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PROPOSAL FOR ENVIRONMENTAL OPERATIONAL PERFORMANCE INDICATORS IN A FINNISH CONSTRUCTION COMPANY

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Espoo, October 24, 2005

Supervisor: Professor Janne Hukkinen
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The construction industry (including building construction and civil engineering) has a tremendous impact on the natural environment. Not only is it a significant consumer of natural resources as well as a producer of wastes and emissions, but its products usually continue impacting the environment for decades, if not for centuries. However, the Finnish construction industry has not yet established an extensive and standardized method for measuring the environmental performance of its actors. A few instances have provided guidance for building construction companies to develop environmental metrics and indicators, but the field is still disorganized and immature. The civil construction industry in Finland is a virgin territory in terms of guidance and regulation for environmental metrics and indicators.

This thesis describes the process and results of developing a proposal for environmental operational performance indicators in a Finnish construction company. The study is based on constructive research methodology, where a problem is solved by constructing a model, a plan or some other tool. Here, a model for developing a proposal for new indicators has first been generated and then carried out. The model comprises ten steps that range from considering the company's organization and operations to selecting indicators for development to defining responsibilities.

Operational performance indicators are indicators that provide information about the environmental performance of the organization's operations. The indicators may be absolute, relative, indexed, aggregated or weighed. Whereas the case company operates in numerous business areas, the indicators are developed for its building construction unit and civil engineering unit, and primarily for in-house use.

Key words: Environmental indicators, operational performance indicators (OPIs), environmental business accounting (EBA), environmental management, construction industry, constructive research.	Language of publication: English

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Rakennusteollisuudella on merkittäviä ympäristövaikutuksia. Rakennusteollisuus kuluttaa runsaasti luonnonvaroja sekä tuottaa jätettä, minkä lisäksi sen tuotokset säilyvät vaikuttaen ympäristöön vuosikymmenten, ellei jopa vuosisatojen ajan. Suomen rakennusteollisuus ei kuitenkaan ole kehittänyt laajamittaisia ja standardisoituja menetelmiä toimijoidensa ympäristösuorituskyvyn mittaamiseksi. Talonrakennuksessa muutamat toimijat ovat ohjeistaneet rakennusyrityksiä ympäristömittareiden kehittämisessä, mutta toiminta on vielä epäjärjestelmällistä ja kehittymätöntä. Yhdyskuntarakentamisessa yritystason ympäristömittareihin ei ole panostettu juuri lainkaan.

Tässä työssä kuvataan suomalaisen rakennusliikkeen toimintojen ympäristötehokkuusindikaattorien kehittäminen ja tulokset. Työ noudattaa konstruktiivista tutkimusmetodologiaa, jossa ongelma ratkaistaan kehittämällä malli, suunnitelma tai muu työkalu. Tässä tapauksessa tuotettiin malli, jota noudattamalla kehitettiin ehdotus uusiksi ympäristömittareiksi. Malli käsittää kymmenen vaihetta yrityksen organisaation ja toimintojen huomioimisesta mittareiden valitsemiseen ja vastuiden määrittämiseen.

Toimintojen tehokkuusindikaattorit tuottavat tietoa organisaation toiminnan ympäristösuorituskyvystä. Mittarit voivat olla absoluuttisia, suhteellisia, indeksimittareita, kokoomamittareita tai painotettuja mittareita. Vaikka tutkimuksessa käytetty yritys toimii useilla toimialoilla, mittarit on kehitetty sen talonrakennus- ja yhdyskuntarakennusyksiköille sisäiseen käyttöön.

Avainsanat: ympäristöindikaattorit, toimintojen tehokkuusindikaattorit, ympäristölaskenta, ympäristöjohtaminen, rakennusteollisuus, konstruktiivinen tutkimus.	Julkaisukieli: Englanti

Preface

Writing a Master's thesis can be a tremendous ordeal for a variety of reasons. Luckily, none of those reasons applied in this particular case. Admittedly, there were numerous hardships along the way: days filled with frustration and questions that seemed destined to remain unanswered forever. There might have even been times when the very completion of the thesis appeared doubtful. Yet, on the whole, completing this project was a far less strenuous task than I had anticipated.

I had barely started thinking about a Master's thesis when my instructor Tuula Pohjola approached me with a readily thought-out topic. From that point on, her instructions and guidance were timely, insightful and highly invaluable. In our monthly meetings, she always provided me with a fresh boost that prevented the process from stagnating. Her input in every phase of the project was crucial for the completion of this thesis.

