could be used for setting objectives for and measuring the performance of a product or service. They could also be used for monitoring the progress (towards the strategic vision, or performance objectives). Thus, indicators served both to show the state, and for pointing at trends and the indicators could serve different purposes and be defined as:

- A measuring tool, expressed in clear and precise terms measuring progress towards an objective; they provide a measurement unit through which modelling and monitoring can be conducted.
- A forecasting tool giving indications, describing or calculating the state of a phenomenon or a situation in the future. Indicators can reflect cause-to-effect relationship between an action and its consequences.
- An improvement tool to guide the strategic and overall innovation of the different enterprises and performance of buildings, where results of analyses of different indicators and long-term changes can point out new opportunities for improvement of quality and effectiveness. May be it could also support a paradigm shift in the sector for more industrial thinking and end-user involvement.

All variables in CREDIT were called performance indicators. Qualified performance indicators must meet certain quality criteria, such as

- Relevance a clear link to the performance goal
- Objectivity must be based of reliable information
- Accessibility appropriate data exist and can be obtained
- Readability understandable for the community
- Measurability can be validated
- Sensibility reliable in use.

A qualified performance indicator must also have a clear focus on:

- Who and how can the indicator be documented? – Indicator input
- Who and how can the indicator be used? – Indicator output
- Can the indicator be measured exactly and quantitatively or evaluated emotionally and qualitatively?
- In what part of the construction and real estate process (including time) is it used? - Process relation
- To what physical object and location is it related? - Product relation

CREDIT performance indicator framework should be perceived as a 'gross' inventory of building-related indicators. Therefore, the CREDIT performance indicator framework did not cover all these different situations and purposes in a plain and common system useable for all professional partners in the construction and real estate sectors., It is constructed with the hope that it can work as a model for establishing a common understanding in the sectors and as a framework for the individual user's choice of key performance indicators as well as the level of details fit for their purpose. The indicator classification was therefore constructed to fill in the gap between the different levels of performance indicators, users and innovations as shown in Figure 8. Over time it could result in common standards for parts of the sector or between authorities in the Nordic and Baltic countries.

Figure 8. The CREDIT performance indicator framework complements the gap between the different levels of performance indicators, users and innovations.

1. Indicators	a. A hierarchy of quantitative and exact indicators	<i>The gap is complemented by the CREDIT indicator classification</i>	b. A facet system of qualitative and emotional indicators
2. Users	a. Technical users and a high degree of details		b. General users and a low degree of details
3. Innovation	a. Research and scientific thinking		b. World-class enterprises

2.3 The first levels of facets in indicator framework

Figure 9. The main facets and the first level of sub-facets in the CREDIT performance indicator framework

1. Costs, price and life cycle economy (LCE)
11 Capital, investment, construction, commissioning and decommissioning costs
12 Building services related to operation, maintenance and development
13 Business services related to the activities in the building (not building related)

2. Location, plot, region and country
21 Location and address
22 Social-cultural context
23 Plot opportunities
24 Spatial solution and plot aesthetics
25 Services in surrounding area
26 User experience and feelings

3. Building performance and indoor environment
31 Category of building, quantity, size and area
32 Safety and security
33 Usability and adaptability
34 Thermal climate
35 Air quality
36 Lighting conditions
37 Acoustic climate
38 Aesthetics quality of building and indoor spaces
39 User experience and feelings

4. Building part and product performance
41 Category of building part, quantity, size and area
42 Safety
43 Usability and durability
44 Thermal quality
45 Impact on air quality
46 Lighting quality
47 Acoustic quality
48 Aesthetic quality of building part
49 User experience and feelings

5. Facility performance in operation and use
51 Category of tenancy and operation and area of space
52 Applicability of the facility
53 Building services related to operation, maintenance and development
54 Business services related the activities in the building (not building related)
55 Social performance and user experience

6. Process performance in design and construction
61 Category of process, supplier and organisation
62 Resource control and project management
63 Health and safety and work environment
64 Quality management
65 Experience of participants or involved parties

7. Impact environmentally, socially and economically
71 Plot
72 Emissions
73 Resources
74 Waste to disposal
75 Social and economical impact on the local community

Based on the intentions and objectives of the CREDIT performance indicator framework mentioned above, 7 facets of performance indicators that represent various perspectives on building and real estate were chosen.

Above the 7 facets (level 1) and the first level of sub-facets (level 2) are shown in Figure 9.

End-user, owners and tenants are primarily looking at the following three performance indicators in a descending order of priority: The economy; the location of the building; and the standard and quality of the building and the internal spaces and rooms as a whole. Normally end-users, owners and tenants have a minor interest in the design and construction processes or the facility management process, and only few users are interested in how the building affects their neighbours, society, the national economy or the global environment. When they are confronted with such issues, they expect the authorities to have included the impact on society and the global environment in building regulations and other public requirements to the building and the construction process.

The suppliers' primary interest is how to manufacture products and how to design, construct and operate the building. Obviously the professional suppliers know the importance of understanding and satisfying the end-user and the client's needs and demands. But still the majority of enterprises in the construction and real estate sectors are production-oriented rather than client-oriented. To inspire and motivate them to participate in improving the construction and real estate sectors, it is therefore important that parts of the performance indicators also are relevant for them. This could for example be expressed through performance indicators on building parts and components as well as through performance indicators on the construction and real estate processes.

All performance indicators including the 7 main facets, the first level of sub-facets (level 2) and the next level of sub-facets (level 3) as well as the units or measures that can be used in the assessment of the performance indicators (level 4) are described in Chapter 4.

Performance indicators addressed in one assessment

As costs, performance and impact perspectives are separated into individual facets in the classification and as master data such as building type, participating organisation or party are included as indicators; many indicators are addressed in a single assessment. An example of the relations between individual performance indicators could be:

- If the performance of the thermal climate in an office building were to be assessed, the indicators mentioned below would be addressed:
 - 311 Application and function of building (office building),
 - 341 Room temperature and
 - 342 Air velocity would be addressed.

- If additionally the costs of providing these conditions were to be assessed in a facility management perspective, the indicators listed below would be addressed:
 - 122 Operation (costs)
 - 126 Consumption (costs)
 - in connection with:
 - 532 Operation (in facility performance)
 - 536 Consumption (in facility performance).

This means that at least two indicators were addressed in all assessments, and typically three or four would be addressed at the same time.

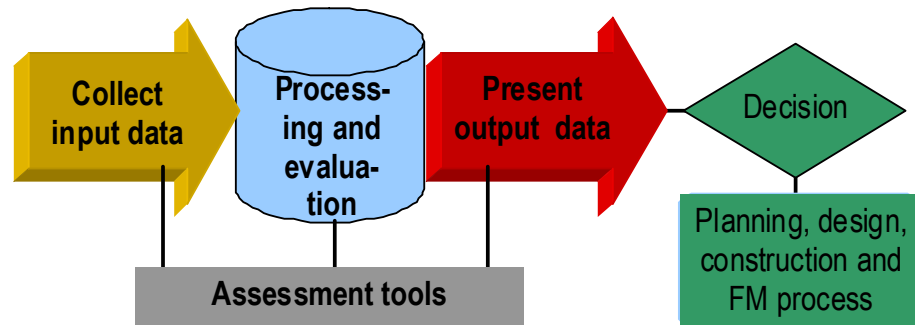
2.4 Indicators in assessment, benchmarking and decisions

In CREDIT the assessment process is according to CREDIT Report 4 divided into the following three activities that are supported by various assessment tools from manual calculations to digital programs for 3D live presentation of information:

- To collect and file input data and general information including how to capture end-users needs and experience
- To calculate and evaluate information and compare with other data
- To present and report output data and information ready for decision.

The CREDIT national case studies (referred in Chapter 3) and the research and standardisation work (referred in Chapter 3 and in detail in Appendix A) showed that the assessment of the various indicators differed depending on the kind of input and knowledge that it was based on and what kind of output data that was relevant for the user.

Figure 10. CREDIT assessment model of the three parts of data handling in an assessment: The collection of input data, the processing or assessment of data and finally the presentation of output-data.



Below the various types of assessments are briefly listed, distinguishing between input data, assessments/processing and output data, based on the observations made in the CREDIT case studies (see Chapter 3 or in CREDIT Report 2, 4 and 5 for more details).

Types of input, assessment and output

On the basis of the national case studies and international standards, three types of input were recognised:

- Measurements
- Master data
- Descriptive data

Likewise four assessments or processing types were recognised:

- Comparison
- Calculation
- Testing
- Qualitative assessment

Finally five types of output or presented data were recognised:

- Master data
- Classes
- Measures
- Related data
- Qualitative descriptions:

Output measures in the CREDIT performance indicator framework

CREDIT performance indicator framework basically used three types of output measures:

- Master data such as address, function of building, building part, organisation or party, size or amount
- Currency per unit e.g. euro / m²
- Classes on a scale from 1 to 5 with (1 was the best and 5 was the worst) or specified measured classes (kg, N, U)

The value for each of the classes from 1 to 5 is not defined for all performance indicators in the framework, because standardisation work and research in the various fields have not reached that concord and clarity. And in some fields such classes is not relevant. As regards safety of a building construction, classes of safety are not relevant, whereas a classification on building parts and the number of people using the building is relevant for the consultants designing the building.

For some groups of performance indicators there are classes already defined and in use, e.g. energy efficiency and indoor climate.

Regarding accessibility, it is possible at the moment only to describe whether the building meets the requirements (are they met or not), whereas ranking the solution's level of compliance with the requirements is not possible.

This applies for many of the other performance indicators.

In the CREDIT performance indicator framework there is referred to definitions of classes when possible. In all other instances, the unit that the performance indicator is measured by is given.

2.5 How to use the CREDIT performance indicator framework

The CREDIT performance indicator framework is intended as a gross inventory that encompassed the view of many users or parties in various building-related processes concerning building and the built environment. The case studies showed that the indicators applied in an assessment or benchmarking scheme were linked to the purpose of the assessment and the user or recipient of this assessment and the activity in the building process. Some performance indicators were only relevant for some users or parties, while other indicators were of no interest, and some indicators were relevant at some point in the building process in relation to some activities while others were irrelevant. Therefore, in order to work with the indicators different sets of key performance indicators must be chosen specific in relation to different processes or parties or buildings.

Figure 11. Illustration of the facets of indicators and their relevance in relation to different process activities. Horizontally each performance indicator facet can cover few or all processes. Vertically each facet can have a high or low intensity, but the intension with the framework is that the individual performance indicator facets are independent.

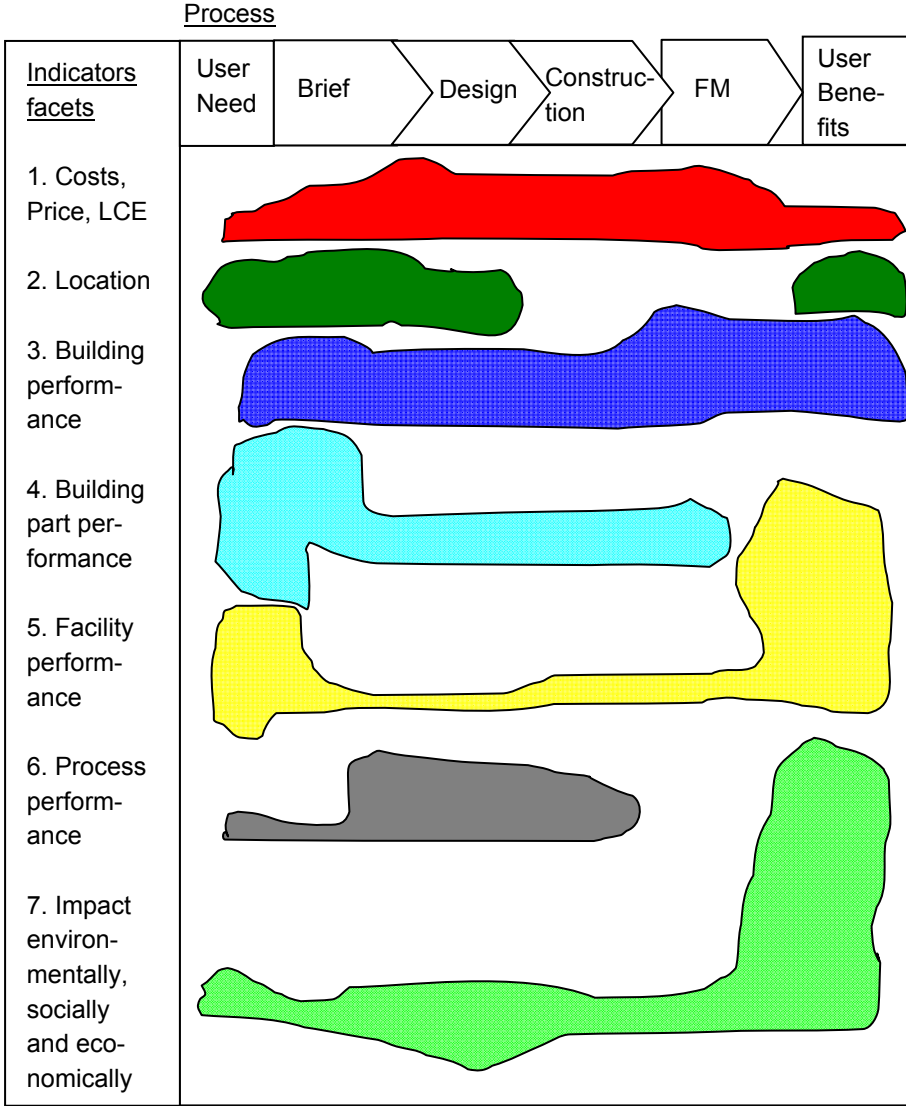


Figure 11 shows the facets of indicators and their relevance in relation to the activities at different points in the construction and real estate process. It is the intention of CREDIT to address the whole life cycle process including the facility management and use phases. This last part of a building's life cycle process has the longest extension in time and has potentially a much bigger economic impact for the business/user occupying the building than design and construction. Knowledge about the user experience and facility performance in operation from this phase could be valuable to obtain in order to inform future building projects as well as shedding light on the potential relation between e.g. productivity and facility performance and user satisfaction.

In CREDIT one set of key performance indicators is proposed as an example of a set of key performance indicators that reflect some of the needs a building client or owner such as the Finnish SENATE has. Below in Figure 12 is this set of key performance indicators listed.

CREDIT recommends that different sets of key performance indicators should be selected that reflect the purpose of the assessment and what in-

formation/knowledge the recipients would need. It was not possible in CREDIT to select a set of key performance indicators relevant for all purposes and recipients. Maybe in the long term such a selection of general key performance indicators will be achievable.

Figure 12. An example of 10 key performance indicators (KPI) reflecting the needs of building owners or administrators proposed in CREDIT e.g. by the Finnish building administrator and facility manager Senate.

KPI	Facet no and name in three levels
Key 1:	1. Costs, price and life cycle economy (LCE)
	2. Location, plot, region and country
Key 2:	23 Plot opportunities
Key 3:	252 Access to public transport
Key 4:	3. Building performance and indoor environment
	332 Adaptability to needs (now and over time)
Key 5:	34 Thermal climate
Key 6:	352 Pollutants in indoor air
Key 7:	4. Building part and product performance
	5. Facility performance in operation and use
Key 7:	521 Tenancy agreement
Key 8:	6. Process performance in design and construction
	622 Working plan and time consumption
Key 9:	7. Impact environmentally, socially and economically
	721 Climate change (CO ₂)
Key 10:	731 Energy efficiency

How to develop a set of key performance indicators using the framework

Focus

When developing a set of key indicators, the first step should be to choose or outline the focus of the assessment:

- The location (country, region) – what other areas would be it relevant to be compared with?
- The building type (office building, school, housing etc.) or building part - what buildings/building parts would it be relevant to assess and what other buildings or building parts would it be relevant compare it to
- The building process – when in the building process are the building assessed/which activities are relevant to assess?

Segment

Next step would be to outline who the recipients of the assessment would be and the kind of information they would need.

Selection of performance indicators

On the basis of the former questions, indicators that reflected the purpose of the assessment and activity in the building process to be assessed should be selected

Measures

When deciding how to measure the individual indicator, CREDIT recommends that international standards, research in the field and national building regulations are observed.

3 Results of the study in the CREDIT project

This chapter summarises the guideline, findings and experience acquired from the CREDIT national case studies relevant in relation to the CREDIT performance indicator framework and reported in CREDIT Reports 2, 4 and 5. In addition a summary is given that outlines the CREDIT study of international standards and research and a study of national regulations in the Nordic and Baltic countries, which have been the background for describing the various CREDIT facets in Chapter 4. More detailed descriptions of these studies are given in Appendices A and B.

3.1 General guideline for analysing case studies

All the CREDIT national case studies were based on the same guideline in order to get comparable information from the many segments of the building and real estate sectors in 7 different countries. The case studies were divided into 4 main chapters, not including the introduction. Three of the chapters addressed the assessments made and their application on building level, enterprise level and national benchmarking level respectively. In the final chapter the conclusions from each of the previous chapters was discussed and concluded

Questions on state-of-the-art in different segments

Common for all three levels of building, enterprise and national benchmarking four main questions were asked addressing:

- Type of building, enterprise or national benchmarking
- Assessment and tools applied
- Cost and performance indicators applied
- Relation between the building case, enterprise or national benchmarking to the other levels

Questions on plans and visions in different segments

In all the cases on three levels, visions or innovations for future improvements were addressed.

Questions on the consequences of the CREDIT proposal

The discussion and conclusions of each case addressed the lessons learnt from each of the three levels of the case as well as extracted recommendations relevant in relation to CREDIT.

How to analyse and report the findings

The analysis of the national case studies made in relation to the CREDIT performance indicator framework addressed mainly two issues:

- What cost and performance indicators were applied in the case? This question was addressed to ensure that the CREDIT performance indicator framework included the right and relevant indicators as well as to spot potential key performance indicators.
- How was the relation between input data and output data? This issue was addressed to get an overview of what type of output data and what kind of assessment was relevant for different users of the assessments and the various purposes of the assessments.

3.2 Experience from CREDIT Reports 2 and 4 on building level

The experience from CREDIT reports 2 and 4 on building level are discussed according to the different building types and performance indicator applied. A list of types of input data, processing data and presenting output data is given last.

Building types

The building cases in the national case studies included a range of types and uses of buildings including public non-profit housing, teaching and university buildings, private dwellings, residential property and office buildings.

Performance indicators applied

The indicators applied in the assessment of the various building types covered a broad range of different issues and parameters relevant for the assessment of buildings and real estate. As the case studies formed one of the bases for the CREDIT performance indicator framework, the indicators applied in the cases corresponded to those of the classification.

Regarding key performance indicators, few indicators turned up in many cases and building types whatever the assessment of the building did address. These were primarily indicators on cost, location, building type and size/square meters.

In a context of public housing where most types of assessment and indicators were applied, the performance indicators ranging from location of the building, building and product performance, facility management, process performance as well as both costs and aspects of environmental impact. Furthermore, it was in relation to public housing that the user's experience and feelings played an important role in the assessments. The assessments of the other building types were limited to one or two parameters apart from private dwellings and were all primarily based on measures and calculations.

It was not possible on the basis of the case studies to link specific indicators to specific building types. Though public housing and private dwellings seemed be the building types where a broad range of indicators were addressed, it could not be argued that user experience and the technical standard of the building were more important in relation to housing and dwellings than to university or office buildings. Probably, the differences of applied indicators reflected to a greater extent that the user of the assessment differed (client, consultant, facility manager, potential buyer or investor) as well as the purpose of it.

Types of input data, processing data and presented output data

The review of the case studies showed that the assessment of various indicators differed depending on the kind of input data it was based on and what kind of output data that was relevant for the recipient of the assessment.

Below the various types of assessments are listed, distinguishing between input data, processing and output data.

Input data

Measurements:	Area, height, db, meter, reverberation time, kg, MJ, euro, numbers, amounts, dimensions, demographic data, temperature, satisfaction etc.
Master data:	Address, postal code, indications in a map, function.

Descriptive data:	Drawings, models, description of material or execution, shape, observation, perception.
Processing data	
Comparison:	Comparing or levelling of measurements to predefined classes. This could be threshold values such as allowed dB in living spaces, or comparing dimensions of spaces, constructions components (measures taken from drawing material or the building itself) with predefined dimensions enabling the durability, function or use, or ensuring the safety of the construction/building.
Calculations:	Making calculations based on a predefined calculations formula and a set of input data about the properties of building components. An example of this kind of assessment was the energy labelling system. On the basis of registrations of building components/materials, heating and cooling system and their insulation and convective properties, a calculation of the whole building's energy demand was made.
Testing:	Testing the qualities or properties on site or using e.g. drawing material. An example could be the testing of whether it was possible to furnish a space/-room in more than one way.
Qualitative assessment:	The fourth type of assessment was qualitative assessments that rely on a personal (professional) judgement that was based on observation and analysis (without input data such as measures). An example of this kind of assessment could be the professional assessing the quality of the spatial relation of series of indoor spaces, or whether a building was worth preserving.
Presented output data	
Master data:	Address, postal code, function, assessed party, assessor.
Classes:	Classes that referred to predefined classes or rankings that could be quantitative measures and 'soft' qualitative assessments. An example of such classes was the marks A1 – G in the Danish energy labelling scheme. Another example was the classes applied in the Danish mapping scheme SAVE of buildings worth preserving. In that case a personal professional observation and analysis of the building's cultural, spatial, aesthetic qualities ended with a ranking of the building in a class – worth preserving or not.
Measures:	This could be statistical data, numbers, amounts or ratios. Examples of this sort of output could be the ratio of satisfied users or the price per unit, e.g. m ² .
Related data:	Output in this case was compiling data together for the user in a readable way. An example of this kind of output was the maps that are linked to all the house adverts that the Danish real estate agents 'Home' show on their website. Here you can see

the location of the house in relation to whatever you find relevant (schools, kindergartens, shopping, public transportation etc.).

Qualitative descriptions: Output in this case could be a description of the performance of the building; both of the 'soft' character and the objective characters that were the background explanation for the class or mark that the performance was given. An example could be a description of an analysis of the architectural and spatial preservation values that was the foundation for the assessment of whether the building was worth preserving together with a mark.

3.3 Experience from CREDIT Reports 2 and 4 on enterprises

The enterprises included in the national case studies ranged from non-profit housing associations and public building owners and administrators to private consultants, real estate agents and investors.

The clients and owners of the cases addressed primarily qualitative performance indicators on location, building, product and process (user experience and feelings, product and building components convective and insulating qualities, durability and defects). They were used both for specification in the briefing as a method to ensure that the result complied with the requirements and for the assessment of quality the finished building after handover.

A building administrator among cases addressed facility performance in operation and use. Here the focus was on the facility performance in relation to costs in order to be able to compare the expenses of one facility with another, whereas the quality of the performance was not addressed.

The consultant addressed primarily the user's experience of and feelings for location and building performance as a tool to develop a brief that encompassed the user's wishes.

When it came to the enterprises investing or facilitating sale and purchase, the primary focus was on costs, prices and income and total return seen in relation to the building type and use, its size and location.

Besides the basic performance indicators on location, building type, size and price, there were no indicators that turned up in all cases. The importance and relevance of specific indicators seemed to be linked to the purpose of the assessment as well as the type of enterprise.

3.4 Experience from CREDIT Report 5 on benchmarking

Looking at the national benchmarking and what performance indicators they applied, it appeared that the public mandatory systems had a focus on the performance aspects (experienced and professionally measured spatial quality, quality of execution, process performance and energy performance). In this group of systems there was only one exception, where the focus was on economy, but it included life cycle costing and energy consumption.