I am equally grateful to Skanska Oy and its environmental manager Kaisa Kekki for their entrepreneurial spirit in embarking on a pioneering project. Despite her crowded schedule, Kaisa always managed to find time when I needed her guidance. Her input concerning every aspect of my thesis was always accurately targeted and insightful. There are also numerous other people at Skanska and other organizations who have influenced the content of this thesis: I am deeply indebted to them all.

Wholehearted thanks to my supervisor Janne Hukkinen for his critical role in the final steps of the thesis. His fluent and professional involvement ensured the successful completion of a truly fulfilling project.

Thanks also to the people at Ecobio for showing such flexibility and understanding toward my absenteeism during the project.

Finally and foremost, thanks to all family members and friends who have supported me during this endeavor. Thanks especially to my wife Taru for the magnificent display of patience, understanding and encouragement. Thanks simply for being there all the way.

Isto Nuorkivi

Espoo, October 2005.

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1 Introduction

1.1 Background

The construction industry is a significant consumer of natural resources, as well as a significant producer of wastes and emissions. In Finland, civil construction consumes approximately 150 million metric tons of soil and rock per year, whereas building construction consumes 10 million metric tons of construction products and materials per year (REM 2005). Furthermore, the CO_2 emissions from producing certain construction materials have been considered significant enough to be included in the EU emissions trading scheme (KTM 2004). The products of the construction industry typically persist for decades, thus impacting the environment over a long period of time. Despite its significant impacts on the environment, the Finnish construction industry has failed to establish an extensive and standardized set of environmental performance indicators for its actors.

1.2 Research objective

The objective of this study is to develop a suggestion for new operational performance indicators (OPIs) for Skanska Oy. More accurately put, the indicators are targeted at Skanska Oy's operations in the construction phase of building and civil construction projects.

The indicators are expected to be applicable to decision-making − that is, they should have some influence on the company's operations as opposed to merely providing information about the company's past performance.

Skanska Oy has already some OPIs in use, but recently a demand has arisen for additional indicators to coexist with or replace the existing indicators. Skanska Oy has also done some elementary work on planning new OPIs, which will be reviewed in this study.

1.3 Research questions

In order to achieve the objective, the following primary research questions were devised:

- Which OPIs should Skanska Oy utilize?
- How is the suggestion for new OPIs developed?

In accordance with the primary research questions, the following secondary research questions were devised:

- What is an OPI?
- How are OPIs developed for organizations?
- What are the significant environmental aspects of building construction and civil construction?

Answers to the secondary research questions are sought primarily with a theoretical approach: from the literature concerning environmental management, environmental accounting, environmental indicators and the construction industry. Answering the primary research questions comprises the empirical research part of this study.

1.4 Scope of research

The case under research is Skanska Oy, a Finnish construction corporation. Since the company is involved in numerous business fields, the suggestion for new OPIs is directed at the building construction unit (Skanska Talonrakennus Oy) and the civil construction unit (Skanska Tekra Oy) in order to maintain a manageable scope. The suggested indicators may be targeted exclusively at either Skanska Talonrakennus Oy or Skanska Tekra Oy, or they may suitable for both of them.

Skanska Oy itself is a subsidiary of Skanska AB, a Swedish construction corporation. Although the scope of this study only extends to Skanska Oy, collaboration between Skanska Oy and Skanska AB is at times noted and examined.

Selecting the indicators is limited to operational performance indicators (OPIs), thus excluding the environmental condition indicators (ECIs) and management performance indicators (MPIs). OPIs, MPIs and ECIs are all environmental indicator categories (see ISO 14031: 1999).

The indicators are expected to address the construction phase of building and civil construction. Hence, the indicators are primarily directed at the environmental performance of construction sites and their operations. The design phase is also included to some extent. However, Skanska Oy does not always have direct control on the decisions made in design, and cannot therefore be held accountable for every environmental aspect of the design phase. To this end, the indicators are primarily intended for the construction phase, but due to the design phase's significance in affecting a project's environmental aspects (such as energy or material efficiency), the design phase is also considered.

This study includes a literature review. While searching for references, various Internet and database searches were conducted, and different parties (most often Skanska's employees) were contacted for advice. Although the search for references may not be considered exhaustive, it has been adequate enough to serve the purpose of this study.