In the private and semi-private systems, economy was the primary focus, either alone or in connection with FM, or location. An exception from that is the search engine for real estate (Boligsiden Boliga), which covered all perform-

ance indicator categories with the prioritisation set by the user/potential buyer. But the basic indicators or search criteria were still price, location and size.

3.5 Lessons learned from international standard and research

Appendix A describes a CREDIT study of international standards and research as background for the description of the individual facets in Chapter 4. The following categories of standards and research were selected as it includes important fields and gives sufficient information to describe the CREDIT facets:

- Life cycle economy
- Facility management
- Environment
- Quality management
- Energy
- Indoor climate
- Architecture

The general lesson learned from the study was that:

- Information in the technical standards were difficult to understand and compare for non-experts
- The individual areas were at different maturity levels regarding assessment methods, definition of classes or dissemination in the sector
- Research and new improvements constantly change the contents and definitions in the standards, which cause updating problems.

Life cycle economy standards and research activities

Life cycle economy is the estimation of the economic implications of different design solutions throughout the service life of the building and not only the acquisition costs. ISO/DIS 15686-5 (ISO 2004a) have influenced CREDIT facets:

- 1. Costs, price and life cycle economy (LCE)

The study shows that the main focus in the sector is on facet 11 (Capital, investment, construction, commissioning and decommissioning costs) followed by facet 12 (Building services related to operation, maintenance and development), but there is a growing interest for putting more efforts in research on not building related services in facet 13 (Business services related to the activities in the building (not building related)). It was expected that it may change the focus from buildings as an expense to more focus on values for the end-users of the building and the business and social life in the building.

Facility management standards and research activities

Two terms for FM are often used synonymously: Facility management and facilities management. In CREDIT we used the term facility management. FM is well developed in the most European countries. In the Nordic countries there are several national FM-organisations both non-profit organisations and private companies, and they cooperate in the Nordic region according to international standards. The purposes of these associations are to establish a common set of benchmarks in and between companies and facilities in order to support management decisions and increase competitiveness. Some are more successful than others, and there is a movement in the direction of more cooperation, use of common international standards, more comprehensive FM-databases and digital treatment of information. On the international level there is ongoing research concerning FM in order to elaborate European standards.

Experiences from FM-organisations, prEN 15221-3:2008 (CEN, 2008b) and prEN 15221-4:2009 (CEN, 2009) have influenced the CREDIT facets:

- 1. Costs, price and life cycle economy
- 5. Facility performance in operation and use.

Environmental standards and research activities

The standardisation work for classifying the environmental impact of a building and the building process that precedes it looks at environmental impact in a very broad perspective. Sustainability, a central concept in that work, addresses not only resource consumption and emission of impurities but also the socio-cultural impact as well as the economic and architectural impact of buildings on the surroundings.

The standards ISO/AWI 21929 (ISO, 2009) and DSF prEN 15942 (Dansk Standard, 2009b) on sustainability and environmental impact influenced facets:

- 7. Impact environmentally, socially and economically
- Some sub-facets in facet 1, 2, 3 and 4.

Quality management standards and research activities

Today some of the best known international standards in Quality Management (QM) are the ISO 9000 series (ISO, 2008). These standards are used as generic standards to optimize and systemise QM and not only relevant in relation to products but also in a processes and services. The ISO 9000 standards do not include product requirements as they are specified in a big number of product standards. In the Nordic and Baltic countries there are requirements for quality control when working on the basis of the general conditions for the provision of works and supplies within building and engineering. For governmental buildings and government-financed buildings including non-profit housing there are further requirements. At the same time the companies are recommended to apply ISO 9000, but this is not mandatory.

The ISO 9000 series (ISO, 2008) and other documents (Bertelsen, 2009; EBST, 2004) have influenced the CREDIT facet:

- 6. Process performance in design and construction

Energy standards and research activities

The European Union Directive on energy performance of buildings (EPBD, 2002) requires of all the member states the implementation of mandatory energy performance certificates for all buildings and minimum energy requirements for new buildings and buildings that undergo major renovation. This means that all countries participating in CREDIT, except Iceland, had implemented or are in the process of implementing these requirements. The Nordic countries in CREDIT have all accepted the standard EN/ISO 13790:2008 (CEN, 2008a) for calculating the energy demand of existing and planned buildings.

The European Union Directive on energy performance of buildings (EPBD, 2002) and the related standards have influenced the CREDIT facets:

- 34 Thermal climate
- 44 Thermal climate
- 73 Resources (731 Energy efficiency).

Indoor climate standards and research activities

WHO has defined health as: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). Currently, there is standardisation work in progress for classifying the indoor climate in classes of quality. An example is DSF 3033, 2009

(Dansk Standard, 2009a) that classifies the indoor climate (thermal conditions, air quality, daylight conditions and acoustic conditions) in dwellings, institutions and offices into five classes A-E. 'A' is really good indoor climate and 'D' is indoor climate with a small negative health risk. The classification standard measures nine different parameters, and distinguishes between housing, institutions and office buildings, e.g. after finishing a building (after the standard phases) it will get the class C.

The individual parameters in the European standards for indoor climate including thermal condition, air quality, daylight and acoustic conditions influenced CREDIT facets:

- 3 Building performance and indoor environment:
- 4 Building part and product performance
- 5 Facility performance in operation and use

Architectural design and aesthetic evaluation and standards

Standardisation work (Dansk Standard, 2001, Dansk Standard, 1982; Dansk Standard, 1999; ISO, 2009) on the quality of architectural design primarily addresses issues such as dimensions and indoor climate as well as:

- Dimensions for the room height of the internal space in buildings and distinguishes between different building types
- Accessibility and to ensure disabled persons access distinguishes between six groups of disabled with differing needs
- Usability and adaptability defines serviceability as "the quality of space design and technical services of the building in relation to the intended use and user needs"
- Spatial and aesthetic quality. No standards directly address the spatial and aesthetic qualities of architectural design, but standards on sustainability address maintenance of architectural quality and cultural heritage. The SAVE system (Survey of Architectural Values in the Environment) (SNS, 1997) developed in Denmark addresses architectural, spatial and cultural quality.

The different standards influence CREDIT facets:

- 22 Social-cultural context
- 23 Plot opportunities
- 24 Spatial solution and plot aesthetics
- 33 Usability and adaptability
- 38 Aesthetics quality of building and indoor spaces
- 39 User experience and feelings
- 43 Usability and durability
- 48 Aesthetic quality of building part.

3.6 Lessons learned from the national building regulations

Appendix B describes a study of the impact on the CREDIT indicators from the building regulations of the following countries participating in CREDIT:

- Danish building regulations
- Norwegian building regulations
- Swedish building regulations
- Icelandic building regulations
- Lithuanian building regulations

The Finnish and Estonian Building regulations were not treated in Appendix B, since the Finnish building regulations look very much like the regulations of the other Nordic countries, and likewise the Estonian building regulations resemble the Lithuanian ones. The individual sections in Appendix B on the

national building regulations were written by a researcher from the country in question. Together with experiences from Appendix A it forms the background for the description of the individual facets in Chapter 4.

With a few exceptions all the building regulations are performance-based requirements. By and large, the structure CREDIT performance indicator framework corresponded to the individual regulations.

There were facets in the indicator classification that are not included in the regulations. Generally facility management is not addressed in the regulations except for requirements for parking facilities. Nor is process performance and process management addressed except for requirements for commissioning processes in the Norwegian regulations. All the regulations except the Icelandic include requirements for energy consumption and classes ranging from A (A1 in DK) to G for energy efficiency that follow the European directive. The minimum requirement for energy efficiency in new buildings is the energy class B in Denmark and class C in Norway.

In Denmark and Norway there is only one climate zone for the assessment of energy efficiency, whereas Sweden operates with two climate zones.

The Norwegian building regulations have applied the concept 'Universal design', whereas the other countries operate with the concept 'accessibility' to ensure access for the disabled. These two concepts imply two different approaches to the design of the buildings and the extent of 'accessibility'.

4 Specification of the 7 main facets of performance indicators

This chapter describes and defines the 7 main facets in the CREDIT performance indicators framework, including two levels of sub-facets. The specifications of the 7 main facets were based on the input referred in Chapters 2 and 3. It is the first common proposal and it can be changed over time when new information and experience become available. Some indicators were based on specific standards and others were based on input from researchers with insight in the various fields of knowledge covered by the indicator classification. The units by which each indicator was measured were given. Values for classes ranking from 1 to 5 were disclosed when referable standards or other types of valid foundation existed.

4.1 Facet 1 - Costs, price and life cycle economy

Costs, prices and life cycle economy were linked to many of the product and process performance indicators but are not a performance indicators, therefore indicators related to costs were separated from the performance indicators as the first of seven main indicator facets. As shown in chapter 2 the second indicator level for costs was divided into three facets that related respectively to the construction, the operation of the building and not building related services connected with the key business of the building. Each of the three facets was divided further into 7 to 9 sub-facets as shown in Figure 13.

The specification of the indicators in this facet was based *Buildings and constructed assets – Service life planning* (ISO, 2004a) *Taxonomy of Facility Management – Classification and Structures* (CEN, 2009) and *Advancing Life Cycle Economics in the Nordic Countries* (Haugbølle & Hansen, 2005). A short review of the standards and research that form the basis for the facets are given in Chapter 3 and Appendix A.

Facet 11 Capital, investment, construction, commissioning and decommissioning costs

This indicator addressed the total acquisition costs for the building throughout its lifetime including decommissioning costs. This was further subdivided into 7 sub-facets.

Measure: Currency per unit e.g. €/m²

Facet 111 Plot costs

This indicator expressed the price of the plot.

Measure: Currency per unit e.g. €/m²

Facet 112 Programming and planning costs

This indicator expressed the expenditure for the first phase of the building process where the needs and time schedule for the building process is determined.

Measure: Currency per man hour e.g. €/h

Facet 113 Design and engineering costs

This indicator expressed the fees of the engineers and architects.

Measure: Currency per man hour e.g. €/h

Facet 114 Construction work on the plot

This indicator expressed the expenditure of the construction work on site and the surveyor including terrain, ways and paths, drain, planting etc.

Measure: Currency per m² e.g. €/m²

Facet 115 Construction of building

This indicator expressed the costs of the construction of the building including equipment, materials and works hours.

Measure: Currency per m² e.g. €/m²

Facet 116 Administration costs and commissioning fees

This indicator expressed the costs of the administration of the building project and the commissioning process.

Measure: Currency per unit e.g. €/m²

Facet 117 Decommissioning costs

This indicator expressed the decommissioning costs including the demolition worker, state tax etc.

Measure: Currency per unit e.g. €/m²

Figure 13. The first main facet in the CREDIT performance indicator framework - 1. Costs, price and life cycle economy (LCE).

1. Costs, price and life cycle economy (LCE)

11 Capital, investment, construction, commissioning and decommissioning costs

111 Plot costs

112 Programming and planning costs

113 Design and engineering costs

114 Construction work on the plot

115 Construction of building

116 Administration costs and commissioning fees

117 Decommissioning costs

12 Building services related to operation, maintenance and development

121 Administration

122 Operation

123 Maintenance

124 Repair

125 Development

126 Consumption

127 Cleaning

128 Parking

13 Business services related to the activities in the building (not building related)

131 Security and safety

132 Reception and switchboard

133 Mail

134 IT service

135 Moving

136 Catering

137 Accessories and copying

138 Administrative support

139 Furniture and inventories

Facet 12 Building services related to operation, maintenance and development

This indicator expressed the costs related to the operation of the building during the use phase of the building, divided into 8 sub-facets.

Measure: Currency per unit e.g. €/m²

Facet 121 Administration

This indicator expressed administration costs associated with the operation of the building.

Measure: Currency per unit e.g. €/h

Facet 122 Operation

This indicator expressed the costs associated with the actual operation of the building such as technical staff.

Measure: Currency per unit e.g. €/h or €/m²

Facet 123 Maintenance

This indicator expressed the expenditures for maintaining the building such as new filters for ventilation, painting of existing walls, windows etc.

Measure: Currency per unit e.g. €/h or €/m²

Facet 124 Repair

This indicator expressed the expenditures for repairing the building e.g. a punctured windows, moulds, termites etc.

Measure: Currency per unit e.g. €/h or €/m²

Facet 125 Development

This indicator expressed the expenditures for development in the building such as upgrading indoor climate etc.

Measure: Currency per unit e.g. €/m²

Facet 126 Consumption

This indicator expressed the consumption costs of heating/cooling, electricity, water, waste etc.

Measure: Currency per unit e.g. €/kWh or €/m³

Facet 127 Cleaning

This indicator expressed the costs of cleaning the building including both periodic and special cleaning.

Measure: Currency per unit e.g. €/m²

Facet 128 Parking

This indicator expressed the costs of having parking space for the users of the building.

Measure: Currency per unit e.g. €/m² or €/parking space

Facet 13 Business services related to the activities in the building (not building related)

This indicator addressed the costs of services related and needed to keep the activities running (such as teaching, living, commercial activities) that are housed in the building. This facet was divided into 9 sub-facets.

Measure: Currency per unit e.g. €/m² or €/employee

Facet 131 Security and safety

This indicator expressed the costs of ensuring the needed levels of safety and security such as external guard agency, surveillance, lock systems etc.

Measure: Currency per unit e.g. €/m² or €/employee

Facet 132 Reception and switchboard

This indicator expressed the costs of having a reception and switchboard.

Measure: Currency per unit e.g. €/h or €/employee

Facet 133 Mail

This indicator expressed the costs of having a mail system for both/either outgoing letters or internal post etc.

Measure: Currency per unit e.g. €/h or €/employee

Facet 134 IT service

This indicator expressed the costs of IT services needed for the activities in the building such as IT programmes, IT support, internal IT courses etc.

Measure: Currency per unit e.g. €/h or €/employee

Facet 135 Moving

This indicator expressed the costs related to moving offices internally in the building or in to a new building including TC/IP connection etc.

Measure: Currency per unit e.g. €/unit

Facet 136 Catering

This indicator expressed the costs of having some sort of catering in the building such as a canteen, vending machines etc.

Measure: Currency per unit e.g. €/unit or €/employee

Facet 137 Accessories and copying

This indicator expressed the costs of accessories such as uniforms, pencils, copying machines, papers etc.

Measure: Currency per unit e.g. €/unit or €/employee

Facet 138 Administrative support

This indicator expressed the costs of administrative support such as consulting fees for external consultants, outsourcing to external administrator etc.

Measure: Currency per unit e.g. €/unit

Facet 139 Furniture and inventories

This indicator expressed the costs of furniture and equipment such as chairs, sofas, lamps, book shelves etc.

Measure: Currency per unit e.g. €/unit

4.2 Facet 2 Location, plot, region and country

In this second indicator facet, location i.e. plot, region and country, the location of the building was described from various perspectives ranging from the address and postal code to the social context and spatial solution. This indicator facet was divided into 6 sub-facets:

- Location and address
- Socio-cultural context
- Plot opportunities
- Spatial solution and plot aesthetics
- Services in the surrounding area
- User experience and feelings

Each of them was further divided into 3 to 7 sub-facets (see Figure 14).

The specification was based on *Building Construction – Sustainability in Building Construction* (ISO, 2009), the national building regulations in the participating countries (EBST, 2009; BE, 2010; Boverket, 1998b; Boverket, 2008; IME (1998); Ministry of Environment, 1996; Ministry of Environment, 2001) A short review of the standards and research that form the basis for the facets are given in Chapter 3 and Appendix A.

Facet 21 Location and address

This indicator addressed the exact location of a building and classified the surroundings. It was divided into 4 sub-facets.

Figure 14. The second main facet of indicators – 2. Location, plot, region and country

2. Location plot, region and country	
21 Location and address	
211 Country and region	
212 Address, postal code and city	
213 Land, village, town, city or city centre	
214 Location coordinates	
<hr/>	
22 Socio-cultural context	
221 Cultural heritage	
222 Community acceptance	
223 Social context	
<hr/>	
23 Plot opportunities	
231 Size of the plot	
232 Bearing capacity	
233 Topography of the plot (e.g. sea level)	
234 Outdoor environment and climate	
235 Diversity of activities	
236 Building efficiency and density	
237 Accessibility of the plot (e.g. topography)	
238 Legal requirements for the plot	
<hr/>	
24 Spatial solution and plot aesthetics	
241 Adaptability and compliance with needs	
242 Accessibility of the building and outdoor spaces	
243 Spatial quality of the outdoor spaces	
244 Indoor outdoor relationship	
<hr/>	
25 Services in the surrounding area	
251 Distance to growing neighbourhood	
252 Access to public transport	
253 Access to infrastructure (roads, motorways...)	
254 Pedestrian and bicycle access	
255 Parking possibilities	
256 Access to services (schools, shops, cultural offers)	
257 Access to recreational places	
<hr/>	
26 User experience and feelings	
261 Security	
262 Adaptability and usability of outdoor spaces	
263 Well-being in outdoor spaces	
264 Comfort (wind, light, noise)	
265 Services in the surrounding neighbourhood	

Facet 211 Country and region

This indicator expressed the country and region where the building was situated.

Measure: Naming the country and region.

Facet 212 Address, postal code and city

This indicator expressed the postal address.

Measure: Postal address.

Facet 213 Land, village, town, city or city centre

This indicator expressed the density and type of built-up area that characterised the location.

Measure: A chosen class in a actual classification e.g. in five classes.

Facet 214 Location coordinates

This indicator expressed the exact geographical coordinates of the location.

Measure: Latitude and longitude.

Facet 22 Socio-cultural context

This indicator facet expressed the context of the building/location from a social, demographic or cultural perspective divided into 3 sub-facets.

Facet 221 Cultural heritage

This indicator expressed the cultural value (architectural, symbolic or historical) of the building or the area or buildings nearby whether it was worth preserving or otherwise distinguished by remarkable qualities.

Measure: Descriptive classification and classes (whether worth preserving or not) e.g. in five classes.

Facet 222 Community acceptance

This indicator expressed the local population's or politicians' acceptance of the building or building project.

Measure: Level of acceptance measured in surveys in 5 classes from 'High level of acceptance' to 'High level of resistance'.

Facet 223 Social context

This indicator expressed the demographic and occupational structure of the area where the building was situated.

Measure: Descriptive quantitative classification in % of the social diversity.

Facet 23 Plot opportunities

This facet of indicators addressed the character, challenges and possibilities of the plot where the building was (to be) constructed. It was divided into 8 sub-facets ranging from physical characteristics to legal requirements.

Facet 231 Size of the plot

This indicator expressed the total area of the plot.

Measure: m²

Facet 232 Bearing capacity

This indicator expressed the bearing capacity.

Measure: Bearing capacity kg/m².

Facet 233 Topography of the plot

This indicator expressed the topography e.g. the plot's inclination, the height above sea level or other topographical conditions that might influence how to build

Measure: % inclination, meters above sea level, meters above ground-water level e.g. expressed in the following five classes:

Class 1: < 1 %

Class 2: 1 - 4 %

Class 3: 4 - 8 %

Class 4: 8 - 12 %

Class 5: > 12 %

Class 1: > 5m above groundwater level

Class 2: 2.5 - 5m above ground-water level

Class 3: 1 - 2.5m above ground-water level

Class 4: 0 - 1 m above ground-water level

Class 5: Below ground-water level

Class 1: > 5m above sea level

Class 2: 2.5 - 5m above sea level

Class 3: 1 - 2.5m above sea level

Class 4: 0 - 1 m above sea level

Class 5: Below sea level

Facet 234 Outdoor environment and climate

This indicator expressed the surrounding environment in terms of climate, exposure to wind, darkness/shadows or other conditions that influenced how to build to ensure a pleasant indoor climate and outdoor conditions.

Measure: °C, meters per second, shadiness, dB.

Facet 235 Diversity of activities

This indicator expressed the diversity of functions in the proximity of the building.

Measure: Functions listed or % of distribution between different activities

Facet 236 Building efficiency and density

This indicator expressed the proportion or percentage of land used for building.

Measure: m²/m², percentage.

Facet 237 Accessibility of the plot (topography)

This indicator expressed the feasibility of the site/ topography for accessibility for disabled users.

Measure: % inclination, difference of height in meters

Facet 238 Legal requirements for the plot

This indicator expressed the requirements for volume, height, density and distance to the boundary of the site provided by national building regulations or plans by the local authorities.

Measure: Meters, m², percentage.

Facet 24 Spatial solution and plot aesthetics

This facet of indicators addressed the architectural and aesthetic qualities of the outdoor spaces on the location in terms of adaptability, accessibility and spatial quality.

Facet 241 Adaptability and compliance with needs

This indicator expressed the usability of the outdoor spaces connected to the building and the adaptability of these spaces to changing functions and needs.

Measure: Descriptive classes 1 – 5.

Facet 242 Accessibility of the building and outdoor spaces

This indicator expressed the possibility for disabled users to access the building and the outdoor spaces connected to it.

Measure: Barrier-free, % inclination, dimensions, evenness of flooring and surfaces, warning markings in the surfaces, clearness and tactility of signage.

Facet 243 Spatial quality of outdoor spaces

This indicator expressed the way that the building was placed and formed in relation to the surrounding buildings, area or landscape and the spatial quality of the outdoor spaces that surrounded it.

Measure: Descriptive classes 1 – 5.

Facet 244 Indoor outdoor relationship

This indicator expressed the relation between the internal spaces of the building and the external spaces or the surrounding buildings/area.

Measure: Descriptive classes 1 – 5.

Facet 25 Services in the surrounding area

This facet of indicators addressed what the surroundings offered to the locations in terms of a vibrant neighbourhood, transportation, infrastructure, services, parking and recreational areas.

Facet 251 Distance to growing neighbourhood

This indicator expressed the distance from growing or developing existing and vibrant neighbourhoods.

Measure: Meters, (minutes of walk), indication on a map (classes 1 – 5 must be locally defined).

Facet 252 Access to public transport

This indicator expressed the presence and proximity of public transportation in the building's neighbourhood.

Measure: Meters or minutes of walk, number of transportation types, intervals or frequency, indication on a map or e.g. in five classes where

- Class 1 is Public transport connection within 500 m, good connections and frequency and
- Class 5 is no public transport connection within 500 m.

Facet 253 Access to infrastructure

This indicator expressed the proximity and range of road systems or motorways near the plot/building.

Measure: Meters or minutes drive, indication on a map.

Facet 254 Pedestrian and bicycle access

This indicator expressed both the proximity and range of pedestrian and cycle paths and networks as well as facilities that ensured easy use of bicycles.

Measure: Meters or minutes, Quality: description, indication on a map e.g. in five classes as:

- Class 1: Immediate access to pedestrian and bicycle paths, good protected shelter for bicycles
- Class 5: No access to pedestrian or bicycle paths within 500 m, no bicycle stands?

Facet 255 Parking possibilities

This indicator expressed the presence, proximity to parking places in the neighbourhood of the building.

Measure: Parking spaces/user or employee. Meters or minutes of walk, indication on a map.

Facet 256 Access to services

This indicator expressed the availability and proximity to basic services needed by the users in the building. What types of basic services that were needed depends on the building type (primary health services, schools, kindergartens, food shops/super markets, places for cultural/leisure activities, work places / residential areas....)

Measure: Meter or minutes, number and types, indication on a map. (Lists and distance had to be locally defined).

Facet 257 Access to recreational places

This indicator expressed the presence and proximity to open areas and the sea that were open to the public.

Measure: Meters, minutes of walk or indication on a map. (Distance had to be locally defined).

Facet 26 User experience and feelings

This facet of indicators addressed the users' experience and feelings regarding the location.

Facet 261 Security

This indicator expressed the users' sense of security in the outdoor spaces on the location.

Measure: Sense of security in classes from 1 – 5 ranging from 'feeling very safe' to 'feeling uneasy'.

Facet 262 Adaptability and usability of outdoor spaces

This indicator expressed the users' experience of the adaptability and usability of the outdoor areas in connection with the building

Measure: Satisfaction with adaptability and usability in classes 1 – 5 ranging from 'very satisfied' to 'unusable and inadaptable to needs'.

Facet 263 Well-being in outdoor spaces

This indicator expressed the users' experience and sense of well-being in the outdoor spaces including the attractiveness of its layout.

Measure: Level of well-being in classes 1 – 5 ranging from 'feeling very well' – 'feeling bad' or descriptive assessment that related the sense of well-being, etc. to the lay-out.

Facet 264 Comfort (wind, light, noise, shelter)

This indicator expressed the users' experience and feeling of comfort in the outdoor spaces and reflected how the climatic conditions were treated.

Measure: Sense of comfort in classes 1- 5 ranging from 'very good' to 'very bad'.

Facet 265 - Services in the surrounding neighbourhood

This indicator expressed the users' perception of services in the surrounding neighbourhood.

Measure: Satisfaction level in classes 1 – 5 ranging from 'very good' to 'very bad'. (Services in question must be locally defined).

4.3 Facet 3 - Building performance and indoor environment

In the indicator category for building performance and indoor environment, many facets of the interior of a building were addressed with indicators ranging from the category and size of the building to the users' sense of well-being and spaciousness. This indicator category was divided into 9 sub-facets.

The specification of the indicators in this facet was based on the standards *General accessibility* (Dansk Standard, 2001), *Building Construction – Sustainability in Building Construction* (ISO, 2009), *Classification of climate in dwellings ...*(Dansk Standard, 2009a) and *Survey of Architectural Values in the Environment* (SNS 1997), *Experience with evaluation of standard and quality* (EBST 2003). A short review of the standards and research that form the basis for the facets are given in Chapter 3 and Appendix A.

Facet 31 Category of building and quantity, size and areas

This facet of indicators addressed the function of the building, the size, area and quantity. It was further divided into 9 sub-facets.

Measure: Description, number, square meter or shape.

Facet 311 Application and function of the building

The indicator expressed what function the building was made or used for.

Measure: Description (office, housing, school, hospital etc.).

Facet 312 Shape of building

The indicator expressed the shape and form of the building.

Measure: Descriptive class (row house, detached, atrium house, tower block, one-storey, multi-storey) or description and drawings of the building.

Figure 15. The third facet of indicators – 3. Building performance and indoor environment

3. Building performance and indoor environment	
31	Category of building, quantity, size and area
311	Application and function of building
312	Shape of building
313	Number of storeys
314	Built-up area
315	Gross floor area
316	Net floor area
317	Building volume
318	Room height
319	Number of occupants
32	Safety and security
321	Construction safety
322	Fire safety
323	Security
324	Safe access for different users
33	Usability and adaptability
331	Durability
332	Adaptability to needs (now and over time)
333	Usability (functional)
334	Accessibility for different users
335	Spatial layout
34	Thermal climate
341	Room temperature
342	Air velocity
35	Air quality
351	Air change
352	Pollutants in indoor air (chemical or particles)
353	Moisture/moulds
36	Lighting conditions
361	Daylight access
362	View to the outside
363	Artificial lighting
37	Acoustic climate
371	Sound and noise levels
372	Reverberation time
38	Aesthetic quality of building and indoor spaces
381	Aesthetic quality of the building
382	Spatial quality of indoor spaces
383	Quality of the spatial layout
39	User experience and feelings
391	Security
392	Well-arranged layout
393	Spaciousness
394	Well-being
395	Comfort (thermal, air, daylight and acoustics)

Facet 313 Number of storeys

The indicator expressed the height of the building.

Measure: Number of floors.

Facet 314 Built-up area

The indicator expressed the built-up area.

Measure: m².

Facet 315 Gross floor area

The indicator expressed the total floor area of the building including exterior and interior walls.

Measure: m².

Facet 316 Net floor area

The indicator expressed the total floor area of the building excluding exterior and interior walls.

Measure: m².

Facet 317 Building volume

The indicator expressed the total volume (area and height) of the building.

Measure: m³.

Facet 318 Room height

The indicator expressed the height from floor to ceiling.

Measure: meter.

Facet 319 Number of occupants

The indicator expressed the amount of persons that use the building.

Measure: Number of persons.

Facet 32 Safety and security

This facet of indicator addressed various facets of safety and security when occupying and using a building. It was divided into 4 sub-facets:

Facet 321 Construction safety

The indicator expressed how the main constructions supported the internal load and load of the building and it's resistance to the external environment and climate such as wind, water, frost, snow, rats and other vermin, earthquakes, avalanches, mud flows etc.

Measure: Compliance with building regulations.

Facet 322 Fire safety

The indicator expressed the fire protecting solutions and fire escape strategies applied in the building regarding location, construction, lay-out and equipment.

Measure: Compliance with building regulations, dimension/person ratio of escape routes, destruction or burning time – minutes.

Facet 323 Security

The indicator expressed the crime preventive measures applied in the building or lay-out of the area.

Measure: Descriptive classes (1 – 5) reflecting the level of prevention.

Facet 324 Safe access for different users

The indicator expressed the safety for different user groups (physically impaired, elderly, children) when using the building (staircases, balconies, lifts etc.).

Measure: Descriptive classes (1 – 5) reflecting the level of safety.

Facet 33 Usability and adaptability

This facet of indicators expressed how well the lay-out and design of the building provided conditions for satisfactory use of the building. It was divided into 5 facets of usability or functionality:

Measure: Descriptive classes (1 – 5) reflecting how the buildable was designed.

Facet 331 Durability

This indicator expressed the quality of the chosen solutions in the building, its structures and surfaces in relation to the durability and maintainability.

Measure: Descriptive classes (1 – 5) reflecting how buildable the design was as well as the structures, materials and surfaces maintainability.

Facet 332 Adaptability to needs (now and over time)

The indicator expressed the buildings adaptability to changing needs that stemmed from changing users or changing activities.

Measure: Descriptive classes (1 – 5) reflecting flexibility in construction allowing flexible division of spaces, technical flexibility.

Facet 333 Usability (functional)

The indicator expressed the usability of the rooms and spaces in the building and how it complies with the needs of the end-user etc.

Measure: Descriptive classes (1 – 5) reflecting flexibility in furnishing options, spaciousness.

Facet 334 Accessibility for different users

The indicator expressed how access for different user groups (physically or functionally impaired, elderly, children etc) was provided in the building and in the individual rooms and spaces.

Measure: Descriptive classes (1 – 5) reflecting how the standards were met (Barrier-free, dimensions, % inclination, evenness of flooring and surfaces, elevators, reverberation time, warning markings in the flooring, clear and tactile signage, no glaring light).

Facet 335 Spatial layout

The indicator expressed the usability of the lay-out and the spatial organisation of the building in relation to the functions or activities it housed.

Measure: Descriptive classes (1 – 5) reflecting how well the spatial organisation facilitated the different functions and activities in the building.

Facet 34 Thermal climate

This facet of indicator addressed the thermal condition of the indoor climate. It was divided into 2 sub-facets.

Measure: Compliance with building regulations e.g. in five classes.

Facet 341 Room temperature

The indicator expressed the room temperature.

Measure: Classes A - E reflecting the operational room temperature (see Appendix A Section A6 for definition of the classes).

Facet 342 Air velocity

The indicator expressed the velocity of the air.

Measure: Classes A – E reflecting the air velocity in m / s (see Appendix A Section A6 for definition of the classes).

Facet 35 Air quality

The indicator facet addressed the quality of the air inside the building. It was divided into 3 sub-facets.

Measure: Compliance with building regulations e.g. in five classes.

Facet 351 Air change

This indicator expressed the provision of ventilation of the indoor environment.

Measure: Classes A – E reflecting the air change per hour (h^{-1}) (see Appendix A Section A6 for definition of the classes).

Facet 352 Pollutants in indoor air

The indicator expressed the level of pollution in the indoor air coming from emissions from building materials, particles from the outdoor polluted air and other pollutants – chemical or particles.

Measure: Classes A – E reflecting the CO₂ (ppm), Radon (Bq/m³), Formaldehyde (see section 5.6 for definition of the classes).

Facet 353 Moisture/moulds

The indicator expressed the level of moisture or moulds indoor.

Measure: Classes A – E reflecting whether there were signs of moisture or moulds, (see section 5.6 for definition of the classes).

Facet 36 Lighting conditions

This category of indicators addressed the quality of daylight and lighting conditions in the building. It was subdivided into 3 sub-facets.

Measure: Compliance with building regulations e.g. in five classes.

Facet 361 Daylight access

The indicator expressed whether there was access to daylight in the room/-building and the window area relative to the floor area.

Measure: Glass area / floor area ratio in % and the daylight factor in classes from A – E (see Appendix A Section A6 for definition of the classes).

Facet 362 View to the outside

The indicator expressed whether it was possible to view the outside from the room/building.

Measure: Light transmittance of glass and to what extent the light came from roof lighting, in classes from A – E (see Appendix A Section A6 for definition of the classes).

Facet 363 Artificial lighting

The indicator expressed the quality of the artificial light in relation to the purpose of the light.

Measure: Luminance (lux), colour (Kelvin degrees), blinding, blinding reflections, direction.

Facet 37 Acoustic climate

This facet of indicators addressed the acoustic conditions in the room/building that depended on the construction and surface materials as well as the sound or noise level of the activities in the building or in the surroundings.

Measure: Compliance with building regulations e.g. in five classes.

Facet 371 Sound and noise levels

The indicator expressed the level of sound or noise in the room/building that was linked to the activity of the building or that of the location/site.

Measure: dB in classes from A – E (see Appendix A Section A6 for definition of the classes).

Facet 372 Reverberation time

The indicator expressed the reverberation time in the room/building that depended on the construction and surface materials.

Measure: s - seconds it took from the sound stops till the sound pressure level decreased with 60 dB in classes from A – E (see Appendix A Section A6 for definition of the classes).

Facet 38 Aesthetics quality of the building and indoor spaces

This facet of indicators addressed the aesthetic qualities of the form and space of the building both as a whole viewed from the outside, and the build-

ing from within, with focus on the spatial quality of the various rooms and spaces and the relation between them.

Measure: Descriptive classes (1 – 5) reflecting the overall aesthetics quality.

Facet 381 Aesthetic quality of the building

This indicator expressed the aesthetic quality of form and spatial solution of the building seen as a whole. Did it stand out as something special sculpturally, did it fit in with the context regarding choice of material, form, scale.

Measure: Descriptive classes (1 – 5) reflecting an assessment that related the building's form, scale, material to function and use, context and climate.

Facet 382 Spatial quality of the indoor spaces

This indicator expressed the spatial quality of the indoor spaces including scale, daylight, material, internal relation, details.

Measure: Descriptive classes (1 – 5) reflecting an assessment that related the form of the indoor spaces including, scale, daylight, material, internal relations, and details with the function and use of the building.

Facet 383 Quality of the spatial layout

This indicator expressed the spatial layout of the building including distribution of functions and their internal relation, ease of orientation.

Measure: Descriptive classes (1- 5) reflecting an assessment that related the spatial organisation including distribution of functions/activities, orientation, clearness of lay-out to the function and use of the building.

Facet 39 User experience and feelings

This facet of the indicator addressed the occupants' experience and feelings off/for the building both from outside and from within; How was the building experienced regarding of security, well-being, orientation, spaciousness, inspiration, delight, and comfort?

Measure: Descriptive classes (1 – 5) reflection the overall experience and feelings.

Facet 391 Security

This indicator expressed the user's sense of security within the building or the area that surrounded it.

Measure: Descriptive classes (1 – 5) ranging from 'feeling safe and secure' to 'feeling uneasy').

Facet 392 Well-arranged layout

This indicator expressed the user's experience of the usability of the lay-out and distribution of functions in the building and in rooms/spaces.

Measure: Descriptive classes (1 – 5) ranging from 'well organised' to 'unable' or descriptive assessment that related the layout to the use and activities of the building.

Facet 393 Spaciousness

This indicator expressed the user's sense of space in the building in relation to the use of the building.

Measure: Descriptive classes (1 – 5) ranging from 'Spacious' – 'tight/cramped'.

Facet 394 Well-being

This indicator expressed the user's sense of well-being in the building or in the rooms/spaces including the attractiveness.

Measure: Descriptive classes (1 – 5) ranging from 'feeling very well' – 'feeling bad' or a descriptive assessment that related the sense of well-being to the attractiveness of the lay-out and design of the building regarding daylight, material, details and scale.

Facet 395 Comfort (thermal, air, daylight and acoustics)

This indicator expressed the user's sense of physical and emotional comfort in the building including the temperature, air, light and acoustics.

Measure: Descriptive classes (1 - 5) ranging from 'very good' – 'very bad' reflecting the experience of the temperature, the air, the daylight/light and the acoustic in relation to the use/activities of the building.

4.4 Facet 4 Building part and product performance

This facet of indicators addressed various facets or properties of building parts and products performance ranging from the type, size and quantity of the building part to its impact on the air quality and the users experience of it. The facet was divided into 9 sub-facets.

The specifications of the indicators in this facet were based on *General accessibility* (Dansk Standard, 2001), *Classification of climate in dwellings ...* (Dansk Standard, 2009a), and *Survey of Architectural Values in the Environment* (SNS 1997), *Experience with evaluation of standard and quality* (EBST 2003), *BR 08* (EBST, 2009). A short review of the standards and research that form the basis for the facets are given in Appendix A.

Facet 41 Category of building part, quantity, size and area

This indicator addressed the application, number and size of the building part. It was divided in 3 sub-facets.

Facet 411 - Application and function of the building part

This indicator expressed where the building part was applied and the function it performed in the building .(Building parts such as facades, windows, roofs, foundations and floors, or installation components such as heating, ventilation, water, drain, electricity, or fixture and furniture).

Measure: Descriptive

Facet 412 - Quantity of building component

This indicator expressed the amount, size, area or number of the building part in question applied in the building.

Measure: Amount in number, meters, weight, m², m³

Facet 42 Safety and security

This facet of indicators addressed the properties of the building part regarding safety of the construction in relation to load, fire and personal injuries. It was divided into 3 sub-facets:

Measure: Compliance with building regulations e.g. in five classes.

Facet 421 Construction safety

This indicator expressed the properties of the building component that were relevant when assessing the safety of the construction such as the load bearing capacity of components and their strain capacity.

Measure: Load (N) and strength (MPa/m²).

Facet 422 Fire safety

This indicator expressed the properties of the building component that were relevant for assessing the fire safety and fire resistance of the building. This included R – load bearing capacity (resistance to collapse), E - integrity (resistance to penetration of flames and hot gasses), I - insulation and W - thermal radiation.

Measure: Classes (1 – 5) reflecting R, E, I and W defined by time of resistance (minutes).

Facet 423 Security

This indicator expressed the properties of the building component that were relevant for assessing the safety and security of the building. This included properties such as child-proofing, prevention of personal injury and break-in. Measure: Classes (1 – 5) reflecting the level of compliance with the required dimensions, strengths to withstand blows, weight and being child proof.

Figure 16. The fourth main facet of indicators – 4. Building part and product performance.

4. Building part and product performance

- Construction parts as facades, windows, roofs, foundation and floors
- Installation parts for heating, ventilation, water, drain and electricity
- Fixture and furniture

41 Category of building part, quantity, size and area

411 Application and function of the building component

412 Quantity of building component

42 Safety and security

421 Construction safety

422 Fire safety

423 Security

43 Usability and durability

431 Durability

432 Adaptability to needs

433 Usability

434 Accessibility

44 Thermal quality

441 Convective loss

442 Energy transmission

45 Impact on air quality

451 Pollutant emissions

452 Air change

453 Moisture and moulds

46 Lighting quality

461 Transmittance

462 Luminance

463 Reflectance

47 Acoustic quality

471 Sound absorption

472 Sound insulation

48 Aesthetic quality of building part

481 Shape of building parts in relation to the whole building or space

482 Colour and surfaces in relation to the whole building or space

483 Details

49 User experience and feelings

491 Security

492 Usability

493 Well-being

494 Comfort (thermal, air, light and acoustics)

Facet 43 Usability and durability

This facet of indicators addressed how the building part provided conditions for a satisfactory use of the building. It was divided into 4 sub-facets of usability and functionality:

Measure: Descriptive classes (1 – 5) reflection the overall usability and durability.

Facet 431 Durability

This indicator expressed how properties and functions such as resistance to blows, wind, water and wear from use were changed over time and according to how the part was built and maintained.

Measure: Descriptive classes (1 – 5) reflecting how the part fulfils the requirements over time as well as the part's maintainability.

Facet 432 Adaptability to needs

This indicator expressed the flexibility and adaptability of the building component now and over time.

Measure: Descriptive classes (1 – 5) reflecting the part's ability to accommodate changes of use and modularity.

Facet 433 Usability

This indicator expressed the functionality and usability of the building part in relation to the construction process as well as its use.

Measure: Descriptive classes (1 – 5) reflecting the building part's ability to facilitate satisfactory use and fulfil its purpose and required compliance with standards or legal regulations.

Facet 434 Accessibility

This indicator expressed the building part's usability by disabled persons (mobility, hearing, visually or cognitively impaired).

Measure: Descriptive classes (1 – 5) reflecting the part's compliance with required standards (e.g. dimensions, heights, surface properties such as evenness, sound absorption, sound or light reflection).

Facet 44 Thermal quality

This facet of indicators addressed the building part's ability to provide a stable temperature indoors in the building without high energy consumption.

Measure: Compliance with building regulations e.g. in five classes.

Facet 441 Convective loss

This indicator expressed the convective loss through the building component.

Measure: Classes volume of air (m^3 air/ m^2 surface).

Facet 442 Energy transmission

This indicator expressed the energy transmission through the building part or component including inwards transmission from the sun for example through glass.

Measure: Classes reflecting the part's U-value and g-value ($\text{W}/\text{m}^2\text{K}$ and W/K).

Facet 45 Impact on air quality

This facet of indicator addressed the building part's impact on the air quality in the indoor environment in relation to 3 facets: Ventilation, pollutants and moisture/moulds.

Measure: Compliance with building regulations e.g. in five classes.

Facet 451 Pollutant emissions

This indicator expressed the emission of pollutants stemming from the building part.

Measure: Classes reflecting the emission of CO_2 (ppm), radon (Bq/m^3), formaldehyde in relation to threshold values based on chemical analysis and sensory assessment.

Facet 452 Air change

This indicator expressed the building part's provision of ventilation of the interior of the building.

Measure: Classes reflecting the air change per hour (h^{-1}).

Facet 453 Moisture and moulds (level 3)

This indicator expressed the building part's susceptibility to moisture intrusion or the moisture/moulds in it.

Measure: Classes (1 – 5) reflecting the components susceptibility to moisture intrusion or whether there were signs of moisture/moulds in the component.

Facet 46 Lighting quality

This facet of indicators addressed the building part's impact (directly or indirectly) on the lighting quality within the building.

Measure: Compliance with building regulations e.g. in five classes.

Facet 461 Transmittance

This indicator expressed the light transmitting and the light-colour transmitting properties of the building part.

Measure: Classes (1 – 5) reflecting the level of light transmittance (%) light-colour transmittance (Kelvin).

Facet 462 Luminance

This indicator expressed the light intensity provided by the part (fixture, furniture) or luminance measured on the building part (furniture, surface etc.)

Measure: Classes (1 – 5) reflecting the intensity (lumen), luminance (lux), glare.

Facet 463 Reflectance

This indicator expressed the reflective properties of the surface of the building part.

Measure: Classes (1 – 5) reflecting the level of reflection (%).

Facet 47 Acoustic quality

This facet of indicators addressed properties of the building part that had an impact on the acoustic climate of the indoor environment.

Measure: Compliance with building regulations e.g. in five classes.

Facet 471 Sound absorption

This indicator expressed the sound absorbing properties of the building part.

Measure: Classes (1 – 5) reflecting the sound absorption/reflection properties.

Facet 472 Sound insulation

This indicator expressed the sound insulating properties of the building part.

Measure: Classes (1 – 5) reflecting the sound insulating properties.

Facet 48 Aesthetic quality of building part

This category of indicators addressed the aesthetic quality of the shape, colour, texture and detailing of the building component.

Measure: Descriptive classes (1 – 5) reflecting the overall aesthetics quality.

Facet 481 Shape of building parts in relation to the whole building or space

This indicator expressed the aesthetic quality of the building part's shape and scale seen in relation to the design of the whole building or space.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the shape and scale of the component in relation to the purpose of it, to the function of the building/space, to other components and to building/space as a whole.

Facet 482 Colour and surfaces in relation to the whole building and space

This indicator expressed the aesthetic quality of the colour, material of surface texture of the building part seen in relation to the whole building or space.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the colour, material of surface texture of the component in relation to the purpose of it, to the function of the building/space, to other components and to building/space as a whole.

Facet 483 Details

This indicator expressed the aesthetic quality of the detailing of the building component including the joints between the component and other components or parts of the building.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the detailing of the building component including the joints between the component and other components in relation to the purpose of it, to the function of the building/space and to building/space as a whole.

Facet 49 Experience and feelings

This facet of indicators addressed the user's experience of and feelings for the building component.

Measure: Descriptive classes (1 – 5) reflecting the overall assessment of experience and feelings on building parts or components and the level of satisfaction.

Facet 491 Security

This indicator expressed the user's sense of the safety or security that the building part provided in relation to such things as child-proofing, prevention of personal injury or prevention of break-in or intrusion by strangers.

Measure: Descriptive classes (1 – 5) reflecting the level of satisfaction ranging from 'feeling very safe' – 'feeling uneasy'.

Facet 492 Usability

This indicator expressed the user's sense or experience of the building part's usability (operable, spacious and easy to open or close etc.)

Measure: Descriptive classes (1 – 5) reflecting the function of the part and level of satisfaction.

Facet 493 Well-being

This indicator expressed the building part's attractiveness to the user that could stem from the form, size, scale, beauty, function of the building part.

Measure: Descriptive classes (1 – 5) reflecting the level of satisfaction ranging from 'very pleased/delightful' to 'unpleasing'.

Facet 494 Comfort (thermal, air, light and acoustics)

This indicator expressed the user's sense or experience of comfort that the building part provided (insulation, ventilation, view, light, good sound etc.)

Measure (level 4): Descriptive classes (1 – 5) reflecting the function of the part and the level of satisfaction.

4.5 Facet 5 Facility performance in operation and use

This facet of indicators addressed performance of the facilities management in terms of standard and quality of the operation of the building and the services related to the activities that were situated in the building. It was divided into 5 sub-facets.

The specification of the indicators in this facet was based on the standard *Taxonomy of Facility Management – Classification and Structures* (CEN, 2009). A short review of the standards and research that form the basis for the facets are given in Appendix A.

Figure 17. The fifth main facet of indicators – 5. Facility performance in operation and use.

5. Facility performance in operation and use	
51	Category of tenancy, operation and area of space
511	Type of tenant occupying the building
512	Organisation occupying the building
513	Operation type
514	Size and area of the facility
52	Applicability of the facility
521	Tenancy agreement
522	Branding and certification
523	Meeting owner's strategy
524	Meeting users' strategies
53	Building services related to operation, maintenance and development
531	Administration
532	Operation
533	Maintenance
534	Repair
535	Development
536	Consumption
537	Cleaning
538	Parking
54	Business services related the activities in the building (not building related)
541	Security and safety
542	Reception and switchboard
543	Mail
544	IT service
545	Moving
546	Catering
547	Office supply and copying
548	Administrative support
549	Furniture and inventories
55	Social performance and user experience
551	Employment
552	Social diversity
553	User experience and perception of building services
554	User experience and perception of business services

Facet 51 Category of tenancy, operation and area of space

This facet of indicators addressed the type of tenant occupying the building, the size of the operation, the size of the facility to be able to compare the various indicators between facilities.