It should be stressed that the research objective merely concerns coming up with a suggestion for new OPIs. It does not include their actual implementation, which is deemed beyond the scope of this study.

1.5 Research methodology

This research study follows the *constructive research* methodology. Constructive research aims at solving a problem by constructing a model, a plan, an organization or some other tool. Not every case of problem solving is an example of constructive research: it is inherent in constructive research that the problem is attached to previous knowledge, and the novelty and functionality of the solution is confirmed. (Kasanen et al 1991) The nature of constructive research is depicted in Figure 1.

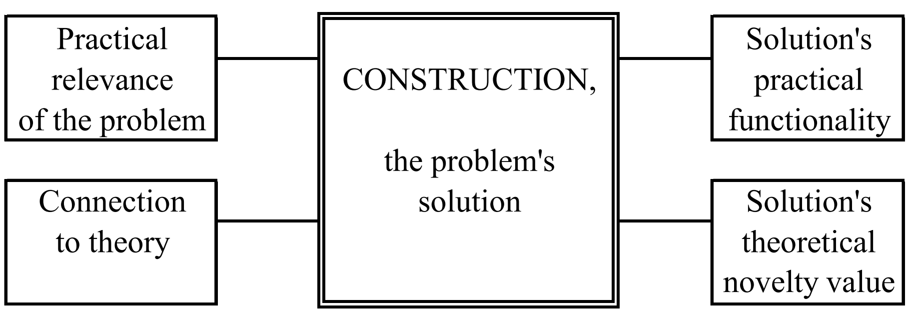

Figure 1. Features of constructive research (Kasanen et al 1991: 306).

Constructive research can be further illustrated by breaking the work down into phases:

- Finding a relevant research problem that has research potential.
- Obtaining a preliminary understanding of the subject.
- Constructing a model for the solution (the innovation phase).
- Testing the functionality of the solution; confirming the construction.
- Showing the solution's connections to theory, and demonstrating the scientific novelty value of the solution.
- Considering the scope of the solution's territory of application. (Kasanen et al 1991: 306)

In this thesis, a model for developing OPIs for Skanska Oy is constructed and utilized. The model itself is presented in Section 3.1. The practical relevance of the problem has been discussed in other parts of Chapter 1. The problem is attached to previous knowledge in Section 2.10, which presents existing models for designing environmental indicators. Connections between theory and the model are established in Section 3.1. The model's practical functionality and theoretical novelty value are examined in Section 5.1. It should be stressed that developing the model is not the primary objective of this study; rather, it is merely a staging post in the quest of developing a suggestion for new OPIs in the case company.

Besides constructive research, this thesis employs elements of numerous other research methodologies, as well. Some of those methodologies are

- *Action research*, in which the researcher uses his/her findings for the benefit of the research subject (here: Skanska Oy); and
- *Case study*, in which the research is focused on an individual or an organization. (See Järvenpää & Kosonen 1996)

This research can be classified as *qualitative* (as opposed to *quantitative*) and *descriptive* (as opposed to *explanatory*). It is qualitative, since it does not involve any quantitative data or statistical analysis. It is descriptive, since it does not set out to explain any cause and effect relationships, nor test causality hypotheses. Instead, to an appropriate extent, it is aimed at giving accurate and detailed descriptions of the subject under consideration. (See Järvenpää & Kosonen 1996)

Finally, this thesis is a mix of *theoretical* and *empirical* research (see Järvenpää & Kosonen 1996). First, there is the theoretical research represented by the literature review. Second, there is the empirical research, where the suggestion for new OPIs is actually developed.

1.6 Research methods

For the duration of this study, the researcher had a workstation at Skanska Oy's premises. Consequently, the research methods of *observation* and *interviewing* were actively utilized.

The observation was most often *participatory* (as opposed to *monitoring*). In monitoring observation, the researcher merely monitors a situation without participating in it in any other way. In participatory observation, the researcher takes notes and participates in the situation at hand. (Järvenpää & Kosonen 1996)

In the interviews, the entire range of interviewing methods was utilized: Some of the interviews were *structured* (the questions were prepared beforehand), some were *semi-structured*, and some were purely *thematic* interviews that only concern a certain topic without any precise and pre-set questions. (See Järvenpää & Kosonen 1996)

Case study is, besides a research methodology, a research method as well. A case study involves researching one or a few cases. The research subject may be an organization or a person. (Järvenpää & Kosonen 1996) Consequently, case study as a research method was also utilized in this thesis.