Measure: Description in five classes.

Facet 511 Type of tenant occupying the building

This indicator expressed what kind of tenant that occupied the building (functions and type such as lawyer's office, architectural office, university, housing etc.).

Measure: Description.

Facet 512 Organisation occupying the building

This indicator expressed the size and the category of the organisation occupying the building in use e.g. in terms of employees, users, company or organisation applying the facility.

Measure: Number of users/employees and description of organisation reflecting the relevant types of organisation.

Facet 513 Operation type

This indicator expressed how the facility operation was organised and connected to the facility, whether the facility operation was an in-house organisation, an external firm or a combination of the two.

Measure: Descriptive classes reflecting the relevant types of organisation.

Facet 514 Size and area of the facility

This indicator expresses the size of the facility.

Measure: m²

52 Applicability of the facility

This facet of indicators addressed the applicability of the building in terms of image, branding, capacity and workplace management.

Measure: Descriptive five classes reflecting the applicability of the facility.

Facet 521 Tenancy agreement

This indicator expressed the type and time frame of the rental agreements applied on the building.

Measure: Descriptions reflecting the types of tenancy agreements and the time frames of the agreements.

Facet 522 Branding and certification

This indicator expressed the branding or certificates of the building such as its energy efficiency, environmental impact and indoor climate.

Measure: Description (SBA, PromisE, BREEAM, LEED, Energy label).

Facet 523 Meeting owner's strategy

This indicator expressed the building's capacity to accommodate diverse functions and activities.

Measure: Descriptive five classes reflecting the fulfilment of the owner's strategy.

Facet 524 Meeting users' strategies

This indicator expressed to what extent the building complied with the tenant's/user's strategies for example for workplace management.

Measure: Descriptive five classes reflecting the fulfilment of the users' strategy.

Facet 53 Building services related to operation, maintenance and development

This facet of indicators addressed the type, standard and quality of the operation of the facility.

Measure: Five classes reflecting the fulfilment of the building services.

Facet 531 Administration

This indicator expressed the type of organisation of the facility administration (in-house administration, external administration, technical advisor, lawyers).

Measure: Descriptive classes reflecting the type of facility administration.

Facet 532 Operation

This indicator expressed the standard of the facility operation in terms of work resources allocated and user-controlled indoor environment.

Measure: Classes reflecting the resources allocated to operation man-hours/m² or man-hours/user and user control of the indoor environment.

Facet 533 Maintenance

This indicator expressed the quality of the maintenance in terms of procedures and organisation of the maintenance and the serviceability of the facility.

Measure: Classes (1 – 5) reflecting availability of the O&M manual including short- and long-term measures, systematic procedures for updating the manual, and training of staff.

Classes (1 – 5) reflecting the serviceability of the facility:

- Class 1: The whole building and all its parts were in a proper condition
- Class 2: Minor defects existed in parts of the building
- Class 3: Significant defects existed that decreased its performance
- Class 4: Parts of the building were unserviceable
- Class 5: The building was unserviceable.

Facet 534 Repair

This indicator expressed the quality of the repair in terms of the buildings serviceability.

Measure: Classes (1 – 5) reflecting the serviceability of the facility:

- Class 1: The whole building and all its parts were in a proper condition
- Class 2: Minor defects existed in parts of the building
- Class 3: Significant defects existed that decreased its performance
- Class 4: Parts of the building were unrepaired
- Class 5: The building was unrepaired.

Facet 535 Development

This indicator expressed the development strategies regarding the management of the facility such as improvement of energy efficiency, indoor climate or the operation.

Measure: Classes (1 – 5) reflecting the level of development strategies.

Facet 536 Consumption

This indicator expressed the consumptions of resources for heating cooling, electricity, domestic hot water and waste etc.

Measure: Classes (1 – 5) reflecting the level of consumption.

Facet 537 Cleaning

This indicator expressed the standard of the cleaning in the facility in terms of work resources allocated to cleaning, cleaning manual with the required level of quality described and quality control.

Measure: Classes (1- 5) reflecting work-hours /m², classes (1- 5) reflecting the procedures for cleaning manual and quality control.

Facet 538 Parking

This indicator expressed the standard and quality of the facility's car parking including proximity, number of parking places, and the level of sheltering.

Measure: Descriptive classes (1 – 5) reflecting distance, parking place/ user ratio, quality and sheltering. The classes for the two last are for example:

Classes for quality descriptive:

- Class 1: Heated or semi-heated
- Class 2: Cold, covered with plug box
- Class 3: Cold, covered
- Class 4: Cold, uncovered with plug box
- Class 5: Cold, uncovered.

Classes of sheltering:

- Class 1: Heated or semi-heated
- Class 2: Cold, covered with plug box
- Class 3: Cold, covered
- Class 4: Cold, uncovered with plug box
- Class 5: Cold, uncovered.

Facet 54 Business services related to the activities in the building (not building-related)

This facet of indicators addressed the type, standard and quality of the services related to the activities taking place in the building.

Measure: Descriptive classes (1 - 5) reflecting the level of not building related services.

Facet 541 Security and safety

This indicator expressed the standard of the security and safety measures in the facility such as surveillance, guards and locking installations.

Measure: Descriptive classes (1 - 5) reflecting the level of applied security measures.

Facet 542 Reception and switchboard

This indicator expressed the standard and quality of the reception and/or switchboard service in the facility in terms of work allocated resources and the range of the services.

Measure: Classes (1 – 5) reflecting work-hours/user ratio and the range of services provided.

Facet 543 Mail

This indicator expressed the standard the mail system in the facility in terms of mail-sorting services and delivery intervals.

Measure: Classes (1 – 5) reflecting the level of sorting service and intervals of mail delivery.

Facet 544 IT service

This indicator expressed whether there was an internal or external IT support and the standard of the IT service in terms of allocated man-hours for support, number of IT programs and courses.

Measure: Description of type of support plus classes (1 – 5) reflecting man-hour/user support ratio, number of programmes and courses.

Facet 545 Moving

This indicator expressed the easiness of moving internally in the building in relation to TC/IP connections.

Measure: Descriptive classes (1 – 5) reflecting the easiness of moving internally.

Facet 546 Catering

This indicator expressed the standard of the catering such as a canteen with food prepared in the building, external catering or vending machines and the number of meals served per day.

Measure: Descriptive classes (1 – 5) ranging from 'very good' to 'low' reflecting whether there was a canteen with food prepared in the building or only a vending machine or coffee kitchens.

Facet 547 Office supply and copying

This indicator expressed the standard of office supplies, copy machines and printers in terms of proximity of these services and the number of users per machine.

Measure: Descriptive classes (1 – 5) reflecting the vicinity and ratio of e.g. copy machine/printers per user.

Facet 548 Administrative support

This indicator expressed standard of administrative support such as external consultants, outsourcing to extern administrator etc.

Measure: Descriptive classes (1 – 5) reflecting the level of administrative support.

Facet 549 Furniture and inventories

This indicator expressed the standard of the furniture and equipment such as chairs, sofas, lamps and book shelves etc. reflecting the user's need and the ergonomic quality.

Measure: classes (1 – 5) reflecting the furniture/user ratio.

Facet 55 Social performance and user experience

This facet of indicators addressed the social performance and the user's experience.

Measure: Classes (1 - 5) reflecting the overall assessment of the user experience.

Facet 551 Employment

This indicator expressed the diversity of employments in the facility (both in the core business and the facility management).

Measure: Listing the types of employments.

Facet 552 Social diversity

This indicator expressed the diversity of the people/ teams employed in the company or facility regarding their social or cultural background, profession, age and psychical or functional impairment.

Measure: Classes (1 - 5) reflecting the % of different groups.

Facet 553 User experience and perception of building services

This indicator expressed the users' experience of the operation, maintenance, repair, cleaning, and parking conditions.

Measure: Descriptive classes (1 – 5) ranging from 'very satisfactory' to 'not satisfactory' reflecting the percentage of satisfied users.

Facet 554 User experience and perception of business services

This indicator expressed the users' experience and feeling of the security and safety, reception and switchboard, mail, internal moving, catering, office supply, administrative support furniture and equipment.

Measure: Descriptive classes (1 – 5) ranging from 'very satisfied' to 'not satisfactory' reflecting the percentage of satisfied users.

4.6 Facet 6 Process performance in design and construction

This facet of indicators addressed many facets of process management and performance ranging from resource control and project management, work environment to the participants' experience of the process. In this facet of indicators, all participants in the building process could be assessed as well as all sub-processes or the whole process. This meant that the activity assessed (611), the assessed (612) and the assessor (613) had to be defined in relation to the assessment of all the other indicators.

The specifications of the indicators in this facet were based on the ISO 9000 series on Quality management systems (ISO 2008), standard on Environmental management systems (ISO, 2004b), AB 92 (EBST 1992), ABT 93 (EBST 2001) and *A new handover process for construction* (Bertelsen 2009). A short review of the standards and research that form the basis for the facets are given in Appendix A.

Figure 18. The sixth main facet of indicators – 6. Process performance in design and construction.

6. Process performance in design and construction	
61	Category of process, supplier and organisation
611	Activity in the building process that is assessed
612	Assessed party, supplier or organisation
613	The party making the assessment
62	Resource control and project management
621	Control of economy
622	Working plan and time consumption
623	Logistics of materials and equipment
624	Internal cooperation
625	External cooperation
63	Health and safety and work environment
631	Health and safety control and documentation
632	Accidents
633	Physical work environment
634	Mental work environment
64	Quality management
641	Quality control and documentation
642	Operation and maintenance instruction
643	Handover defects and repairs
644	Guarantee for period defects and repairing
65	Experience of participants or involved parties
661	Cooperation and dialogue
662	Involvement of end-users and their needs and wishes
663	Documentation of proposals and solutions
664	Quality of the project material
665	Process management and commissioning process

Facet 61 Category of process, supplier and organisation

This indicator addressed the activity in the building process that was assessed, the party whose performance was assessed and by whom. It was divided into three sub-facets.

Measure: Description the processes in six classes according to Figure 7 CREDIT carpenter model.

Facet 611 Activity in the building process that is assessed

The indicator expressed the activities of tasks in the planning, construction or facility management phases that were assessed.

Measure: Description of the activities in the process (strategic briefing, briefing, design, construction, facility management and use of the building)

Facet 612 Assessed party, supplier or organisation

The indicator expressed the party in the building process whose performance was assessed.

Measure: Description of the parties (client, consultant, contractor, facility manager, operator, organisation, public authority).

Facet 613 Party making the assessment

The indicator expressed the party who was assessing the performance, experience or needs of another party in the building process.

Measure: Description of the parties in the assessment (client, consultant, contractor, facility manager/operator, organisation, public authority, and user).

Facet 62 Resource control and project management

This indicator addressed the project management including the meeting deadlines, keeping the budget, internal and external cooperation. It was divided into five sub-facets.

Measure: Description in five classes reflecting different standards of project management.

Facet 621 Control of economy

The indicator expressed whether the budget was kept or overrun in the project.

Measure: Classes (1 – 5) reflecting how well the budget was kept ranging from 'much overrun' to 'kept all the way' or the size of the exceeding of the budget in %.

Facet 622 Working plan and time consumption

The indicator expressed whether the schedule and the planned consumption of time were kept.

Measure: Classes (1 – 5) reflecting how well the time schedule was kept ranging from 'much delayed all the way' to 'delivered on time all the way' and how well the planned consumption of time was kept or overrun in %.

Facet 623 Logistics of materials and equipment

The indicator expressed the availability of material and equipment when needed as well as the amount of wastage and pilferage.

Measure: Classes (1 – 5) reflecting the availability of the material and equipment, the right materials and equipment on time in the right quantity and quality. Classes (1 – 5) reflecting the amount wastage removed from the site in kg. Classes (1 – 5) reflecting the amount of pilferage.

Facet 624 Internal cooperation

This indicator expressed how well the internal cooperation with client and other involved in the process was.

Measure: Classes (1 – 5) reflecting the number of conflicts and positive reflections occurred during the building process or/and the level of satisfaction among the cooperating teams registered in surveys.

Facet 625 External cooperation

This indicator expressed how well the external cooperation with users, authorities and the press was.

Measure: Classes (1 – 5) reflecting the number of conflicts and positive reflections occurred during the project or the level of satisfaction registered in surveys.

Facet 63 Health and safety and work environment

This indicator addressed the quality of the work environment and the level of safety. It was divided into 4 sub-facets.

Measure: Five classes reflecting the overall assessment of health, safety and work environment.

Facet 631 Health and safety control and documentation

This indicator expressed the steps taken to ensure healthy and safe working conditions.

Measure: Classes (1 – 5) reflecting the level of the applied precautions ranging from 'few' to 'many' and 'compliance with the legal requirements' as the middle class.

Facet 632 Accidents

This indicator expressed the number of injuries occurred during the building process. An (industrial) injury was defined as a sudden, unexpected injurious accident that happened at work and lead to personal injury.

Measure: Classes (1 – 5) reflecting the number of injuries and their severity in proportion to contract sum given in billions.

Facet 633 Physical work environment

This indicator expressed the quality of the physical work environment in the building process.

Measure: Classes (1 – 5) reflecting the number of days with employees absent/ total work days as well as surveys of the employees' perception of the physical work environment ranging from 'very good' to 'hard'.

Facet 634 Mental work environment

This indicator expressed the quality of the mental work environment in the building process.

Measure: Classes (1 – 5) reflecting the number of days with employees absent/total work days as well as surveys of the employees' perception of the mental work environment 'very good' to 'unpleasant'.

Facet 64 Quality management

This indicator addressed the quality of the management of the building process. It was divided into 4 sub-facets.

Measure: Five classes reflecting the overall assessment of quality management.

Facet 641 Quality control and documentation

This indicator expressed to what extend quality control had been planned and documented during the building process. In addition the indicator could also express whether the client/consultant/contractor had been chosen based on quality certificates or other documentation of quality control.

Measure: Classes (1 – 5) reflecting the level of quality control. Classes (1 - 5) of the quality control certification, where 1 was an international certification audit by official authorities and 5 was no certification.

Facet 642 Operation and maintenance instruction

This indicator expressed the level/amount of instruction applied activity during commissioning.

Measure: Classes (1 – 5) reflecting the instruction level.

Facet 643 Handover defects and repairs

This indicator expressed the number of defects and repairs as well as their severity registered when handing over.

Measure: Classes (1 – 5) reflecting the number of defects and the work hours and cost for repairing them.

Facet 644 Guarantee for period defects and repairing

This indicator expressed the number of defects and repairs as well as their severity registered during the warranty period.

Measure: Classes (1 – 5) reflecting the number of defects and repairs as well as their severity during the warranty period and the work hours and cost of repairing them.

Facet 65 Experience of participants or involved parties

This indicator addressed either the client's or the end-user's experience of the building process and of the performance of the participating parties.

Measure: Five classes reflecting the overall assessment of the experience of the involved parties.

Facet 661 Cooperation and dialogue

This indicator expressed the client's experience of the cooperation and dialogue during the building process with the participating party in question.
Measure: Classes (1 – 5) reflecting the level of satisfaction with the cooperation and dialogue, ranging from 'very good' to 'very bad'.

Facet 662 Involvement of end-users and their needs and wishes

This indicator expressed the client's or end-user's experiences of how much end-users have been involved and their needs have been integrated in the planning and building process in relation to the participating part in question.
Measure: Classes (1 – 5) reflecting the level of satisfaction with the end-user involvement ranging from 'very involved and needs integrated' to 'no involvement'.

Facet 663 Documentation of proposals and solutions

This indicator expressed the client's, consultants' and contractors' and other parties' documentation of different proposals and solutions in the different construction and real estate phases.
Measure: Classes (1 – 5) reflecting the level of satisfaction with the documentation from 'very good' to 'very bad'.

Facet 664 Quality of the project material

This indicator expressed the client's consultants, contractors and suppliers assessment of the quality of the project material.
Measure: Classes (1 – 5) reflecting the level of fulfilling the agreed quality level of the project materials from 'very good' to 'very bad'.

Facet 665 Process management and commissioning process

This indicator expressed the client's, consultants', contractors' and suppliers' experience of the process management and information and instruction in the commissioning process.
Measure: Classes (1 – 5) reflecting the feeling of having received the relevant instruction and information, ranging from 'very well informed' to 'lacking information'.

4.7 Facet 7 Impact environmentally, socially and economically

This facet of indicators addressed the impact that the building had on the environment viewed in a life cycle impact perspective, which included the impact from the material production, transportation of materials, construction, use phase, operational use phase, and end of service life. The big group of indicators in the facet addressed the environmental impact, but the facet included also the sub-facets of impact socially and economically.

The specification of indicators in this facet was based on the standards *Building Construction – Sustainability in Building Construction* (ISO, 2009) and *Sustainability of construction works – Environmental product declarations* (Dansk Standard, 2009 b). A short review of the standards and research that form the basis for the facets are given in Appendix A.

Facet 71 Plot

This facet of indicators addressed the building's impact on the eco-system in terms of brown-fields, non-permeable layers and thereby on the local eco-system.
Measure: Five classes reflecting the overall impact on the plot.

Facet 711 Reuse of land

This indicator expressed the avoided consumption of green land thanks to reuse of brown-fields and derelict areas, refurbishment, filling gaps and development of existing built environment.

Measure: Five classes reflecting a grading of the type of reuse of land and the type of brown-field-use, percentage of true green field versus brown-field.

Facet 712 Soil sealing

This indicator expressed the area covered by low or non-permeable layers because of buildings, yards, roads, vehicle parks and other constructed assets.

Measure: Classes (1 – 5) reflecting the level of non-permeable layers in relation to the area of the building (m²/ m²).

Facet 713 - Eco-system and biodiversity

This indicator expressed the impact that the building had on the local ecosystem and the biodiversity as a result of the degree of use or reuse of land and soil sealing.

Measure: Classes (1 – 5) reflecting the degree of use or reuse of land and soil sealing.

Figure 19. The seventh main facet of indicators – 7. Impact environmentally, socially and economically.

7. Impact environmentally, socially and economically

71 Plot

711 Reuse of land

712 Soil sealing

713 Eco-system and biodiversity

72 Emissions

721 Climate change

722 Destruction of the stratospheric ozone layer

723 Acidification of land and water sources

724 Eutrophication

725 Formation of tropospheric ozone photochemical oxidants

726 Ionising radiation

73 Resources

731 Energy efficiency

732 Depletion of non-renewable material resources

733 Use of renewable material resources

734 Use of renewable energy resources, primary energy

735 Use of non-renewable energy resources, primary energy

74 Waste to disposal

741 Hazardous waste

742 Non-hazardous waste

743 Radioactive waste

75 Social and economic impact on the local community

751 Architectural – spatial impact

752 Impact on the cultural heritage

753 Impact on the social life in the local community

753 Increase in value of neighbouring plots or neighbourhood

Facet 72 Emissions

This facet of indicators addressed the building's impact on the environment in terms of harmful emissions to the air, water and soil viewed in a life cycle impact perspective.

Measure: Five classes reflecting the overall importance of emissions.

Facet 721 Climate change

This indicator expressed the impact that the building had on climate change in a life cycle impact assessment (LCIA) perspective.

Measure: Classes (1 – 5) reflecting the level of kg CO₂ per m².

Facet 722 Destruction of the stratospheric ozone layer

This indicator expressed the building's contribution in a life cycle impact assessment (LCIA) perspective to the destruction of the stratospheric ozone layer.

Measure: Classes (1 – 5) reflecting the level of kg R11/m².

Facet 723 Acidification of land and water sources

This indicator expressed the building's contribution in a life cycle impact assessment (LCIA) perspective to the acidification of the land and water resources.

Measure: Classes (1 – 5) reflecting the level of kg SO₄/m².

Facet 724 Eutrophication

This indicator expressed the building's contribution in a life cycle impact assessment (LCIA) perspective to eutrophication (an increase in the concentration of chemical nutrients in an eco-system that influences the ecological balance and biodiversity) of the environment.

Measure: Classes (1 – 5) reflecting the level of kg PO₄/m².

Facet 725 Formation of tropospheric ozone photochemical oxidants

This indicator expressed the building's contribution in a life cycle impact assessment (LCIA) perspective to the pollution with/formation of tropospheric ozone photochemical oxidants.

Measure: Classes (1 – 5) reflecting the level of kg Ethene/m².

Facet 726 Ionising radiation

This indicator expressed the building's contribution in a life cycle impact assessment (LCIA) perspective to ionising radiation.

Measure: Classes (1 – 5) reflecting the level of emission of radioactive isotopes in kBq./m².

Facet 73 Resources

This facet of indicators addressed the use of resources both material and energy resources through the life cycle of the building.

Measure: Five classes reflecting the overall importance use of resources.

Facet 731 Energy efficiency

This indicator expressed the energy efficiency of the building.

Measure: kWh/m² Classes A (1) – G reflecting the energy efficiency in kWh/m².

Facet 732 - Depletion of non-renewable material resources

This indicator expressed the building's contribution to the depletion of non-renewable material resources other than primary energy through its life cycle (material production, transport, construction, use and end of life).

Measure: Classes (1 – 5) reflecting the level of kg Fe/m² distributed on various materials (Zink, cobber, limestone, sand, granite etc.)

Facet 733 Use of renewable material resources

This indicator expressed the amount of renewable material resources other than primary energy that had been used in the building through its life cycle (material production, transport, construction, use and end of life).

Measure: Classes (1 – 5) reflecting the level of kg/m².

Facet 734 Use of renewable energy resources, primary energy

This indicator expressed the consumption of renewable resources, primary energy through the life cycle of the building (material production, transport, construction, use and end of life).

Measure: Classes (1 – 5) reflecting the level of MJ/m².

Facet 735 Use of non-renewable energy resources, primary energy

This indicator expressed the consumption of non renewable resources, primary energy (coal, lignite, natural gas, uranium, secondary fuels) through the life cycle of the building (material production, transport, construction, use and end of life).

Measure: Classes (1 – 5) reflecting the level of MJ/m².

Facet 74 Waste to disposal

This indicator addressed a building's impact through its whole life cycle on the environment in terms of its contribution to the production of hazardous waste.

Measure: Five classes reflecting the overall quantity of waste to disposal.

Facet 741 Hazardous waste

This indicator expressed the building's contribution to the production of hazardous waste in a life cycle impact assessment (LCIA) perspective.

Measure: Classes (1 – 5) reflecting the level of kg/m².

Facet 742 Non-hazardous waste

This indicator expressed the building's contribution to the production of non-hazardous waste in a life cycle impact assessment (LCIA) perspective.

Measure: Classes (1 – 5) reflecting the level of kg/m²

Facet 743 Radioactive waste

This indicator expressed the building's contribution to the production of radioactive waste in a life cycle impact assessment (LCIA) perspective.

Measure: Classes (1 – 5) reflecting the level of kg/ m².

Facet 75 Social and economic impact on the local community

This facet of indicators addressed the impact that the building had on the environment socially such as architectural impact, social lift of a rough neighbourhood, preservation of cultural heritage.

Measure: Five classes reflecting the overall importance of the impact on the local community.

Facet 751 Architectural – spatial impact

This indicator expressed the building's contribution to maintaining and improving architectural quality in the area where it was located.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the building's form, scale, material and space in relation to the context.

Facet 752 Impact on the cultural heritage

This indicator expressed the building's contribution to maintaining and improving the cultural heritage at its location.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the building's impact on or preservation of the spatial, symbolic, or historical quality of the context.

Facet 753 Impact on the social life in the local community

This indicator expressed the building's contribution to the maintaining and improving the social life in the community.

Measure: Descriptive classes (1 – 5) reflecting an assessment of the building's impact the social life in the local area.

Facet 754 Increase in value of neighbouring sites or the neighbourhood

This indicator expressed the impact that the building had on the increase of value on the neighbourhood.