2 Theory

2.1 Sustainability

Corporate responsibility is a fairly recently emerged concept designed to cover and connect the economic, social and environmental responsibilities of the corporate world. It is defined as action, in which corporations voluntarily integrate environmental and social aspects into their business operations and cooperate with their stakeholders, thus acknowledging the principles of sustainable development. (Finnish Ministry of Trade and Industry 2004) In effect, corporate responsibility signifies the voluntary integration of environmental and social considerations into business operations, over and above legal requirements and contractual obligations. (Juutinen 2004, De Geer 2002 and Finnish Ministry of Trade and Industry 2004).

To clarify the definition offered above, the terms *stakeholder* and *sustainable development* need to be discussed. *Stakeholders* are those who affect or are affected by the accomplishment of the organization's purpose (Freeman 1984). According to Lovio (2004), stakeholders can be divided into two different groups:

1) The business-based stakeholders (owners, managers, financiers, personnel, suppliers, etc.) and
2) The operational environment-based stakeholders (competitors, union organizations, government officials, nearby residents, community organizations, etc.).

Sustainable development, as defined by the Brundtland Commission in 1987, is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987).

The concept of corporate responsibility has spurred controversy among academics and other actors involved with the corporate world. Although some would still argue that corporations should have no other responsibilities than those of being profitable and operating lawfully (See Friedman 1970 and Lehti 2003), others have made strong arguments stating that the concepts of corporate responsibility (See Kallio 2002 and De Geer 2002) and sustainable development (See Springett 2003) are indeed needed to refrain the corporate world from being detrimental to societies.

2.2 Environmental aspects of building construction

The environmental impacts of a building are mostly generated in the production of building products, in the use of land in construction and in the energy consumption of heating, air conditioning, water use and appliance use. (VTT 1999) The overall environmental load is generated by the energy and material streams in producing the building products and in the utilization of the building. (Häkkinen et al 1999) The share of the environmental impacts generated in the construction phase is rather limited in relation to the overall environmental impacts of a building's life cycle. However, the developer has a critical role in making decisions concerning the life cycle of the building under construction. (VTT 1999)

When making decisions concerning the life cycle of a building, a construction company should take at least the following aspects into consideration:

- The service life of buildings, building materials and building products is usually long. Hence, one should consider their future environmental aspects (maintenance, repairs and waste management) as well as the recyclability and reusability of the products and materials.
- The characteristics of building products may affect the environmental impacts in the service phase. (VTT 1999)

The eco-efficiency of the construction industry is largely dependent on the level of logistics and energy consumption. Energy, transportation and construction services in the industry should be comparable in terms of the environmental impacts of their quantitative productions. (REM 2005b)

The energy consumption of a construction site varies from site to site. Aspects that influence a site's energy consumption include

- the time of construction
- the geographic location of the site
- the building type
- the type of production engineering.

Especially critical are the differences between construction on site and construction using prefabricated units: When constructing with prefabricated units, the energy consumption is concentrated on producing the building products. When constructing on site, the energy consumption is concentrated on the operations on site. On average, the energy consumption of a construction site is distributed as follows:

- Heating 68% (the phase of frame construction 18%, the phase of indoor construction 50%).
- Lifting and carrying machinery 20%.
- Social premises 6%.
- Other 6%.

Hence, heating during indoor construction usually creates the greatest energy consumption on a construction site. (REM 2005b)

2.3 Environmental aspects of civil engineering

In Finland, literature concerning the environmental aspects of civil engineering is scarce: Only one publication − that of Tuhola (1997) − deliberately concerning those aspects was found for this thesis. As a result, the environmental aspects of civil engineering were determined by referring to that publication and by taking an environmental point of view when studying literature concerning civil engineering in general.

Although civil engineering comprises land-based as well as marine construction, the emphasis of this study will be on land-based construction, as the case company is most often involved with road and other land-based construction projects.

According to Tuhola (1997), a civil engineering project has the following impacts on the environment:

- Discharges into the air, soil and water. In land-based construction, emissions into the air are usually in the form of dust, exhaust gases from construction machinery, explosion gases, and evaporation compounds from contaminated land. Fuels and oils from construction machinery sometimes generate discharges into soil and water.
- Material use. As virgin rock materials become increasingly scarce, alternative methods for recycling the soil and rock excavated on site need to be developed. Furthermore, methods for recycling wastes generated by different industries as materials for land-based construction also need to be developed.
- Removal of trees and vegetation from the site. The removal of trees and vegetation, as well as the planting of new trees and vegetation, has impacts on the environment of the site and its immediate surroundings.

- Noise. Noise is generated by, for instance, loading and transportation, extraction drillings, crushing and piling. Installing soundproofing devices on construction machinery can reduce noise.
- The construction site's environmental appearance. The environmental appearance of a construction site refers to the overall appearance of the site; its cleanliness, orderliness and traffic arrangements.

A recap of the physical inputs and outputs in a road construction site is presented in Figure 2.

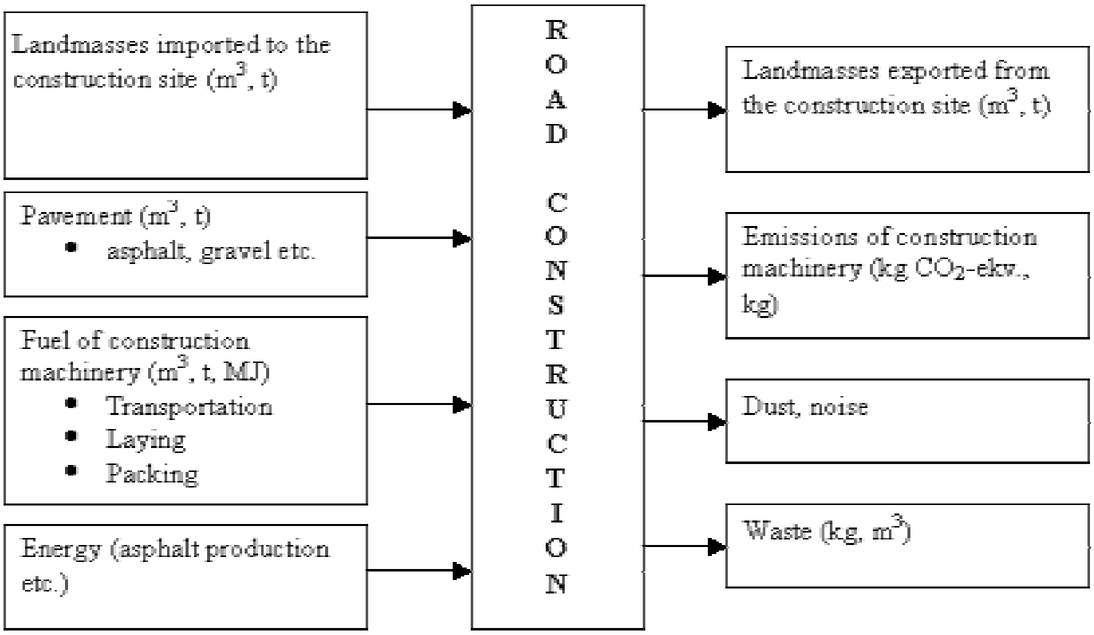

Figure 2. Physical inputs and outputs of road construction (adapted from Hartikainen 2002).

Common materials used in road construction include bitumens, cement and lime, aggregates for bound materials, bituminous materials, cement bound materials and geotextiles. (Watson 1989)

2.4 Environmental business accounting

Environmental accounting in general refers to three separate entities: national environmental accounting, environmental financial accounting and environmental management accounting. National environmental accounting (NEA) is carried out on a national level, and it is often used to guide policymaking and other government-related activities. Environmental financial accounting (EFA) and environmental management accounting (EMA) merge together to form environmental business accounting, which is primarily carried out by organizations in the corporate world. (Pohjola 2003)

Environmental business accounting has a dual function: it can be used for 1) environmental performance evaluation as well as for 2) environmental cost accounting. (Pohjola 2003) Environmental performance evaluation is often performed via such evaluation methods as environmental impact assessment (EIA) and life cycle assessment (LCA). (Pohjola 1999) Environmental cost accounting, on the other hand, is used for determining, evaluating and allocating an organization's environment-related costs. (Mätäsaho et al 1999) Environment-related costs are accrued from activities that an organization targets as part of preventing, remedying or mitigating its environmental load. (KILA 2003)

Environmental business accounting can also be viewed in light of physical and monetary accounting. Physical environmental management accounting (PEMA) deals with information in physical units (m^3, kg, l, t etc.), while monetary environmental management accounting (MEMA) deals with information in monetary units (€, £, $ etc.). Furthermore, environmental business accounting tools can be distinguished from one another based on three dimensions:

1) Time frame − the period being addressed by different tools (past, current or future);
2) Length of time frame − the duration of the period being addressed by the tool (short term or long term); and
3) Routineness of information − ad hoc or routine gathering of information. (Burritt et al 2002).