Measure: Classes (1 - 5) reflecting the increase of value of the neighbouring plots/buildings.

5 Discussion and conclusions

In this chapter conclusions from the process leading to CREDIT performance indicator framework are presented.

First the research focus is discussed and how performance indicators are presented in seven independent facets and expanded to two levels of sub-facets comprising a total of 187 individual performance facets. Next the CREDIT performance indicator framework is discussed in relation to international standards and national building regulation, assessment methods and benchmarking schemes, building types and segments in the building process. The chapter is completed by a proposal on how to implement performance indicators in different segments.

5.1 Research objectives, methods and focus

From the general aim and the specific objectives in the project description and the additional recommendations in the state-of-the-art report (CREDIT Report 1 State-of-the-Art) we extract that the CREDIT performance indicator framework must:

- Improve transparent value creation in both construction and real estate.
- Develop an international performance classification framework focusing on the first step needed by the Nordic and Baltic countries.
- Provide recommendations for international key indicators for buildings.
- Focus on performance demands and requirements to buildings to satisfy the end-user needs and functions of the building rather than to follow a prescriptive approach.
- Distinguish between the demand and the supply perspective in the construction and facility management process.
- Secure that the needed performance information is available throughout the life cycle of the building.

The performance indicator framework developed in CREDIT is a 'gross' inventory of indicators relevant in relation to the construction and real estate sectors in the seven Nordic and Baltic countries: Denmark, Finland, Norway, Sweden, Iceland, Estonia and Lithuania. The content of CREDIT Report 3 is based on the findings of the 28 CREDIT case studies as well as on input from national building regulations and different standards and research topics. The performance indicator framework was developed concurrently with the case study and the study of assessment methods and tools and international benchmarking presented in CREDIT Reports 2, 4 and 5 respectively.

5.2 Performance indicators in seven independent facets

A simple and understandable structure of performance indicators in seven independent facets was developed by CREDIT. The first facet reflected costs and price through the life cycle of the building. The five next facets addressed performance of location, buildings, building parts, facility management and the design and construction processes. They all included both objective measurable performance indicators and indicators that addressed less measurable properties as well as the end-users' experience and feel-

ings. The final facet was the impact of the building on the external environment, social life and economy.

Figure 35. The seven main facets and the first level of sub-facets of the CREDIT performance indicator framework.

1. Costs, price and life cycle economy (LCE)
11 Capital, investment, construction, commissioning and decommissioning costs
12 Building services related to operation, maintenance and development
13 Business services related to the activities in the building (not building-related)

2. Location, plot, region and country
21 Location and address
22 Socio-cultural context
23 Plot opportunities
24 Spatial solution and plot aesthetics
25 Services in surrounding area
26 User experience and feelings

3. Building performance and indoor environment
31 Category of building, quantity, size and area
32 Safety and security
33 Usability and adaptability
34 Thermal climate
35 Air quality
36 Lighting conditions
37 Acoustic climate
38 Aesthetic quality of building and indoor spaces
39 User experience and feelings

4. Building part and product performance
41 Category of building part, quantity, size and area
42 Safety
43 Usability and durability
44 Thermal quality
45 Impact on air quality
46 Lighting quality
47 Acoustic quality
48 Aesthetic quality of building part
49 User experience and feelings

5. Facility performance in operation and use
51 Category of tenancy, operation and area of space
52 Applicability of the facility
53 Building services related to operation, maintenance and development
54 Business services related the activities in the building (not building-related)
55 Social performance and user experience

6. Process performance in design and construction
61 Category of process, supplier and organisation
62 Resource control and project management
63 Health and safety and work environment
64 Quality management
65 Experience of participants or involved-parties

7. Impact environmentally, socially and economically
71 Plot
72 Emissions
73 Resources
74 Waste for disposal
75 Social and economical impact on the local community

Figure 36. Number of facets at the three levels of facets.

Main facets of performance indicators		Sub-facet 1	Sub-facet 2
1. Costs, price and life cycle economy (LCE)	1	3	24
2. Location, plot, region and country	1	6	31
3. Building performance and indoor environment	1	9	36
4. Building part and product performance	1	9	26
5. Facility performance in operation and use	1	5	29
6. Process performance in design and construction	1	5	21
7. Impact environmentally socially and economically	1	5	20
Number of facets at each level:	7	42	187

Figure 37. Example of how an indicator is described in a facet or sub-facet by title, definition and how to measure the indicator and classify the results

Main facet – Title: 3. Building performance and indoor environment

Sub-facet 1 – Title: 36 Lighting conditions

Sub-facet 2 – Title: 361 Daylight access

Definition: Indicator expressing whether there is access to daylight in the room/building and the window area relative to the floor area.

Measure: Glass area / floor area ratio in % and the daylight factor in classes from A – E. See Appendix A6 for definition of the classes.

Each of the seven main facets in the CREDIT performance indicator framework was divided into two levels of sub-facets with an increasing level of detailing ending with 187 facets at sub-facet level 2. Each facet at the three levels of facets was given a one-line title and a brief description of a few lines. In addition, the unit by which the facet was measured is also described. When possible, the definitions of units and classes of measures were taken from standards and national regulations, or otherwise CREDIT proposed a common scale of measures in 5 steps e.g. classes A, B, C, D and E, where class A was the best.

Because of its all-encompassing character, the CREDIT performance indicator framework could work as a tool to improve the performance of buildings as well as to support the cooperation between the parties in the construction and real estate sectors.

End-user's experiences and feelings are important and they were included in five of the seven facets: Location, building performance, building parts performance, facility management, and process performance. This was done with the intention of focusing on values as well as end-user needs and expectations more than on price, costs and standard of execution, and equipment seen from the suppliers' point of view.

It was also important to get a better understanding of how the built environment could create value for the end-users and increase outcome of activities housed in the building. One focus was the assessing of indicators that were directly linked to the building or the perception of it, which was the main focus of the CREDIT project. A second focus was the assessing of indicators that could link the productivity of the enterprises involved with the different processes in construction and real estate, which is the primary focus in the building sector today. The third focus could be to change the view of the

building as an expense to it being a social and economic advantage for the business and the activities in the building in use. This might be a way forward towards in the future.

5.3 Indicators in international standards and national regulations

The CREDIT performance indication framework was linked to both international standards and national regulations. The success of improving transparency of value creation depends on the synergy and the coherence between them.

CREDIT performance indicators and international standards

Selected areas of international standards and research fields were analysed as background for the specification of the CREDIT performance indicator framework. Included were important standards and research experience of the following fields:

- Life cycle economy
- Facility management
- Environmental impact
- Quality management
- Energy consumption
- Indoor climate
- Architectural design and evaluation.

The analyses showed that each standards and research area encompassed a lot of detailed information and included typically one or more of the seven CREDIT indicator facets at the same time. The task was therefore to compress the enormous amount of information into the common and transparent CREDIT performance indicator framework. From the perspective of the different research fields the relation to other research fields was not always easy to see. Likewise, it could be difficult from the same perspective to 'accept' the necessity to translate their expert knowledge to a simple CREDIT framework that targeted the end-user, enterprises, building projects in construction, facility management as well as real estate.

On the other hand, international standards and knowledge in the different research fields is one of the primary foundations for an international indicator classification. In the future it will therefore be important constantly to coordinate and eventually adjust the CREDIT performance indicator framework according to new experience gained by research and international standards. At the same time it is also vital that there must be at constant pressure on research and international standards to be transparent and coherent according to a common system such as the CREDIT proposals.

CREDIT performance indicators and national regulations

The building regulations in five of the seven CREDIT countries were compared to discover inconsistencies between the CREDIT performance indicator framework and the national regulations. All the national building regulations are based on performance-based requirements with a few exceptions. By and large, the indicator framework corresponds to the national regulations. But there are facets of the performance indicators that are not included in the national regulations.

Generally facility management is not addressed in the regulations except for requirements for parking facilities. Nor is process performance and process management addressed except for requirements for commissioning proc-

esses in the Norwegian regulations. All the regulations except the Icelandic have requirements for energy consumption and classes ranging from A (A1 in DK) to G for energy efficiency that follow the European directive. The minimum requirement for energy efficiency in new buildings is energy class B in Denmark and C in Norway. In Denmark and Norway there is only one climate zone in relation to the assessment of energy efficiency whereas Sweden operates with two climate zones.

The Norwegian building regulations have applied the concept of 'Universal design', whereas the other countries operate with the concept of 'accessibility' for ensuring access for disabled persons. These two concepts imply two different approaches to the design of the building and the extent of 'accessibility'.

Besides these differences in the regulations, the size of the five countries and the density of the populations in the individual countries constitute different backgrounds for the assessment of some of the indicators. For example the assessment of distance must be relative to the density of the area. It would not make sense to assess distance with the same measure in the north of Sweden as in the suburbs of Stockholm, of course depending on the purpose with the assessment. Likewise the climate constitutes a basis that differs regarding e.g. load bearing capacity of the construction due to snow, resistance to wind and, as we can see in the regulations, achievement of energy efficiency.

If indicators in national regulations will be more transparent and support international benchmarking better in the future, they should have an unambiguous relation to a system such as the CREDIT performance indicator framework and international standards. A possibility might be to expand the numbers of facets and the CREDIT indicators to be included in the national regulations or to make an adjustment according to the CREDIT performance indicator framework. The background for such a decision could for example be a more detailed analysis of the inconsistencies in national regulations and norms compared with CREDIT indicators.

5.4 Indicators in relation to assessments and benchmarking

Below the CREDIT performance indicator framework will be discussed in relation to assessment methods and tools and national and international benchmarking

Indicators in relation to assessment methods, tools and decisions

We see five groups of patterns in the relation between specific indicator and the applied assessment methods, tools and decisions:

- 1 End-user needs, experiences and feelings are included in five facets of performance: Location, building and building part, facility management and process management. They are captured through interviews and surveys and assessed with calculations of different satisfaction level.
- 2 Usability, adaptability, spatial and aesthetic quality are registered and assessed by professionals through observation, analysis of the actual building and drawing material.
- 3 Input on indoor climate, environmental impact, construction safety, bearing load etc. are gathered with measurements. These are compared either directly or after a calculation with recommended values or threshold values.

- 4 Information on the meeting of deadlines, compliance with standards, keeping of budget etc. are gathered from contracts, time schedules, budgets, and potential deviations are registered and calculated.
- 5 Input on economy is gathered from accounts and costs and price per unit is calculated.

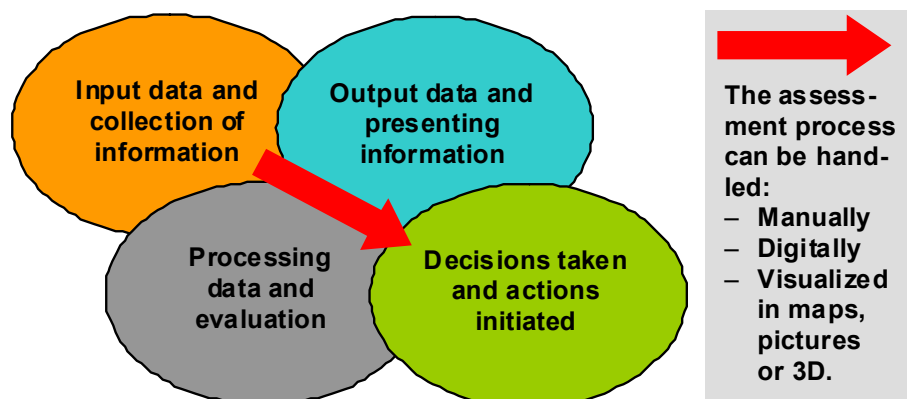
In some instances the three parts of the assessment (collect input data; processing and evaluation; present and output data in Figure 38) are separate phases or actions, perhaps even made by different persons. In other instances they overlap and are difficult to separate.

An example of a classic assessment that clearly fits into the three phases of assessment could be the Danish energy labelling system. Data on what the building consists of, how well it is insulated and the convective properties of the building components are collected by inspecting the building and the drawing material. These data form the basis for the calculation (processing and evaluation in Figure 38) of the buildings energy consumption. Output data are the calculation presented as classes ranging from A – G.

In other instances the collection of data and the processing and evaluation of them can be made almost simultaneously. For example the expert in building construction or accessibility etc. compares the measurements with the predefined standards or recommended dimensions. Dimensions he has at hand or in his head. Therefore, he is able to class the building and space or construction immediately while inspecting the building or the drawing material.

The presentation of information and the final decision of how to act can take place simultaneously as well. A user that needs to decide which building to buy or lease for his expanding firm in relation to access to services and infrastructure can use a map as a simple tool. With a map in his hands that indicate the building in question as well as the nearest public transportation, motorway exit, shopping mall etc., he can without any calculation make an immediate decision on the advantages of the building's location.

Figure 38. The assessment of indicators from the input of data to presentation and decision, as described in the model in Figure 6, can be treated individually or overlapping in an assessment process that can be handled manually, digitally and visualised in maps, pictures and 3D.



Indicators in relation to national and international benchmarking

When looking at the level of national benchmarking, it appears that the distribution pattern of indicators between the public mandatory benchmarking framework focus on the performance aspects (experienced and professionally measured spatial quality, quality of execution, process performance and

energy performance). In this group of benchmarking frameworks there is only one exception, where the focus is on economy, life cycle costing and energy consumption costs.

In the private and semiprivate systems, economy is the prime focus, either alone or in combination with FM or location. The search engine for real estate, for example seen in the Danish "Boligsiden" (in English: The Housing page), covers all facets with the priority set by the user and the potential buyer. But still the basic indicators or search criteria are location, price and size.

The CREDIT case study also indicates a tendency of change in the presentation of output depending on whether it is a first generation or 'young' benchmarking organisation or it has been revised a few or several times and is a more 'mature' benchmarking organisation.

In the 'young' organisation the output is characterised by being a documentation and presentation of "unprocessed" input data typically of a technical kind that is only comprehensible for persons with insight in the area. It was for example seen in the first versions of indicators, when The Benchmark Centre for the Danish Construction Sector was established in 2002. In the second generation organisations the output is input data that e.g. have been calculated and translated into a class in a ranking. It is for example seen in the European energy certification system. Output in the third generation organisations is user-defined through filters so the user only gets the information relevant for his purpose.

Figure 39. The indicators are presented differently in a 'young' benchmarking organisation compared with a more 'mature' benchmarking organisation.

Ordering of indicators	Linear listing of indicators		Third generation
	Facetted – a, b, c, d....		Second generation
	Hierarchical 1, 2, 1.1, ... 2.1, ... 111, ... 211, ...	First generation	
		Input data presented unprocessed	Output presentation e.g. in ranked classes
			Tailored presentations including pictures, maps and 3D models
		Presentation levels	

The output can be a mixture of assessments that rely on expert knowledge and make a specialised knowledge available for the common user in a simple form such as classes. It can also be data such as maps with an indication of the location of the building, a plan or 3D model put in relation to other data making the user able to assess the data himself. An example of this kind of presentation of information is the Danish Home search engine, where you can insert filters in your search that are relevant for your wishes such as vicinity to nursery or kindergarten.

The changes in the presentations are parallel to another tendency in the development of the classification of entries or indicators in the systems. Regarding the classifications, there is a movement away from a hierarchical classification of data as something that cannot be added from data at lower levels like we cannot add apples and pears. And there are even examples of systems with a completely flat and linear listing of indicators that are totally searchable as seen for example on the Internet.

CREDIT performance indicator classification is a faceted classification with output presentation in classes in a ranking, but it can also include a more visualized presentation system fit for the end-users needs as in a third generation system according to Figure 39.

5.5 Indicators in relation to product and process segments

According to the CREDIT product and process models and selected segments described in Chapter 2, the performance indicator framework is discussed in relation to the following essential segments:

- Different building categories.
- Processes in the life cycle of the building.
- Enterprises supplying the construction and real estate sector.

Indicators in relation to different building categories

Non-profit housing is where most types of assessments and indicators are applied ranging from location of the building, building performance, facility management, process performance as well as costs and aspects of environmental impact. Furthermore, it is in relation to public housing that the end-users' experiences and feelings play an important role in the assessments. The assessments of the other building categories are limited to one or two indicators only apart from private dwellings, and they are all primarily based on measurements and calculations.

It is not possible on the basis of the case studies to link certain indicators to specific building categories. Non-profit housing and private dwellings seem to be the building categories where a broad range of indicators are addressed. Despite this, it cannot be argued that user experiences and the technical standard of the building are more important in relation to housing and dwellings than to university or office buildings. Probably, the differences of how to apply indicators more extensively reflect that the users of the assessment differ (building client, consultant, facility manager, potential buyer or investor) as well as the purpose of the assessment. Besides, it tells us more about where the focus is right now in the management of the various building categories and enterprises.

Indicators in relation to processes in the life cycle of the building

The indicators have three different purposes depending on where and when in the building process they are addressed. In the initial phases, they serve as specifications or requirements in the briefing and programming phase. During the design and construction phase they serve as guidelines for the design and how to compare qualities and specifications of building and components in order to meet the requirements. After completion, they serve as tools for assessing the performance and the economic potential of the finished building, and as a delivery to facility management and the users of the building.

The Danish cases show for example that all main facets (not all indicators) are assessed after completion of the construction phases, either in connec-

tion with the commissioning or during the FM and use phase (costs, location, performance of building and building part, FM, process and environmental impact). The only indicators in the cases that are assessed or addressed early and late in the building process are acquisition costs (estimated and actual) in connection with size and location, social context, end-user needs and energy efficiency (estimated). Energy efficiency and acquisition costs are assessed after every phase (briefing, design, construction and FM), whereas the focus on end-user needs seems to fade as the building process advances.

Many other indicators are of course addressed during design and construction in order to comply with the general requirements in the brief of the building or the building regulations, but as an integrated part of the design and construction process with no impartial assessor involved. The building permit from the local authority is a professional assessment of whether the designed building complies with the building regulations.

Indicators in relation to enterprises in construction and real estate

The building clients and owners in the CREDIT cases address primarily qualitative performance indicators of location, buildings, components and process. The indicators in focus are e.g. end-user experiences and feelings; building parts and components insulating qualities; durability and defects; and facility performance.

The assessment of facility and operation performance focuses primarily on the costs of facility management in order to compare the expenses of one facility with another. Whereas building, rooms and building parts performance are not addressed in operation of facilities. The consultant addresses primarily the end-users' experiences and feelings of location and building performance as a tool for developing a brief that comprises the end-users' wishes.

When we looked at enterprises that facilitate sale or invest in real estate their prime focus on costs, price and income and total return, and the indicators are relation to the category of building and its use, size and location.

Besides the basic indicators on location, building categories, size and price there are no indicators that turn up in many cases and thus could be obvious options for common key indicators in the future. On the contrary, importance and relevance of specific indicators seem to be linked to the purpose of the assessment as well as the type of enterprise.

5.6 Implementing CREDIT performance indicators framework

The CREDIT performance indicator framework established an overall framework for classification as part of the CREDIT performance information model. At this first stage the focus of implementation in the CREDIT project was on the construction and real estate sectors in the Nordic and Baltic countries. To implement and disseminate the application of the CREDIT performance indicator framework, the following initiatives are essential:

1. Informing and presenting the indicator framework broadly in the Nordic and Baltic countries including preparing easy-to-read presentation material.
2. Forming a Nordic and Baltic expert group with related reference groups representative of the important segments and users of the CREDIT performance information model to implement and adjust the model according to new experience.

3. National regulations and international standards and have to be coordinated in interaction with the indicator framework.
4. The indicator framework has to be applied in analyses and improvements of existing benchmarking schemes in various cross-border segments according to.
5. Selection of a few key performance indicators for everyday use according to the following proposal.
6. Improving the maturity level for important performance indicators according to the following proposal.

Selection of a few key performance indicators for everyday use

In a CREDIT context key performance indicators could be the seven main facets of indicators reflecting seven important characteristics of building and real estate that the CREDIT performance indicator framework comprises. Or it could be more specific or detailed indicators at sub-facet level 2 reflecting a specific building type as well as a specific user or purpose. Or it could be ten important indicators common for all uses and purposes.

Figure 40. A proposal of 10 key performance indicators reflecting the needs of a building owners or the facility manager.

Key	Main facets	1st sub-facets	2nd sub-facets
Key 1:	1. Costs, price and life cycle economy (LCE)		
	2. Location plot, region and country		
Key 2:		23 Plot opportunities	
Key 3:			252 Access to public transport
	3. Building performance and indoor environment		
Key 4:			332 Adaptability to needs (now and over time)
Key 5:	34 Thermal climate		
Key 6:			352 Pollutants in indoor air
	4. Building part and product performance		
	5. Facility performance in operation and use		
Key 7:			521 Tenancy agreement
	6. Process performance in design and construction		
Key 8:			622 Working plan and time consumption
	7. Impact environmentally, socially and economically		
Key 9:			721 Climate change (CO ₂)
Key10:			731 Energy efficiency

The case studies showed that there were only a few performance indicators that turned up in all cases or in relation to all building categories and therefore could be selected as common key performance indicators in CREDIT. These few common key performance indicators were of a basic character namely: Location, building type, size/area and price/costs. Otherwise the indicators vary primarily depending on the purpose of the assessment and on the user or recipient of the assessment. There did not seem to be a strong linkage between particular indicators and specific building categories.

Therefore CREDIT proposed that several groups of key performance indicators are defined, reflecting the needs of specific users/recipients (end-user, client, authorities, contractors, consultants) of the assessments and benchmarking as well as the needs linked to particular phases in the life cycle of the building.

With the interests and needs of the building owner/client in mind, a set of 10 key performance indicators was proposed with indicators from all facets of

the classification and on various levels of facets, see Figure 40. Other proposals could be prepared in the future as alternatives and for other purposes.

Improving the maturity level for important performance indicators

The various indicators described in the CREDIT performance indicator framework are at very different stages concerning their readiness for inclusion in national or cross-boarder benchmarking. Some of the indicators are already being applied in national benchmarking and international certification schemes in many or all the CREDIT countries and they are covered by international standards. This includes many but not all the indicators on indoor climate, energy efficiency, environmental impact and facility management. To use these indicators in cross-boarder benchmarking requires translation and harmonisation.

For example, in Denmark, Norway and Finland there are certification systems for indoor climate, but the definitions of the classes are not identical. Another example is the indicators on environmental impact. There are international certification schemes (BREEAM, LEEDS, The Nordic Eco-label (The Swan) and The European Eco-label (The Flower)) where many of these indicators are already being assessed. Even though some of these certification systems operate with different classes of certificate, the indicators included have to be translated from a system of weighting in the certification to CREDIT's five classes for each indicator.

Figure 41. Examples of indicators at different stages of development in relation to international benchmarking and standards.

Maturity levels of indicators	Relevant indicator
5. Indicators applied in cross boarder international benchmarking	
4. Indicators assessed nationally in the CREDIT countries based on international standards.	<ul style="list-style-type: none"> – Indoor climate in facets 3 and 4 – Facility performance in operation and use in facet 5 – Impact on the environment, social life and economy in facet 7 – Energy in facets 3, 4, 5 and 7
3. Indicators defined in international standards including what is measured, method and classes.	<ul style="list-style-type: none"> – Costs, price and life cycle economy in facet 1 – Process performance in design and construction in facet 6 – End-user experience in facets 2, 3, 4, 5 and 6.
2. Indicators defined in international standards including what is measured, but not method and classes	<ul style="list-style-type: none"> – Safety in facet 3 – Accessibility in facet 3
1. Indicators that are not defined in international standards and indicators of relative character	<ul style="list-style-type: none"> – Aesthetic quality in facets 2, 3 and 4 – Cultural heritage in facet 2

Other groups of indicator are not quite as readily applicable in cross-boarder benchmarking. This includes areas like process performance and life cycle costing both covered by international standards. In these areas the barrier is the differences in accounting procedures and to determine the amounts and sizes both on the national as well as the international level.