Burritt et al (2002) highlight that the choice of EMA tool should depend on the user of the tool, because different users have different uses for EMA.

The context of environmental business accounting as a part of environmental accounting is presented in Figure 3.

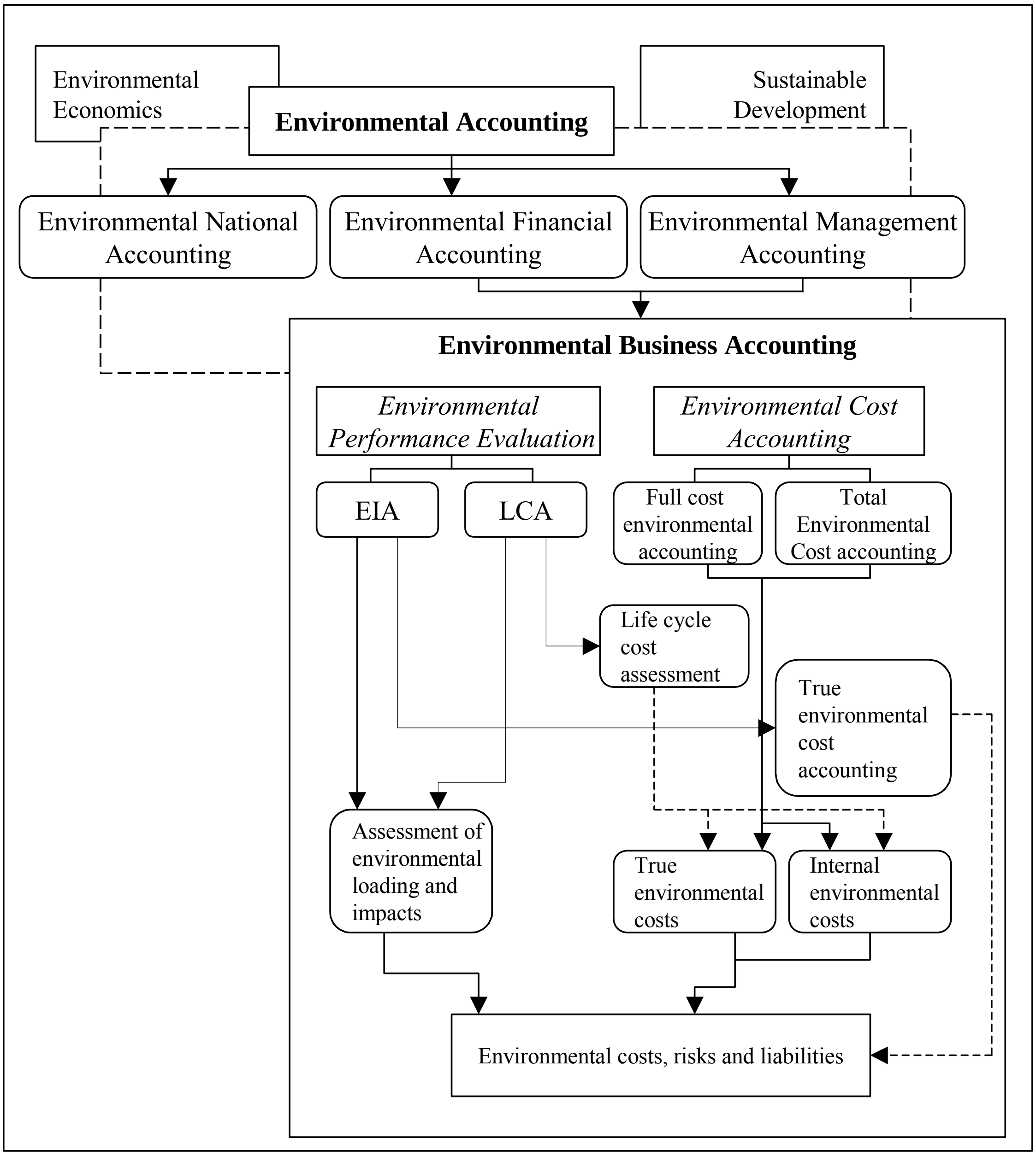

Figure 3. The context of environmental business accounting as a part of environmental accounting. (Pohjola 1999, p. 21)

2.5 Introduction to environmental indicators

The importance of measuring performance varies in companies of different sizes. Obtaining any given measurement may require a lot of work in a large company, but neglecting significant measurements leads to a situation where the company is managed on the basis of opinion and intuition. (Laamanen 2001) Put more decisively: What is not measured cannot be managed.

The objective of measuring is to obtain a comprehension of reality. If managers' comprehensions significantly differ from reality, the organization is bound to end up performing badly. Another objective of measuring is to direct attention to the subject of the measurement: Sometimes the mere measurement leads to an immediate improvement in the subject of the measurement, as people realize its significance. (Laamanen 2001)

Indicators, as understood here, are representations of measurements. Environmental indicators, then, are representations of measurements that concern environmental aspects. The nature of environmental indicators is further considered in the following sections.

2.6 Classifications of environmental indicators

The International Organization for Standardization describes two general categories of environmental indicators for evaluating environmental performance: environmental performance indicators (EPIs) and environmental condition indicators (ECIs). An EPI is defined as a specific expression that provides information about an organization's environmental performance, whereas an ECI is a specific expression that provides information about the local, regional, national or global condition of the environment. (ISO 14031 1999)

EPIs are divided into two types of indicators: management performance indicators (MPIs) and operational performance indicators (OPIs). MPIs are environmental indicators that provide information about the management's efforts to influence an organization's environmental performance. OPIs are environmental performance indicators that provide information about the environmental performance of an organization's operations. (ISO 14031 1999)

The general categorization outlined above can be supplemented and elaborated with other classifications presented in the literature. The following paragraphs are meant to carry out this elaboration.

2.6.1 Environmental Performance Indicators (EPIs)

The 1998 Global Environmental Management Initiative (GEMI) categorizes EPIs into lagging and leading indicators. Lagging indicators are those that measure the results of environmental practices or operations currently in place. Leading or in-process indicators measure the implementation of practices or measures that are expected to lead to improved environmental performance. (GEMI 1998)

Advantages of using *lagging* indicators include that they are usually readily quantifiable and understandable, and the data are often collected for other business purposes. The main disadvantage is the fact that they reflect situations where corrective action can only be taken after the fact, and often after incurring some type of cost. The major advantage of *leading* indicators is that corrective action can often be taken before deficiencies show up in terms of reduced performance. However, leading indicators may be difficult to quantify, and the results may not address the concerns of all the stakeholders. (GEMI 1998)

Bennett and James (1998) classify EPIs at the level of the overall performance measurement system in three categories or generations: First generation indicators describe the business process including indicators for regulated emissions and wastes, and indicators for costly resources and compliance. Second generation indicators reflect energy and material usage and efficiency as well as significant emissions and wastes. They also contain financial and implementation indicators. Third generation indicators include relative indicators; eco-efficiency; stakeholder, environmental condition and product indicators; and the use of a balanced scorecard of these indicators. (Bennett and James 1998)

Operational Performance Indicators (OPIs)

For instance, OPIs can be categorized according to environmental protection areas (energy, transport, emissions, waste, packaging, production, stock-keeping and water management), system boundaries (site or company, process or product) or the level of analysis or representation (level of material and energy flows, polluters, cost or effect level). (Loew and Kottman 1996) According to Schwarz et al (2002), OPIs can be divided into five basic sets of indicators: material intensity, energy intensity, water consumption, toxic emissions and pollutant emissions.

Referring to Olsthoorn et al (2000), OPIs can be categorized into environmental indicators, business activity indicators and productive efficiency indicators.

- Environmental indicators refer here to the quantity and quality of a company’s environmental outputs.
- Business activity indicators link the information provided by environmental indicators with relevant information on the activity of the production or business units under investigation. These indicators are typically in the form of ratios, with the numerator containing the physical

information, and the denominator containing the economic or financial information. Olsthoorn et al (2000) provide a formula for a business activity indicator:

$$Indicator = \frac{\text{Physical and/or environmental quantity}}{\text{Economic and/or financial quantity}}$$

Possible denominators of business activity indicators are revenue or sales, shipment value, value-added, operating profit, number of employees and total investments. (Olsthoorn et al 2000) It is acceptable to use other than purely financial quantities, such as physical output, mass of product (Schwarz et al 2002) and time (ISO 14031 1999).