Another group consists of indicators that are only possible to separate into in two classes: Compliance with building regulations or not. This group includes areas such as accessibility, construction safety and fire safety. The reason differs as to why they are not applicable right now.

Accessibility is described in national and international standards, but the required level of accessibility is not the same in the seven CREDIT countries. Norway for example has implemented Universal design as a standard. At the moment it is only possible to describe whether it complies with the building regulations, while measuring the compliance with requirements in classes is not yet possible.

Construction safety and fire safety are very well covered by international standards with national annexes. These require compliance with the standards and building regulations and do not define classes of quality but instead classes of risk, thus reflecting the impact of a potential accident depending on the use of the building.

Yet another group consists of indicators of a relative character. This includes indicators addressing usability, architectural or aesthetic quality and cultural heritage. Some of these indicators are included in international standards, but are not defined or recognising that they either depends on building function or on cultural or national values.

Figure 42. CREDIT estimate of the years of development for selected indicators ready for international benchmarking in relation to internationally agreed classes and standards

		Years of development		
		5 years	10 years	20 years
5. Indicators applied in cross-boarder international benchmarking:				
– Indoor climate in facets 3 and 4	– Costs, price and life cycle economy in facet 1			
– Performance in operation and use in facet 5	– Process performance in design and construction in facet 6			
– Impact on the environment, social life and economy in facet 7	– Accessibility in facet 3			
– Energy in facets 3, 4, 5 and 7	– Cultural heritage in facet 2			
– End-user experiences in facets 2, 3, 4, 5 and 6				
4. Indicators assessed nationally in countries based on international standards:				
	– Aesthetic quality in facets 2, 3 and 4			

Whether it is possible to assess such indicators nationally or internationally is open to discussion. It will probably be possible to address indicators such as usability and adaptability within a foreseeable future and likewise cultural heritage, whereas aesthetic and architectural qualities are areas that it is much more difficult to agree upon how to assess.

Figure 42 gives a first estimate of how many years it will take for specific indicators to be ready for international benchmarking based on international standards - if the Nordic and Baltic countries decide to do it.

CREDIT reports and references

CREDIT reports and CREDIT case study reports are published by the Danish Building Research Institute (SBI), Aalborg University, Copenhagen, and all reports are available free of charge at

<http://www.sbi.dk/byggeprocessen/evaluering/credit-construction-and-real-estate-developing-indicators-for-transparency-1/?searchterm=None>.

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Appendix A: International standards and research

This Appendix A describes international standards and research that deal with life cycle economy, facility management, sustainability, process management, energy, indoor climate, architecture and aesthetics. It is not a comprehensive list of standards and research, but a selection that established a basis for the CREDIT performance indicators described in Chapter 4. The following standards and research activities are selected and described:

- 1 Life cycle economy
- 2 Facility management
- 3 Environment
- 4 Quality management
- 5 Energy
- 6 Indoor climate
- 7 Architecture

A1 Life cycle economy standards and research activities

This section on life cycle economy was based on *Buildings and constructed assets – Service life planning – Part 5: Whole life costing* ISO/DIS 15686-5 (ISO, 2004a) *Advancing Life Cycle Economics in the Nordic Countries* (Haugbølle & Hansen, 2005) and discussions with Kim Haugbølle, SBI.

Life cycle economy is the estimation of the economic implications of different design solutions throughout the service life of the building and not only the acquisition costs. Such estimations give clients a better foundation for making a decision, because they are informed about the economic impact of alterations of specifications, drawings etc. would have on the building throughout its life time.

In the list cost variables the standard operates with:

Acquisition costs including:

- Site costs
- Temporary work
- Design/engineering costs
- Regulatory/planning costs
- Construction and earthworks
- Commissioning costs/fees
- In-house administration

Maintenance, operation and management costs including:

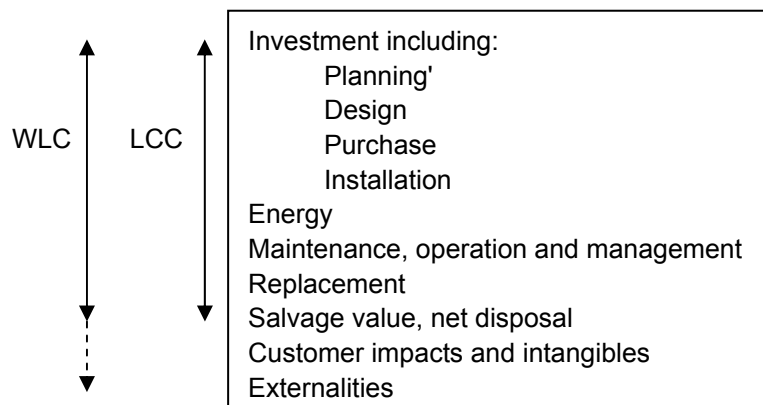
- Rates
- Insurance
- Energy costs
- Utilities
- Facilities management
- Cleaning
- Security
- Annual regulatory costs
- Maintenance (e.g. repair, replacement, refurbishment)
- Revenue forgone

Besides these two groups of costs, the standard operates with externalities and intangibles. Externalities include costs and benefits that actions, firms or people can have on people other than themselves. Intangibles include the impact that the building can have as a brand, making satisfied users or as working condition that increase productivity.

ISO 2004a influenced CREDIT facets:

- 11 Capital, investment, construction, commissioning and decommissioning costs,
- 12 Building services related to operation, maintenance and development
- 13 Business services related to the activities in the building (not building related).

Figure A1. The categories of costs included in whole life costing and life cycle costing according to ISO 2004a.



A completed project for a common Nordic cost classification system was the platform for the classification of the CREDIT Indicators in Life Cycle Economy (LCE) in 8 main services as stated in Figure A2.

Capital investment (Service 1) is the up-front construction cost and the costs of replacements where these are treated as capital expenditures (ISO, 2004a). Haugbølle & Hansen (2005) create a division of capital costs into project costs and remaining costs. The project costs are subdivided. Indicators at all four levels are measured in a currency e.g. euro.

Administration (Service 2). This post covers taxes, fees, insurance etc. (Haugbølle & Hansen, 2005).

Operation (Service 3). Inspection whether it is an internal or external operation (Haugbølle & Hansen, 2005).

Maintenance (Service 4) interior/exterior periodical, replacement, emergency repair (Haugbølle & Hansen, 2005). This can be preventive, scheduled, corrective, condition-based, emergency/unforeseen, predictive, deferred and on-site/off-site (ISO, 2004a).

Development (Service 5) and upgrade (Haugbølle & Hansen, 2005).

Consumption (Service 6) includes energy, water, drainage and waste handling (Haugbølle & Hansen, 2005).

Cleaning (Service 7) includes both periodical and special cleaning.

Service (Service 8) includes security and safety (Keys, guards etc.), reception and switchboard etc. Total cost of salary includes social benefits, uniforms and so on (Haugbølle & Hansen, 2005).

Figure A2. Definitions of main services in the proposal for a common Nordic cost classification. (Haugbølle & Hansen, 2005).

No	Main service	Definition
1	Capital	All investments towards completion including decommissioning by the end of use of the facilities.
2	Administration	Activities for administration, required payments and insurance costs.
3	Operation	This account includes daily, weekly and monthly activities that are repeated within a one-year period for building and technical installation systems that must satisfy given functional demands and requirements.
4	Maintenance	This account includes all activities and efforts put forward in a period of more than one year. For example, planned maintenance, replacement and emergency repairs, so that the building and technical systems satisfy the original level of quality and functional requirements.
5	Development	This account includes activities as a result of a change in the demand for core activities, the authorities, total refurbishment, or all activities to raise the construction standards in relation to the original level.
6	Consumption	This account includes resources in terms of energy, water, and waste handling.
7	Cleaning	All activities inside and outside needed to meet cleaning demands satisfactorily.
8	Service	All non-building related activities in support of the core activities.

Figure A3. The relation between CREDIT Costs, price and life cycle economy; *Buildings and constructed assets – Service life planning – Part 5: Whole life costing* (ISO, 2004a); and Nordic cost classification (Haugbølle & Hansen 2005).

Credit Facets	Credit Indicators	ISO 15686-5	Haugbølle & Hansen
11 Capital investment		x	x
12 Building services related to operation			
	121	x	x
	122	x	x
	123	x	x
	124	x	x
	125	x	x
	126	x	x
	127	x	x
13 Business services related to the activities			
	131	x	x
	132		x

The proposals for a Nordic cost classification and ISO/DIS 15686-5 have influenced CREDIT performance indicator framework facets:

- 11 Capital, investment, construction, commissioning and decommissioning costs,

- 12 Building services related to operation, maintenance and development
- 13 Business services related to the activities in the building (not building related).

To compare key performance figures for different objects in buildings regardless of time, SBI made a report on "Calculation on Price Index" (Sørensen & Hansen, 2009). The model is based on a constructed building and statistics from the national census bureau, Statistics Denmark, and provides key figures for the different building parts. The Calculation on Price Index could be a way of getting key figures for benchmarking on the different categories of building parts regardless of time.

A2 Facility management standards and research activities

This section on facility management was based on *Taxonomy of Facility Management – Classification and Structures* - prEN 15221-4:2009 (CEN, 2009), *Facility Management – Part 3: Guidance how to achieve/ensure quality in Facility Management* - prEN 15221-3:2008 (CEN, 2008b) and input from Per Anker Jensen, professor at the Technical University of Denmark (DTU) and Ole Emil Malmstrøm, committee member of the Danish Facilities Management Net (DFM-Net).

Two terms for FM are often used synonymously; facility management and facilities management. In CREDIT we used the term facility management.

FM Benchmarking is well developed in the most European countries. In Denmark the association Danish Facility Management – benchmarking (DFM-benchmarking) was established in 1996 by facility managers, construction firms, consulting engineers and suppliers for public organisations and institutions. DFM-benchmarking is a non-profit organisation. The activities of DFM-benchmarking 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.

The key figures for benchmarking in Denmark (DFM-Benchmarking) are measured in products, processes and management. The units are e.g. DKK, m² or DKK/m². In DFM-Benchmarking the members compare themselves with "best practice" to see where any disadvantage might be. The organisation can then choose to optimise e.g. by saving resources for minimising the cost per service and/or per m². There is no assessment of quality in DFM-Benchmarking.

On the international level there is ongoing research concerning FM in order to elaborate European standards. *Taxonomy of Facility Management – Classification and Structures* - prEN 15221-4:2009 (CEN, 2009) is a product classification and structure, with associated definitions. It does not define the measuring parameters. The standard in quality control regarding FM is, *Facility Management – Part 3: Guidance how to achieve/ensure quality in Facility Management* - prEN 15221-3:2008 (CEN, 2008 b) follows the context from *Taxonomy of Facility Management*.

The future standard for FM is *Taxonomy of Facility Management – Classification and Structures* (CEN, 2009). The composition of it is shown in Figure A4.

CREDIT facet '1. Costs, Price and LCE' and '5. Facility Performance' is influenced by the standard *Taxonomy of Facility Management – Classification and Structures* - prEN 15221-4:2009 (CEN, 2009). Below in Figure A5 the standard is compared with the CREDIT performance indicator framework facets on costs and facility management.

Figure A4. The main products on strategic, tactical and operational level. prEN 15221-4:2009 (CEN, 2009)

1 Facility Management – Integration of processes on a strategic level

1000 Space & Infrastructure – Integration of processes on tactical level

- 1100 Space
- 1200 Outdoors
- 1300 Cleaning
- 1400 Workplace
- 1900 Primary activity specific

2000 People & Organisation – Integration of processes on tactical level

- 2100 HSSE (Health, Safety, Security and Environment)
- 2200 Hospitality
- 2300 ICT (Information and Communication technology)
- 2400 Logistics
- 2500 Business support
- 2900 Organisation specific

9000 Horizontal or central functions

Figure A5. A comparison of prEN 15221-4:2009 (CEN, 2009) and CREDIT facets '1. Costs, Price and LCE' and '5. Facility Performance5

Facet 1. Costs, price and life cycle economy

11 Capital investment	1100 Space, building initial performance - Initial/Base building incl. Technique/Investment, Improvements, Additions etc. all added up to the total acquisition. 9000 Central or horizontal functions, Sustainability ISO 14 000, Life cycle planning/engineering
12 Building services related to operation	
121 Administration	1100 Space Property administration (CAFM).
122 Operation	1100 Space, maintenance and operation + portfolio optimisation.
123 Maintenance	
124 Development	
125 Consumption	1100 Space, Utilities (Energy, water and waste)
126 Cleaning	1300 Space, Cleaning (periodic < 1 year and ordered)
13 Business services related the activities	
131 Security and safety	2100 HSSE (security, safety and health).

132 Reception and switchboard	2200 Hospitality, reception and contact center
133 Mail	2400 Logistics, documents management.
134 IT service	2300 ICT.
135 Moving	2400 Logistics, mobility.
136 Catering	2200 Hospitality, catering and vending.
137 Accessories and copying	2400 Logistics, office supplies, stationary and documents management
138 Administrative support	2500 Business support.
139 Furniture and inventories	1400 Workplace.

Facet 5. Facility performance in operation and use

51 Category of tenant and operation: size and area of space:

1100 Space,
2900 Organisation specific.

52 Applicability of the facility

521 Branding and certification,	9000 Central or horizontal functions.
522 Meeting owner's strategy	2000 People and organisation – Integration on tactical level and 9000
523 Meeting user's strategy	Central or horizontal functions

53 Building service related to operation, maintenance and development

1100 Space (Maintenance, operation, utilities)
1300 Cleaning

54 Business and service related to the activities in the building (not building related)

2300 ICT
2400 Logistics
2500 Business support
2900 Organisation specific

A3 Environmental standards and research activities

This section on Environmental standards and research was based on *Construction – Sustainability in Building Construction – Sustainability Indicators part 1 Framework for the development of indicators for buildings and key indicators* - ISO/AWI 21929 (ISO, 2009), *Sustainability of construction works – Environmental product declarations* - DSF prEN 15942 (Dansk Standard, 2009b) and input from Klaus Hansen, senior researcher, SBi and Harpa Birgisdottir, researcher, SBi.

The standardisation work for classifying the environmental impact of a building and the building process that precedes it looks at environmental impact in a very broad perspective. Sustainability, a central concept in that work, addresses not only resource consumption and emission of impurities but also the socio-cultural impact as well as the economic and architectural impact of buildings on the surroundings.

An international standard for sustainability in construction of buildings - *Construction – Sustainability in Building Construction ...* - ISO/AWI 21929 (ISO, 2009) was under development. It operates with 3 categories of indicators: Environmental indicators, social indicators and economic indicators on 3 levels: The location, the site and the building.

Environmental indicators of a building address environmental aspects either in terms of loadings or impacts. Loadings are the use of resources and the production of waste, odours, noise and harmful emissions to land, water and air.

Economic indicators of buildings indicate the impact of a building on the economic value and the productivity of activities in the building. The assessment of the economic impact should be based on a life cycle approach. This approach includes, besides the lifecycle costs based on investment, use, maintenance and destruction, the potential income and value development during the service life of the building. The potential income depends on various aspects such as, location, spaces, services for users and the building performance.

Social indicators of buildings indicate the impact of a building on cultural value and the satisfaction, equity of user and health of the users. On a building level, social indicators address the quality of a building as a place to live or work, safety and security, indoor conditions, barrier-free use of the building, access to services needed by the users of the building, architectural quality of the building and protection of cultural heritage.

The measures in the standard range from measurable units like kg, MJ, and money over grading according to classifications to quantitative, qualitative or descriptive measures.

A European draft standard that was very close to finalisation is *Sustainability of construction works – Environmental product declarations* - DSF prEN 15942 (Dansk Standard, 2009b). It was a framework for the declaration of building materials intended for the communication between building product businesses. The draft standard distinguishes between 5 stages in the lifecycle of the material or product: Production, transport and construction, use, operational use, end of service life. Within these 5 stages it operates with 15 indicators for the environmental impact that derives from the LCA (Life-cycle assessment) in 3 groups:

1. Environmental impacts expressed with impact categories of LCIA (Life-cycle impact assessment):
 - Climate change (kg CO₂ equiv.)
 - Destruction of the stratospheric ozone layer (kg R11 equiv.)
 - Acidification (kg SO₄ equiv.)
 - Eutrophication (kg PO₄ equiv.)
 - Formation of tropospheric ozone photo-chemical oxidants (kg Ethene equiv.)
 - Depletion of renewable materials resources other than primary energy (kg Fe equiv.)
 - Ionising radiation (Emissions of radioactive isotopes on kBq)
2. Indicators based on LCI not assigned to LCIA:
 - Use of renewable material resources, other than primary energy (kg)
 - Use of renewable energy resources, primary energy (MJ)
 - Use of renewable resources, primary energy split into use of coal, lignite, natural gas, uranium, secondary fuels (MJ)
3. Waste to disposal:
 - Hazardous waste (kg)
 - Non hazardous waste (kg)
 - Radioactive waste (kg)

The two standards on sustainability and environmental impact (ISO, 2009) and DSF (Dansk Standard, 2009b) influenced the facet of indicators 1, 2, 3,

4, and 7 in the CREDIT performance indicator framework. They formed the basis of the CREDIT performance indicator framework facets:

- 22 Social-cultural context
- 23 Plot opportunities
- 24 Spatial solution and site aesthetics
- 25 Services in surrounding area
- 33 Usability and adaptability
- 55 Social performance and user experience
- 71 Site
- 72 Emissions
- 73 Resources
- 74 Waste to disposal
- 75 Social and economic impact on the local community

A4 Quality management standards and research activities

This section on quality management standards was based on ISO 9000 *Quality management systems series* (ISO 2008), *A new handover process for construction* (Bertelsen, 2009), *Departmental order on quality management of construction works* (EBST, 2004) and input from Niels Haldor Bertelsen, senior researcher, SBi and Ib Steen Olsen, researcher, SBi.

Today some of the best known international standards in Quality Management (QM) are the ISO 9000 series (ISO, 2008). These standards are used as generic standards to optimize and systemise QM and not only in a product but also QM in a process.

In the Nordic countries there are requirements to quality control when working on the basis of the General Conditions for the provision of works and supplies within building and engineering issued by the Danish Ministry of Housing, 1992 in different phases of a building process and a finalising inspection five years after handover, e.g. AB 92 (EBST, 1992) and ABT 93 (EBST, 2001) in Denmark.

For governmental buildings and government-financed buildings including non-profit housing there are further requirements. In Denmark e.g. *Departmental order on quality management of construction work* (in Danish: *Bekendtgørelse om kvalitetssikring af byggearbejder*) (ESBT, 2004). The target for the requirements is the individual building process. At the same time the companies are recommended to apply ISO 9000 (ISO, 2008), but this is not mandatory.

For publicly financed buildings there are also requirements governing the use of logistics and calculations concerning life cycle economy.

Some of the mentioned requirements are included in the National General Conditions for works (e.g. in Denmark AB 92/ABT 93 (EBST 1992; EBST 2001), which are commonly used in Denmark in contracts between clients and contractors.

In Denmark *A new handover process for construction* (in Danish: *Ny afleveringsproces for byggeri*) (Bertelsen, 2009) proposes a pre-handover method that should give an awareness of handover at the end of a building process and focus on quality throughout the building process. It is based on case studies from the Danish construction sector.

The ISO 9000 (ISO, 2008) series influenced the CREDIT performance indicator framework facets:

- 622 Working plan and time consumption
- 623 Logistics of materials and equipment
- 641 Quality control and documentation
- 642 Operation and maintenance instruction
- 643 Handover defects and repairs

A new handover process for construction (Bertelsen, 2009) influenced the CREDIT performance indicator framework facets:

- 641 Quality control and documentation
- 642 Operation and maintenance instruction
- 643 Handover defects and repairs

The above mentioned *Departmental order on the quality management of construction work* (ESBT, 2004) influenced the CREDIT performance indicator framework facets:

- 641 Quality control and documentation
- 642 Operation and maintenance instruction
- 643 Handover defects and repairs

The international standard for environmental management *Environmental management systems – Requirements with guidance for use* - ISO 14001(ISO, 2004b) is not mandatory but some companies have been certified in accordance with the standard.

In the new version of the Danish Building Regulations contain requirements concerning measurements of moisture in materials and components on the building site. Furthermore the local building authority should execute measurements of tightness of a specified number of finished buildings in order to reduce the consumption of energy.

A5 Energy standards and research activities

This section on energy standards and research was based on *Energy performance of buildings - Calculation of energy use for space heating and cooling* - EN/ISO 13790:2008 (CEN, 2008a), *Directive 2002/91/EC of the European Parliament and the council of 16 December 2002 on the energy performance of buildings* (EPBD, 2002) and input from Søren Aggerholm, research director and head of the department Energy and Environment, SBI and Kim Witche, senior researcher, SBI.

The European Union Directive on energy performance of buildings (EPBD, 2002) requires of all the member states the implementation of mandatory energy performance certificates for all buildings and minimum energy requirements for new buildings and buildings that undergo major renovation. This means that all countries participating in CREDIT, except Iceland, had implemented or are in the process of implementing these requirements. Norway plans to have a mandatory energy certification of all buildings in 2010. In Sweden the certificate (in Swedish: Energideklaration) is issued on the basis of the actual consumption in the building, in the rest of the countries the certificate is based on calculations of the energy demand of the building. The four Nordic certifications operate with 7 classes of energy consumption, but the values (kWh/m²) of each of these classes differ from country to country.

A pivotal standard for calculating the energy demand of existing and planned buildings is *Energy performance of buildings - Calculation of energy use for*

space heating and cooling - EN/ISO 13790:2008 (CEN, 2008a). The Nordic countries in CREDIT had all accepted this standard.

The main input needed for the calculation in accordance with EN/ISO 13790:2008 (CEN, 2008a) is:

- Transmission and ventilation properties
- Heat gain from internal heat sources, solar properties
- Climate data
- Description of building and building components, system and use
- Comfort requirements (set-point temperatures and ventilation rates)
- Data related to heating, cooling, hot water, ventilation and lighting systems:
 - Partition of building into zones for calculation (different systems may require different zones)
 - Energy losses dissipated and recoverable or recovered in the building (internal heat gains, recovery of ventilation heat loss)
 - Airflow rate and temperature of ventilation supply air (if centrally pre-heated or pre-cooled) and associated energy use for air circulation and pre-heating or pre-cooling controls

The main outputs of this international standard are the following:

- Annual energy needs for space heating and cooling
- Annual energy use for space heating and cooling
- Length of heating and cooling season (for system running hours) affecting the energy use and auxiliary energy of season-length-dependent technical building systems for heating, cooling and ventilation.

Additional outputs are the following:

- Monthly values of energy needs and energy use (informative)
- Monthly values of main elements in the energy balance, e.g. transmission, ventilation, internal heat gains, solar heat
- Contribution of passive solar gains
- System losses (from heating, cooling, hot water, ventilation and lighting systems) recovered in the building

The CREDIT performance indicator framework facet '34 Thermal climate', '44 Thermal climate' and '731 Energy efficiency' was based on Nordic certifications that are consequences of the *Directive 2002/91/EC of the European Parliament and the council of 16 December 2002 on the energy performance of buildings* (EPBD, 2002) and the related standards.

A6 Indoor climate standards and research activities

This section on indoor climate standards and research was based on *Classification of climate in dwellings, institutions and offices* - DSF 3033:2009 (Dansk Standard, 2009a) and input from Henrik Knudsen, senior researcher, SBI and Kjeld Johnsen, senior researcher, SBI.

WHO has defined health as: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946).

Currently standardisation work for classifying the indoor climate in dwellings, institutions and offices was in process in Denmark in 2009 DSF 3033:2009 (Dansk Standard, 2009a).

The classification of indoor climate is divided into five classes A-E:

- A: Really good indoor environment, comfortable thermal quality all year with the option for individual adjustment. The air has a low pollution level even in situations where there is high pollution production. The quality of sound and light is good with the option for individual changes.
- B: Good indoor climate but compared with A, draught, sound or/and smell discomfort can occur.
- C: Equal to the minimum requirements in the Danish Building Regulations. Buildings constructed today are at a minimum of classification level C, older buildings can get their classification altered by an a reassessment. There is a small risk of a negative health effect and/or discomfort, e.g. high temperatures or bad odours.
- D: Indoor climate with a small negative health risk, greater than in C but still small. The discomfort will show e.g. in hot or cold days.
- E: The lowest of the five classification levels. There is a health risk and the safety margin is limited. The majority of users may experience significant discomfort.

The classification standard measures nine different parameters, and distinguishes between housing, institutions and office buildings, e.g. after finishing a building (after the standard phases) it will get the class C. If the owner believes it is a class A, he/she can pay to get it classified (approx. 1350 €) at the risk of getting a class D or E. This is with the object of branding the building and achieving a higher property value.

The classification of indoor climate uses nine parameters:

- Air change,
- CO₂
- Thermal conditions
- Radon
- Formaldehyde
- Particle
- Moisture/moulds
- Daylight
- Acoustic conditions

For elaboration on measuring methods see (Dansk Standard, 2009a).

Thermal conditions

Assessing the thermal environment for housing includes all bedrooms and living room. For office buildings (< 600 m²) included all office and meeting rooms. Institutions included assessment of all common rooms.

The standard distinguishes between office buildings bigger or smaller than 600 m². Office buildings that are smaller than 600 m² are measured to check their compliance with the standard. If they are bigger than 600 m², computer simulation is permitted.

Figure A6. Classifying thermal conditions in housing, institutions and office buildings <600 m². DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Leaking window frame	No	No	No	-	-
Windows with single glass	No	No	No	No	-
Air heat without other thermal sources	No	No	-	-	-
Large sunny windows without solar screening	No	No	No	-	-
Individual adjustable temperature control	Yes	Yes	-	-	-
Heat sources below all windows higher than 0.7 m or 1.5 m (U-value of less than 2.5 for the low limit)	Yes	-	-	-	-
High windows without adequate protection against cold down draught	No	No	-	-	-

Figure A7. Classifying thermal conditions in office buildings >600 m². Possibility of individual control DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Thermal conditions:					
Operating temperature (°C)					
- Summer	24.5 ± 1.0*	24.5 ± 1.0	24.5 ± 1.5	24.5 ± 2.5	No limit
- Winter	22.0 ± 1.5*	22.0 ± 1.5	22.0 ± 2.0	22.0 ± 2.5	No limit
Air velocity (m/s)					
- Winter	0.18	0.18	0.22	0.25	>0.25
- Summer	0.15	0.15	0.18	0.21	>0.21

Air quality

The classification distinguishes between housing, offices and institutions, which are further subdivided into school, kindergarten and nursery.

Figure A8. Classifying air quality in housing DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Air change (h ⁻¹)	1	0.8	0.5	0.3	<0.3
CO ₂ (ppm)	700	800	1,000	1,200	>1,200
Radon (Bq/m ³)	50	100	200	400	>400
Formaldehyde	0.07	0.10	0.15	0.20	>0.20
Moisture/moulds	No signs	No signs	No signs	Signs of moist./moulds < 400 cm ²	Signs of moist./moulds > 400 cm ² .

The requirement for offices and institution followed the same classification. The different values were altered to get a better indoor climate. The requirements depended on the buildings location and the polluted air from outside. If there is a main road within 100 meters (more than 10,000 cars/24 hours), it is in one classification class and another one if the air is not polluted.

Figure A9. Classifying particle pollution (non-polluted air) DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Exhaust hood above stove	Yes	Yes	Yes	Yes	-
Wood stove in living area	No	No	-	-	-

Figure A10. Classifying particle pollution (polluted air) DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Exhaust hood above stove	Yes	Yes	Yes	Yes	-
Wood stove in living area	No	No	-	-	-
Filtrated outdoor air supply between 0.5 - 1 h ⁻¹ .	-	Yes	-	-	-
Filtrated outdoor air supply above 1 h ⁻¹ .	Yes	-	-	-	-

The definitions of classes in DSF 3033:2009 (Dansk Standard, 2009a) influenced the facet of the CREDIT performance indicator framework facets:

- 35 Air quality
 - 351 Air change,
 - 352 Pollutants in indoor air
 - 353 Moisture/moulds

Daylight

The quality of daylight and the visual environment depends on a number of parameters, but in the proposed standard (Dansk Standard, 2009a) the classification is reduced to two parameters: Daylight access and views to the outside. E.g. Offices and Institutions

Figure A11. Classifying daylight in offices and institutions DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Daylight access:					
- Glass area/floor area %	21-40	11-20	>10	<10 or >45	<7
- Daylight factor	>5	>3	>2	<1	<0.7
Views to the outside:					
- Light transmittance of glass	>0.8	>0.7	>0.6	0.5<LT<0.6	<0.5

The definitions of classes in DSF 3033:2009 (Dansk Standard, 2009a) influenced the facets of CREDIT performance indicator framework facets:

- 36 Lightning conditions
 - 361 Daylight access
 - 362 Views to the outside

Acoustic conditions

The acoustic condition was measured with one parameter, reverberation time. It was divided into three classes: Housing, institutions and offices. There are requirements for offices and institutions, but no time reverberation in housing, e.g. institutions.

Figure A12. Classifying acoustics in institutions DSF 3033:2009 (Dansk Standard, 2009a)

Classes of measures	A	B	C	D	E
Acoustic relation					
time reverberation (s)					
Classrooms	0.4	0.4	0.6	0.8	>0.8
Institutions	0.4	0.4	0.4	0.6	>0.6

The definitions of classes in DSF 3033:2009 (Dansk Standard, 2009a) influenced the facet of the

CREDIT performance indicator framework facets:

- 37 Acoustic quality
 - 372 Reverberation time

The individual parameters for indoor climate defined in DSF 3033:2009 (Dansk Standard, 2009a) influenced the CREDIT performance indicator framework facets:

- 3 Building performance and indoor environment:
 - 34 Thermal quality
 - 35 Air quality
 - 36 Lighting conditions
 - 37 Acoustic climate
- 4 Building part and product performance
 - 44 Thermal quality
 - 45 Impact on air quality
 - 46 Lighting quality
 - 47 Acoustic qualities
- 5 Facility performance in operation and use
 - 52 Applicability of the facility with three sub-facets.

A7 Architectural design and aesthetic evaluation and standards

This section on architectural design and aesthetic evaluation and standards was based on *General accessibility* - DS 3028:2001 (Dansk Standard, 2001) *Building Construction – Sustainability in Building Construction – Sustainability Indicators part 1 Framework for the development of indicators for buildings and key indicators* - ISO/AWI 21929 (ISO, 2009), *Survey of Architectural Values in the Environment* (SNS, 1997), *Experience with evaluation of standard and quality* (EBST, 2003) and input from Inge Mette Kirkeby, senior researcher, SBI and Camilla Ryhl, senior researcher, SBI.

Standardisation work on the quality of architectural design primarily addresses issues such as dimensions, indoor climate and accessibility. The aspects of usability/serviceability, adaptability, architectural quality and cultural heritage are addressed in standards on sustainability. In this context this perspective was supplemented with input from research on evaluation of architectural quality.

Dimensions

Multi-storey housing - Vertical dimensions - DS 1000:1982 (Dansk Standard 1982) gives dimensions for the room height of the internal space in buildings and distinguishes between different building types.

Indoor climate

The standards for indoor climate including daylight conditions are described in section A6.

Accessibility

The ambition of accessibility is to ensure disabled persons access to participate occupationally, culturally and socially in society on equal terms. The standardisation work (Dansk Standard, 2001, Dansk Standard, 1999) distinguishes between six groups of disabled with differing needs:

- Walking-impaired and wheelchair users
- Visually impaired
- Hearing impaired
- Cognitively impaired
- Allergic persons
- Others (including children, persons with impaired use of arms or hands, with impaired coordination, dyslexia, very big or small persons, persons with reduced strength and endurance and the elderly).

The requirements for the buildings are divided into 6 categories of buildings:

- Public buildings
- Commercial buildings
- Dwellings
- Dwellings for private use
- Housing for the elderly
- Second homes.

Accessibility standards for the walking-impaired or wheelchair users address:

- the right dimensions of the rooms, doors and spaces,
- angles of inclination,
- levelled access,
- elevators,
- automatic doors,
- right height of control panels, door handles, desks etc.,
- flooring or cover material.

For the visually impaired, accessibility standards recommend:

- simple and logic lay-out and arrangement of the indoor environment,
- oral and auditory communication and signals,
- separation of traffic,
- tactile signage,
- tactile or contrast marking of the start and end of stairs and ramps, and of the front of the steps, handrail in relation to staircases and ramps,
- warning about unpredictable obstacles, intersecting corridors at right angles
- even and non-skid flooring with tactile guidelines,
- right and not blinding light,
- use of contrasting colours for orientation, clear and well-lit signs.

For the hearing impaired, accessibility standards recommend:

- visually clear lay-out and arrangements,
- appropriate and good lighting,
- visual signage (not only oral),
- sound absorption of background noise, separation of traffic,
- wire loops
- written information (not only oral).

For the cognitively impaired the standards recommend:

- information/communication and signs in short and clear text supplemented by colours and good lighting, separating the messages, if there are more than one in a piece of information,
- use of contrasting materials to facilitate orientation,
- even and non-skid flooring,
- spaciousness

Accessibility standards for allergic persons recommend:

- suitable building materials,
- efficient and good ventilation,
- good and thorough cleaning,
- regular replacement of filters in ventilation systems and air-conditioning systems,
- appropriately situated buildings and choice of plants,
- dwellings and parks situated in areas without smoke, dust, poor air and known allergens.

Whether a building complies with these many different accessibility requirements was assessed by using various indicators, ranging from measurable indicators such as dimensions, reverberation time to indicators such as clearness of lay-out and signs that must rely on a professional but subjective assessment.

The standards on accessibility influence the specification of the CREDIT performance indicator framework facets:

- 237 Accessibility of the plot
- 242 Accessibility of the building and the outdoor spaces
- 324 Safe access for different users
- 334 Accessibility for different users.

A new international standard on accessibility was in preparation.

Like in the Danish standard, the aim in many countries is to ensure disabled persons access to participate occupationally, culturally and socially in society on equal terms. But in some countries (Norway, for example) the level of ambition is higher and 'universal design' is implemented as a general standard.

Usability and adaptability

In *Building Construction – Sustainability in Building Construction – Sustainability Indicators part 1 Framework for the development of indicators for buildings and key indicators* - ISO/AWI 21929 (ISO, 2009) usability/serviceability and adaptability is addressed and it defines serviceability as "the quality of space design and technical services of the building in relation to the intended use and user needs". Serviceability is closely linked to compliance with the owner's demands and the users' needs. The assessment of serviceability is made during the design phases checking whether the specific processes have been implemented in order to identify, understand and consider the user needs. In the use phase the assessment is an expert assessment and post-occupancy evaluations that directly measure the users' satisfaction with usability and serviceability. This definition influences the CREDIT performance indicators framework facets:

- 333 Usability
- 335 Spatial layout
- 392 Well-arranged layout
- 393 Spaciousness

In *Building Construction – Sustainability in Building Construction – Sustainability Indicators part 1 Framework for the development of indicators for*

buildings and key indicators - ISO/AWI 21929 (ISO, 2009) adaptability is defined as adaptability for changed use of space design, openings and capacity as well as ICT and building services and includes aspects of flexibility and convertibility. Classes of adaptability have to be locally defined. The assessment of adaptability can be made both during the design phase and use phase, and rely in both cases on an expert assessment. This definition influenced CREDIT performance indicator framework facets:

- 332 Adaptability now and over time
- 335 Spatial layout.

Spatial and aesthetic quality

No standards directly address the spatial and aesthetic qualities of architectural design, but standards on sustainability address maintenance of architectural quality and cultural heritage and there are evaluation systems and methods that address the evaluation of architectural quality.

Building Construction – Sustainability in Building Construction – Sustainability Indicators part 1 Framework for the development of indicators for buildings and key indicators - ISO/AWI 21929 (ISO, 2009) addresses maintenance of architectural quality and cultural heritage of the built environment as an asset of a planned or new building. This implies that the design of the new building does not cause demolition of culturally valuable construction nor damage cultural values in the vicinity. Such a qualitative indicator must be locally defined. Assessment can be made both during the design phase and in the use phase relying on an expert assessment. This definition influences the CREDIT performance indicator framework facets:

- 221 Cultural heritage
- 243 Spatial quality of the outdoor spaces

Survey of Architectural Values in the Environment (SAVE) (SNS, 1997) is an evaluation system to assess of villages, cities, parts of cities and buildings, their architectural qualities and whether they are worth preserving. It has been used by municipalities all over Denmark to get an overview of what is worth preserving.

The system has two levels – structure of the built-up area and buildings. The built structure is grouped in 3 categories: Dominating feature, patterns in the built-up area, and elements in the area. Furthermore these categories are defined by significant features in the terrain, space defining elements, homogeneous path or stretch, limits, views.

On the basis of a historic analysis of the area and the mapping of the above mentioned categories and features, an assessment of the architectural quality was made. It is a 'subjective' assessment but it had to relate to the mentioned categories and features.

At building level the assessment of whether a building is worth preserving is based on 5 different approaches to the value of the building:

- Architectural value (Proportions, rhythm in the façade, the interplay between form, material and function, and whether the building is an excellent, medium or bad example of its kind.)
- Cultural-historical value (local building tradition, craftsmanship, rarity, technical innovative constructions or use of materials, example of a specific building or construction type, symbolic value)
- Environmental value (Does the building add spatially to the surroundings.)
- Originality (Is the original appearance preserved?)
- The state of the building (maintenance and structural state)

The assessment of each approach is summed up in a mark (marks 1-3 is good, 4-6 is average, 7-9 is poor).

These five approaches are summed in a general assessment indicated with a mark. Again it is a 'subjective' assessment but based on objective registrations of the building's character.

The assessment is made by persons with knowledge of architecture, typically by architects.

SAVE (SNS, 1997) influences the CREDIT performance indicator framework facets that concern architectural and aesthetic quality:

- 221 Cultural heritage,
- 243 Spatial quality of outdoor spaces,
- 381 Quality of the building,
- 481 Shape of the building part in relation to the whole building or space
- 482 Colour and surfaces in relation to the whole building or space
- 483 Details.

The research project *Evaluation of standard and quality* (reported in *Experience with evaluation of standard and quality*, EBST, 2003) carried out by the Danish Building Research Institute addressed the assessment and evaluation of architectural quality, and demonstrated the assessment in public housing. Here architectural quality was viewed as the interplay of technical, functional and aesthetical qualities and the layout on the site, the construction, the internal rooms and spaces and the installations are assessed on the basis of all three components of architectural quality.

Grouped in five categories the evaluation addresses 23 quality indicators:

Layout on the site:

- Surroundings
- Area
- Volume

Spatial quality and layout:

- Sequence of spaces
- Design of spaces/rooms
- Plan
- Furnishing possibilities

Usability:

- Functionality
- Equipment and fixtures
- Adaptability/flexibility

Comfort and indoor climate:

- Daylight
- Acoustics
- Physical well-being
- Privacy
- Experience

Aesthetics:

- Proportions
- Choice of materials
- Cover and textures
- Detailing
- Finish
- Patina

Experience with evaluation of standard and quality (EBST 2003) influences the CREDIT performance indicator framework facets:

- 241 Adaptability and compliance with needs
- 243 Spatial quality of outdoor spaces
- 244 Indoor outdoor relationship,
- 332 Adaptability to needs (now and over time)
- 333 Usability (functional)
- 335 Spatial layout
- 381 Quality of building,
- 382 Spatial quality of indoor spaces
- 383 Quality of the spatial layout,
- 432 Adaptability to needs
- 433 Usability
- 481 Shape of the building part in relation to the whole building or space
- 482 Colour and surfaces in relation the whole building or space
- 483 Details.

Appendix B: National building regulations

This Appendix B provides an overview of where the building regulations of the countries participating in CREDIT had an impact on the CREDIT indicators. Information from Chapter 3 'Results from the studies in CREDIT' and Appendix A 'International standards and research' together with information in this appendix was edited into Chapters 2 and 4. The individual sections on the national building regulations in this appendix were written by a researcher from the country in question. The Finnish and Estonian Building regulations was not treated in the study, since the Finnish building regulations look very much like the regulations from the other Nordic countries, and likewise the Estonian building regulations resembles the Lithuanian.

B1 Danish building regulations

The *Danish Building Regulations 2008* - BR 08 (EBST, 2009) is a part of the building law in Denmark. The BR 08 (EBST, 2009), is a national standard that for most parts consists of performance-based requirements. To get a better understanding of BR 08 specific information is given in SBi Guidelines 216 on the Danish Building Regulations 2008 published by the Danish Building Research Institute (SBI, 2008). In some cases the guidelines gives examples of how to comply with the regulations. It is not mandatory to follow the SBi Guidelines 216 (SBI, 2008), but advisable.

The SBi Guidelines 216 (SBI, 2008) introduces three levels of quality: A, B and C. A is the highest and C the lowest. C corresponds to the criteria of the Danish Building Regulations and the requirements of good building practice, i.e. the minimum requirement for what is legal. For the time being, there are only a few areas in the Danish Building Regulations where the values for these differentiated classes are specified; the requirement for energy consumption is one of these.

Below the agreement between the Danish Building Regulations 2008 (EBST 2009) and the CREDIT facets were compared following the structure of the CREDIT performance indicator framework. Sub-facets were left out where they were not addressed in the BR 08 (EBST, 2009).

Facet 1 Costs, price and life cycle economy

There are no rules for economy or time scheduling in BR 08 except regarding CREDIT facet 123 Maintenance. BR 08 (EBST, 2009) states "Structural measures are deemed to be economically viable if the annual saving multiplied by the lifetime divided by the investment is greater than 1.33."

In (SBI, 2008) Section 7.4 "... significant alterations to the building...". It is stated in Section 7.4.1(3)

$$\frac{\text{Annual savings} \cdot \text{Lifetime of the measure}}{\text{The investment}} > 1.33$$

Facet 2 Location, plot, region and country

In Denmark a local plan serves as the law within a specific geographic area. The local plan is drawn up by the municipality. Only if no local plan exists for

a specific geographical area, BR 08 (EBST, 2009) Chapter 2 is mandatory concerning these types of provisions. BR 08 Chapter 2 provides rules for the allowed height of the building and required distance to the border of the plot. Calculation rules are defined in Appendix 1 in BR 08 (EBST 2009), e.g. calculation of plot ratio.

Facet 3 Building performance and indoor environment

Facet 32 Safety and security:

Facet 321 Construction safety:

4.1(1) *"Buildings must be constructed so as to provide satisfactory conditions of function, safety ..."*. Under Design of structures in Section 4.2(2) it lists several Eurocodes with associated Danish annexes (EBST, 2009).

Facet 322 Fire safety:

Chapter 5 in BR 08 provides a written guide on how to prepare adequate documentation, but there are no mathematic or statistical demands. 5.1(1) *"Buildings must be constructed, laid out and fitted out so as to achieve satisfactory protection against fire and the spread of fire..."* (EBST, 2009).

Facet 33 Usability and adaptability:

The requirements to usability and adaptability are addressed in several chapters in BR 08 (EBST, 2009), but are particularly addressed and specified in relation to accessibility.

Facets 34 Thermal climate - 37 Acoustic climate:

Are found in Sections 4.2-4.5, the requirements are differentiated between building types.

Facet 4 Building part and product performance

BR 08 (EBST, 2009) specifies the maximum U-value ($W/m^2 K$) of different building parts that must be ensured, regardless of whether the energy performance framework or the heat loss framework is used.

451 Pollutant emissions:

As emissions from building materials, *"Building materials may not emit gases, ..., that can result in a unhealthy indoor climate"*. Some materials are not allowed e.g. asbestos, and others are only allowed in a specified concentration. Concerning construction safety, BR 08 does not distinguish between Building Performance and Building Parts Performance. See Sections 4.3, 4.6 and 5.3 in BR 08 (EBST, 2009).

Facet 5 Facility performance in operation and use

The requirements for the facilities should vary according to use BR 08 (EBST, 2009) Sections 2.6.2, 2.6.3 and Chapters 3 and 6, e.g. 2.6.2(1) *"Sufficient parking areas must be provided"*.

Facet 6 Process performance in design and construction

The building process period was not dealt with except for Facet 623.

Facet 623 Logistics of materials and equipment:

The requirement for quality assurance of building materials used is given in the BR 08 in 4.1(5): *"This provision includes ensuring that neither wet moisture-sensitive materials nor materials and building elements which are affected by mould are incorporated during the construction period"* (EBST, 2009).

Facet 7. Impact environmentally, socially and economically

Facet 731 Energy efficiency:

Is dealt with in chapter 7 BR 08 (EBST, 2009). In 7.1(1) it says "*Buildings must be constructed so as to avoid unnecessary energy consumption for ... while at the same time achieving healthy conditions*". This is derived from articles 4, 5 and 6 of directive 2002/91/EC.

B2 Norwegian building regulations

The Norwegian Plan and Building Act were revised in 2008 and 2009 (BE, 2010). The planning part in 2008 and the building part in 2009. The regulations have been on public inquiry and the law and regulations will become effective on 1 July 2010. The National Office of Building Technology and Administration (BE) was in autumn 2009 preparing the regulation on behalf of the Ministry of Local Government and Regional Development.

The regulations are performance-oriented, but the 2010 revision seems to add specific demands on particular matters, (energy, access for the disabled etc.). Due to the harsh weather conditions in Norway, the common technical standards in building constructions are similar to the minimum requirement in the technical regulations (TEK). These regulations together with the instructions (REN) – also developed by BE, do set the standard of quality. Further on the SINTEF Byggforsk building information sheets are referred to as norms.

The adoption of REN can set different standard for disability regarding quality of accessibility,

Facet 1 Costs, price and life cycle economy

There are no general rules for costs, capital, investment, construction, commissioning decommissioning cost or time scheduling. The two exceptions were the Facet 122. Operation and Facet 123 Maintenance.

§ 13.1 and 2. Documentation for the operation phase shall be handed over and kept by the owner.

Facet 2 Location, plot, region and country

Facet 23 Plot opportunities:

In Norway each municipality should make plans for land use – an allocation plan, as a part of the community plan according to the Plan and Building Act. For densely populated areas, municipality sector plans can be prepared, with corresponding community plans.

Facet 231 Size of the plot:

§ 3-1 Utilisation

Purpose, rules, built area etc. Built area according to the allocation plan (BYA), built area share (%-BYA), available area (BRA), available area (%-BRA). Also min. available outdoor area (MUA m²), parking, height of buildings, category of building, number of floors, distance between houses and how to measure. See Areas and Volumes of Buildings - NS 3940:2007 (Norsk Standard, 2007).

Facet 3 Building performance and indoor environment

Facet 32 Safety and security:

Facet 321 Construction safety:

§ 4-2 Basic requirement for documentation of products used in buildings.

1. Each and all products under the Council Directive of 21 December 1988 relating to construction products, shall have capacity and quality, when used correct, that satisfies basic requirement according to:

- a) Mechanical resistance and safety

- b) Fire safety
 - c) Hygiene, health and environment
 - d) Safety in use
 - e) Noise protection
 - f) Energy saving and heat insulation (as written in this regulation and in appendix I in the Council Directive
2. Products shall be within approval and control system according to the requirements in Declaration of Conformity, see. § 4-5.

Facet 322 Fire safety:

Chapter IX Fire Safety § 9-1 General Requirement

1. Requirement for the planned solution, and execution that, in case of fire, gives acceptable safety for people in the building, tangible goods and environmental and social consideration. This means possibilities.

3. When change of the use of a building, the whole building and fire safety should be evaluated by approved designers.

4. When change of the use, the local authorities can make the permit dependant on fire safety action for other parts of the building than the actual part.

Figure B1. Classes of risk § 9-2 Classes of risk and classes of fire

Class of risk	Building only for sporadic occupancy for people	All in the building knows the escape route, and can bring themselves to safety	Building for accommodation	Provided use of the building is low risk of fire
1	Yes	Yes	No	Yes
2	Yes/No	Yes	No	No
3	No	Yes	No	Yes
4	No	Yes	Yes	Yes
5	No	No	No	Yes
6	No	No	Yes	Yes

Figure B2. Classes of fire.

Class	Consequence
1	Minor
2	Medium
3	Large
4	Very Large

Facet 33 Usability and adaptability:

Chapter VII Planned solutions, communication road etc.

§ 7-1 Buildings with demand for universal design and access.

1. Buildings with demand for universal design should be designed according to the requirement in this chapter.

2. Buildings with demand for accessibility and useable accommodation, i.e. with all main functions in the entrance floor in the building and/or with demand for lift, should be accessible and useable for people with disabilities according to the requirement in this chapter.

§ 7-2 Buildings with demand for lift

1. Buildings for the public and for work with two stories or more should have a lift. Smaller buildings for work may have a low-speed lift.

2. Buildings with three stories or more with common entrance to min. three flats on top of each other should have a lift. Residences with three stories and less traffic may have a low-speed lift.
3. In buildings with more than three stories, the lift should have room for a stretcher.

§ 7-3 Floor plan

The building should have:

- Layout fit for the function of the building.
- Layout that avoids harming people and animals/pets.
- Layout that makes it easy to orientate oneself
- Residential building with **demand for accessibility** has to have main function inclusive hall and should have a layout that gives possibility for flexible use, i.e. access for wheelchairs, with sufficient space for turning and giving the wheelchair user access to the most necessary functions.
- Residential building with **demand for universal design** should have layout and distribution of rooms making it possible for most people in an equivalent way to use the part of the building accessible for the public.
- Building made for working should also have layout and rooms making it possible for disabled to work in the building, unless the building makes it impossible for disabled to work there.

§ 7-4 to 7-20 Requirement to the rooms, communication, doors, Here the most important requirement to rooms, size and height fit for purpose are listed. Rooms for use/residence must be min 7 m² BRA 1.

The regulations have a strong focus on universal design and access and use for people with different disability/handicap, with detailed listing of the space, accessibility to and equipment in the bathroom, shower and toilet, easy access to the main entrance and terrace/garden. There is also a requirement for storage both inside (min 3 m²) and outside.

Communication (roads) both inside and outside the building must be easy to find and use. Different height between levels must be properly marked and illuminated.

Requirement and dimensions are given for openings, railing, corridors, staircases, ramps, windows, glass partition.

Also for these objects, the regulation differs between accessibility and universal design, and residential and building for public access.

Facet 4 Building part and product performance

Most of the requirements in the Norwegian Regulations for these facets do overlap with those listed for Facet 3 Building performance. However the Regulations refer to the CE Marking. This is stated in § 4-12 CE-marking. The properties and performance documented according to the CE marking can then be used according to the harmonised set of rules. A CE-marked product for construction works should be free to be marketed and sold without further assessment of the requirements under this regulation.

For the requirement for documentation, se Facet 32 Safety and security.

§ 4-3 Marketing, trading and use of product for buildings

1. Manufacturer or importer of products for buildings should see to it that the inherent qualities are documented and product documentation are available before it is available in the market, being realized or used in buildings.
2. The documentation should state the characteristics and quality according to relevant specifications and the origin of the product. The documentation should be available in Norwegian or another Scandinavian language.

§ 4-13 Product with defects

1. Products for construction that do not comply with the requirements of this regulation, including incomplete or improper documentation, should not be marketed, sold or used in structures.
2. This provision also applies to products for construction works, which even if it is declared to be in compliance with the requirements, may result in danger to safety, health or the environment.

Facet 5 Facility performance in operation and use

There are no requirements concerning facility management.

Facet 6 Process performance in design and construction

Facet 642 Operation and maintenance instruction:

Chap XIII in the Regulation requires documentation as a basis for management, operation, maintenance and use of the building

§ 13-1 Documentation for the operational phase

1. The designers should ensure that there is written documentation as the basis for how to start up the building and how the management, operation and maintenance of buildings and technical installations should be carried on satisfactorily. In projects where such documentation is obviously superfluous, this requirement is dropped.
2. Documentation for the operational phase should include information necessary for the use, the operation and the maintenance of the structure, so that these regulations are satisfied.

§ 13-2 Storage of documentation for the operating phase

Documentation for the operational phase should be handed over to and retained by the owner of the building. The Norwegian Plan and Building Act and regulation do not deal with processes between the client and the designer, contractors or suppliers. In these matters the several Norwegian Standards in the 84-series are commonly used. The authorities certify, on a local level or on a central level:

- The professional applicants (operating on behalf of and together with the client)
- Designers (different trades/professions)
- Executing companies/crafts and
- Independent controllers.

Facet 7 Impact environmentally, socially and economically

The scheduled 2010 revision of the Norwegian Plan and Building Act and regulation, do implement the European directives and the political agreement of reducing energy consumption and carbon footprint in Norway. In addition to the new regulation, the authorities foresee even stronger focus on these matters in the years to come. They assume that stepwise changes in the regulation to occur every three year. This first step has been in effect since 1 July 2009.

Facet 72 Emissions

Regarding emission and carbon footprint, there are no requirements in the regulations except the requirements concerning the discharge from wood-burning stoves (with a long tradition in Norway) and the requirements concerning threshold levels for pollution in the soil.

Facet 73 Resources

731. Energy efficiency.

§ 10.3 Energy efficiency

Requirement for the energy efficiency in buildings, also holiday cottages.

Examples:

1. Transmission loss:
 - The glass, windows, and door area ≤ 20 % of the heated available area (BRA).
 - U-value of the external walls ≤ 0.18 W/(m²K)
 - U-value of the roof ≤ 0.13 W/(m²K)
 - U-value of the floor ≤ 0.15 W/(m²K)
 - U-value of the glass/window/doors (frames included) ≤ 1.2 W/(m²K).
2. Heat loss due to infiltration and ventilation:
 - Leakage numbers by 50 Pa difference in pressure:
 - Detached houses ≤ 2.5 air change rate per hour
 - Other buildings ≤ 1.5 air change rate per hour
 - Heat recovery unit in the ventilation system:
 - Residential buildings ≥ 70 %
 - Other buildings and areas ≥ 80 %
3. *Net energy requirement should not exceed (Draft technical regulations 2009-06-09):

Figure B3. Net energy requirements

Building type	Net energy requirement (kWh/m ² heated BRA per year)
Detached houses	125 + 1600/heated BRA
Block of flats	120
Kindergarten	140
Office buildings	150
School buildings	120
Universities	160
Hospitals	300 (335)
Nursing homes	215 (250)
Hotels	220
Sports centres	170
Office buildings	210
Cultural centre	165
Light industry/workshops	175 (190)

§ 10-4 Energy supply

1. The building's design should confirm that min 40 % of the energy consumption are expected to be covered by other sources than electricity and fossil fuel. This is derived from articles 4, 5 and 6 of directive 2002/91/EC (EPBD, 2002).

Facet 723 Depletion of non-renewable material- waste and Facet 732 Use of renewable material resources ... - recycling

§ 7.11 Waste storage and source separation

1. This should be prepared for the recycling of waste. Waste storage or waste system should be designed and carried out so that no annoying noise, odour or other nuisance occur.
2. Residential building with requirements for accessible and universal designed dwellings should have:
 - Common waste system near the dwelling or workplace, have barrier-free access and have a throw-in height between 0.6 m and 1.4 m.

B3 Swedish building regulations

The important part of the legislation for the building sector contains the Planning and Building Act (Boverket, 1987a), the Act on Technical Require-

ments for Construction Works (Boverket, 1994b) and the Swedish Environmental Code (Boverket, 1998a). The National Board of Housing, Building and Planning (Boverket), is the national agency for planning, the management of land and water resources, urban development, building and housing. Boverket monitors the function of the legislative system under the Planning and Building Act and related legislation and proposes regulatory changes. The Swedish Building Regulations (BBR 2008:6) (Boverket 2008) of the Swedish Board of Housing, Building and Planning contains mandatory provisions and general recommendations pursuant to the Planning and Building Act (Boverket, 1987a) the Act on Technical Requirements for Construction Works (Boverket, 1994b), etc and the Decree on Technical Requirements for Construction Works.

Facet 1 Costs, price and life cycle economy

There are no rules in building regulations for economy or time scheduling. Useful definitions of different kinds of costs can be found in *Begrepp i bygg- och fastighetssektorn* (Hansson B. et al., 2009).

Facet 2 Location, plot, region and country

According to the law (PBA) the municipality decides what to build and when. This is exercised through detailed development plans. A detailed development plan may cover only a limited part of a municipality (Boverket, 1987a, Chapter 3)

Facet 3 Building performance and indoor environment

Facet 31 Category of building, quantity, size and areas:

In the BBR 2008:6 (Boverket 2008) some mandatory provisions exist for the height of habitable rooms; workrooms should not be less than 2.40 m high. There is no longer any mandatory provision concerning the height of bedrooms or other rooms in dwellings.

Facet 32 Safety and security:

In the BBR 2008:6 (Boverket 2008) , Section 8 some mandatory provisions exist for spaces in buildings where children are been present.

Facet 321 Construction safety:

Mandatory provisions and general recommendations pursuant to Sections 3 and 4 of BVF regarding the mechanical resistance and stability of loadbearing structures etc. are contained in the Board's Design Regulations (BKR) Boverket (1998b).

Facet 322 Fire safety:

Section 5 of BR contains mandatory provisions and general recommendations pursuant to Chapter 3 Section 15 and Chapter 9 Section 1 of PBA (Boverket, 1987a) and Section 4 of OTRC (Boverket, 1994a).

Facets 34 Thermal climate – 37 Acoustic climate:

According to Section 6 in BBR 2008:6 (Boverket 2008) "*buildings and their installations shall be designed so that the quality of air and water, as well as light, humidity, temperature and sanitary conditions are satisfactory during the building's working life, thereby avoiding conditions detrimental to human health*".

Facet 4 Building part and product performance

Facet 441 Convective loss:

Section 9 Energy Management states the maximum U-value (W/m² K) of different building parts that must be ensured, regardless of whether the energy performance framework or the heat loss framework is used. Section 6 states "Materials and construction products used in a building shall not in themself-

ves, or through their treatment, negatively affect the indoor environment or the local environment of the building, when the performance requirements of these regulations are fulfilled."

Facet 5 Facility performance in operation and use

Facility performance in operation and use is not regulated by building regulations.

Facet 6 Process performance in design and construction

The building process period is not dealt with.

Facet 632 Accidents:

The Work Environment Act defines the framework for Provisions issued by the Work Environment Authority. These Provisions contain more detailed stipulations and obligations with reference to the working environment. For example, they may concern risks of particular kinds, mental stress and physical loads, dangerous substances or machinery. The Provisions are worked out in collaboration with the labour market parties.

Facet 7 Impact environmentally, socially and economically

Facet 731 Energy efficiency:

Chapter 9, Energy management, in BBR 2008:6 (Boverket 2008) contains mandatory provisions and general recommendations pursuant to Article 8 and paragraph 3 of Article 10 of The Ordinance on Technical Requirements for Construction Works (Boverket, 1994a). "Buildings shall be designed in such a way that energy consumption is limited by low heat losses, low cooling demands, efficient use of heat and cooling and efficient use of electricity."

For dwellings there are specific mandatory provisions:

"Dwellings shall be designed so that the specific energy consumption of the building does not exceed 110 kWh per sqm of floor area (A_{temp}) per year in the Southern climate zone, and 130 kWh per sqm of floor area (A_{temp}) per year in the Northern climate zone.

For single and two-dwelling houses with direct electrical heating as the main source of heating, the specific energy consumption of the building must not exceed 75 kWh per sqm of floor area (A_{temp}) per year in the Southern climate zone and 95 kWh per sqm of floor area (A_{temp}) per year in the Northern climate zone."

It is dealt with in Chapter 9. Energy management.

B4 Icelandic building regulations

The Icelandic building regulation (BR) 1998 with later additions; *Byggingarreglugerð Stjótið. B, nr. 441/1998*, Ministry for the Environment (IME, 1998) is a part of the building law in Iceland. The regulation consists of minimum requirements that must be fulfilled; the requirements either a descriptive text or performance-based.

There are only very limited guidelines on how to interpret the regulation, mostly in the field of fire security.

The regulation is valid for all buildings, and the same basic requirements are made to all buildings and then specified requirements based on the type of building (living, schools, hospitals, etc). A differentiation based on different quality requirements are only made regarding structural stiffness (three classes) and thermal comfort (two classes).

The building regulation (IME, 1998) is mainly written in descriptive text and with lots of values given regarding minimum requirements. These values should be seen as design values that must be fulfilled rather than performance requirements; sometimes they are a blend of both. As an example of this, the requirements on maximum U-values of building components can be taken; these are design values to ensure that thermal climate and heating cost will be considered in design. The actual U-value depends on both design and work quality, and it can be measured as a performance indicator. A performance indicator for energy use could be the actual energy use of the building, but any guiding values for this are not given. However, the regulation expects the designer to state the amount of calculated heat loss per m² floor area and degree Kelvin (W/m²K).

In the following text it will be mentioned if specific required values should be fulfilled.

Facet 1 Costs, price and life cycle economy

There are no rules for economy or time scheduling.

In planning, design and building the total cost (LCC) should be considered and the work should be economically and environmentally viable.

The head designer is required to have insurance (and the minimum amount is mentioned and connected to building cost index).

The head supervisor of the construction process is required to have insurance (and the minimum amount is mentioned and connected to the building cost index).

Facet 2 Location, plot, region and country

A local plan is required in Iceland before a building permit is given. The local plan outlines requirements for what type of building/activity is allowed, maximum height of building, orientation etc.

Facet 232 Bearing capacity:

A structural designer states what the maximum load of a building will be and what bearing capacity this requires of the site (BR § 124).

The BR stipulates minimum requirements for what minimum distance from building to border of the building plot should be (due to fire safety), based on the material used in the building (BR § 75).

Facet 3 Building performance and indoor environment

“Buildings shall be planned and built such that they fulfil functional requirements made, are economically feasible, safe, healthy and built in agreement with surroundings....”

Facet 31 Category of building, quantity, size and areas:

Minimum requirements to room height in an apartment (rooms for living; general requirement min 2.5m, BR § 78).

Minimum requirements to room size in residential buildings; hall, bathroom, main living room, storage room and kitchen (BR § 80, 92-94).

Facet 33 Usability and adaptability;

All main doors, and all doors in public buildings should have the required minimum size (BR § 79.8).

Accessibility; max width and inclination of corridors is outlined in (BR § 200).

Elevators; size and minimum number depending on type of building and numbers of floor levels (BR § 2001)

Maximum inclination of ramps for wheelchairs (BR § 203).

Facet 34 Thermal climate:

No requirements.

Facet 35 Air quality:

All living rooms and all rooms for working should have an openable window, except if the activity demands otherwise (BR § 79.1, 79.3).

For all kinds of rooms for living or working, the average value of CO₂ should be lower than 800 ppm and the maximum value lower than 1000 ppm (BR § 186).

Minimum volume of ventilation (area of opening or amount of air) is stated for different rooms (BR § 187).

For houses heated to above 18°C, the maximum air infiltration is stated (max m³/m²h) for two different classes of buildings (BR § 182).

Facet 36 Lighting conditions:

Window area in a room should be $\geq 1/10$ of floor area, though always $\geq 1 \text{ m}^2$.

Facet 37 Acoustic climate:

Requirements made on maximum average sound reverberation time for different kinds of rooms and spaces (BR § 175).

Facet 38 Aesthetics of building and indoor spaces:

Colour, material use and form of building shall be chosen in agreement with surroundings (BR § 103, 115).

Facet 4 Building part and product performance

Facet 42 Safety and security:

Many requirements on fire safety and performance requirements on components (spread all over the regulation).

Maximum load on ground (bearing capacity required) – see Facet 232

The maximum allowed deflection and movement of structural components is given for three different quality classes of buildings (BR § 128).

The form and maximum/minimum size of stairs and height of banister is given in (BR § 202).

Maximum surface temperature indoor of accessible surfaces in living rooms (e.g. chimney, radiators, pipes) should be less than 60 °C (BR § 189, 193).

Maximum hot water temperature is 38 – 60 °C (depending on type of building).

General text on buildings required to be durable.

Specific requirements made on maximum alkali-chisel reactivity (BR § 131).

Maximum allowed w/c ratio in concrete for outdoor use (BR § 131).

Minimum requirements to ventilation of attics (if ventilated BR § 136).

Air leakage and water penetration

Specific requirements to the minimum roof inclination for various roofing materials (BR § 136).

Facet 44 Thermal quality:

Maximum allowed U-values for different components in the building envelope, depending on indoor temperature; two classes; $\theta_i \geq 18 \text{ °C}$, $18 > \theta_i \geq 10 \text{ °C}$ (BR § 180).

The calculated thermal convective loss for the building (including thermal bridges) should not be higher than the sum calculated from the size of components and given maximum U-values for each component.

Facet 45 Impact on air quality:

Building materials may not be dangerous or give off dangerous materials or volatile compounds (BR § 170).

Facet 47 Acoustic quality:

Various minimum requirements to sound reduction of components for different kinds of rooms and spaces (BR § 173-177).

Facet 5 Facility performance in operation and use

There is not a specific chapter or requirements for facility performance in BR.

Facet 6 Process performance in design and construction

There is not a specific chapter on this in BR but there are requirements given in the general text that put some requirements on the total process and parts of it. Stability of structure should be ensured during the building process (BR § 119).

Facet 7 Impact environmentally, socially and economically

There is not a chapter specifically on environmental impact in BR but there are requirements imbedded in general text that put some requirements on this.

B5 Lithuanian building regulations

Law on Construction (Ministry of Environment, 1996) and Technical Construction Regulations (STR) (Ministry of Environment, 2001) is part of the building law in Lithuania (Ministry of Environment, 2007). STR is a national standard that for the most part consists of function-based requirements.

Law on Building (Ministry of Environment, 2007) established the essential requirements for all construction works that are built, reconstructed and repaired within the territory of the Republic of Lithuania, the procedure for technical regulation of construction, construction investigation, design of construction works, construction, reconstruction, repair of new construction works, acceptance of them as fit for use, utilisation and maintenance, demolition of construction works, as well as the procedure of supervision over the above activities, the principles of activities of the participants in the construction, public administration entities, owners (or users) of engineering and utility networks and traffic routes, and other legal and natural persons in this field.

Facet 1 Costs, price and life cycle economy

There are no rules governing costs, price and life cycle economy. One exception is Facet 126 Consumption.

Facet 2 Location, plot, region and country

Law on Construction (19 March 1996 No I-1240) (Ministry of Environment, 1996).

30. "Mandatory documents related to the preparation of a design documentation of a construction works" means physical planning documents (in the cases provided for by the Law on Territorial Planning), documents confirming the right of ownership or other rights to the land (construction plot); design proposals (if prepared); the set of design conditions for a construction works, a task of design of a construction works, documents pertaining to investigations of a construction works and a construction plot.

Facet 3 Building performance and indoor environment

Facet 32 Safety and security:

Facet 321 Construction safety:

Law on Construction (19 March 1996 No I-1240):

55. "Normative documents pertaining to the safety and purpose of a construction works" means documents which, on the basis of other laws and legal acts, sets requirements for the protection and safety of a construction works, protection and safety of people who use such construction works, protection and safety of construction works' environment according to the spheres indicated in paragraph 1 of Article 6 of this Law, ... (Ministry of Environment, 1996).

Also it states Eurocodes with associated Lithuanian annexes.

Facet 322 Fire safety:

Law on Construction (19 March 1996 No I-1240):

Preservation of fire safety measures established by documents regulating fire safety. (Ministry of Environment, 1996).

Facet 33 Usability and adaptability:

Requirements on usability and adaptability are addressed in several sections of the Law on Construction (Ministry of Environment, 1996).

Facets 34 Thermal climate - 37 Acoustic climate:

Law on Construction (19 March 1996 No I-1240):

Protection against noise, i.e. noise perceived by the occupants or people nearby should be kept down to a level that does not threaten their health and will allow them to sleep, rest and work in satisfactory conditions; energy economy and heat retention, i.e. the amount of thermal energy required for the use of the building should not exceed the required amount, with regard to the climatic conditions of the location and the occupants (i.e. calculated in accordance with the requirements of hygiene norms and the purpose of a building or its spaces) (Ministry of Environment, 1996)..

Also above indicators are regulated by Technical Construction Regulations:

- STR 2.01.01(3):1999. Hygiene, health, environment protection.
- STR 2.01.01(5):2008. Noise protection.
- STR 2.01.01(6):2008. Energy saving and heat protection.
- STR 2.01.07:2003. Protection of interior and exterior environment of buildings against noise (Ministry of Environment, 2001).

Facet 4 Building part and product performance

Technical Construction Regulation (STR 2.01.01(2):1999. Hygiene, health, environment protection) regulates some aspects of 63. Health and safety and work environment (631 Health and safety control and documentation; 632 Accidents; 633 Physical work environment) (Ministry of Environment, 2001).

Facet 5 Facility performance in operation and use

Technical Construction Regulations required that "Sufficient parking areas must be provided" (Ministry of Environment, 2001).

Facet 7 Impact environmentally, socially and economically

Facet 731 Energy efficiency:

Law on Construction (19 March 1996 No I-1240):

Article 4: 6) energy economy and heat retention, i.e. the amount of thermal energy required in use should not exceed the required amount, having regard to the climatic conditions of the location and the occupants (i.e. calculated in accordance with the requirements of hygiene norms and the purpose of a building or its spaces).

Chapter 7: Energy consumption: In section 7.1(1) it says "*Building must be constructed so as to avoid unnecessary energy consumption for ... while at the same time achieving healthy conditions*". This is derived from articles 4, 5 and 6 of directive 2002/91/EC (the directive was adopted in Lithuania on 4 January 2006) (Ministry of Environment, 1996).

Energy consumption is regulated by Technical Construction Regulations:

- STR 2.01.01(6):2008. Energy saving and heat protection.
- STR 2.01.09:2005. Building energy efficiency. Certification of energy utility (Ministry of Environment, 2001).

Facets 72 Emissions and 713 Eco-system and biodiversity:

According to the Kyoto Protocol, like the EU, Lithuania is committed to reduce the emission of gases causing greenhouse effect by 8 % compared with the basic year 1990 by 2008-2012.



CREDIT Report 3 CREDIT Performance Indicator Framework – A proposal based on studies of building cases, regulations, standards and research in seven Nordic and Baltic countries presents a classification of building cost, performance and impact indicators. It is a part of the Nordic and Baltic project CREDIT: Construction and Real Estate – Developing Indicators for Transparency.

The Indicator classification is based on case studies of evaluations building processes and projects and benchmarking systems dealing with built environment, international standards and research and the building regulations in the 7 countries participating in CREDIT.

The classification includes 7 main facets of indicators reflect performance aspects of both product and process, cost and life cycle economy and the impact a building or facility has on the surroundings.

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