– Productive efficiency indicators are based on quantities and information that are readily available. These indicators are used in comparing the productive efficiency of different actors. Actors that are efficient – i.e., produce more with the same level of inputs or release a smaller quantity of undesirable outputs for a given level of production – have their respective productive efficiency indicators assigned the value one. Inefficient actors have their indicators assigned a value less than one.

Management Performance Indicators (MPIs)

Olsthoorn et al (2000: 19-20) identify two broad classes in the MPIs (or management indicators, as the authors call them): "qualitative, subjective" indicators and "quantitative, objective" indicators. Indicators of the first class, respectively, are designed for the measurement of perceptions, attitudes and strategies toward the environment. The second broad class of MPIs has the same goals as the previous one, but there the information is based on quantifiable and verifiable information. Examples of MPIs are environmental investments, running costs, number of employees with specific environmental tasks, number of reported incidents and degree of compliance with regulations. (Olsthoorn et al 2000)

2.6.2 Environmental Condition Indicators (ECIs)

Environmental impact indicators and monetary aggregate indicators, as dubbed by Olsthoorn et al (2000), can be viewed as sub-categories of the ECIs. *Environmental impact indicators* measure environmental impacts instead of environmental outputs and are used by political actors as well as firms. *Monetary aggregate indicators* concern the monetary value of environmental impacts. For these indicators, environmental impacts need to be priced, and as the aggregated impacts are determined, the aggregated monetary value of the impacts is determined simultaneously. (Olsthoorn et al 2000)

2.6.3 Synthesis of classifications

As becomes evident in the previous paragraphs, the literature concerning environmental indicators is heterogeneous and lacking in uniformity. What follows next is the attempt to synthesize some of the aspects covered above in another classification derived from the ISO 14031 standard. ISO 14031 (1999) presents the following examples of characteristics of data for environmental indicators:

- *Direct measures or calculations:* basic data or information, such as metric tons of contaminant emitted (ISO 14031 1999). This category can be regarded as containing what Olsthoorn et al (2000) called environmental indicators.
- *Relative measures or calculations:* data or information compared to or in relation to another parameter such as metric tons of contaminant emitted per ton of product manufactured, or tons of contaminant emitted per unit of sales revenue (ISO 14031 1999). This category can be viewed to contain what Olsthoorn et al (2000) called business activity indicators and what Schwarz et al (2002: 59) called "expressing the metrics as ratios."
- *Indexed:* describing data or information converted to basic units or to a form which relates the information to a chosen standard or baseline (ISO 14031 1999). This category can be regarded as containing what Olsthoorn et al (2000) called productive efficiency indicators.
- *Aggregated*: data of the same type but from different sources, expressed as a combined value. (ISO 14031 1999)
- *Weighted*: describing data or information modified by applying a factor related to its significance. (ISO 14031 1999)

2.7 Content of environmental indicators

The literature on environmental indicators is rich in terms of pools and selections of already existing indicators. This section is intended to scan some of the vast selections of indicators that the actors of environmental accounting have compiled.

Sustainability metrics

According to Schwarz et al (2002), five basic indicators of sustainability are material intensity, energy intensity, water consumption, toxic emissions and pollutant emissions.

Schwarz et al (2002) also argue that complementary metrics within the aforementioned categories can be developed as the need for further areas of decision support arises.

Indicators of sustainable development

Krajnc & Glavič (2003) have offered an entire set of environmental indicators (actually OPIs). Their set is composed of input (resource use) and output (wastes and emissions) indicators. The input indicators are divided into energy use indicators, material use indicators and water use indicators. The output indicators are divided into product indicators, solid waste indicators, liquid waste indicators and air emissions indicators. This categorization, with examples of each indicator type, is presented in Appendix 1. The indicators suggested by Krajnc & Glavič (2003) can be utilized both on a product level and on a project or a company level. In the latter cases, the product level indicators need to be turned into aggregate indicators.

ISO 14031

The International Standardization Organization (ISO 14031 1999) has provided numerous examples of OPIs. Their categorization differs somewhat from that of Krajnc & Glavič (2003): The indicators are categorized into materials, energy, services supporting the organization's operations, physical facilities and equipment, supply and delivery, products, services provided by the organization, wastes and emissions.

The indicators suggested by ISO 14031 (1999) vary in terms of system boundaries: Some indicators are clearly designed for a project level, whereas some indicators are designed for a company level. Naturally, indicators designed for a product level can be turned into aggregated indicators (where the information about different products is added up) to reflect the project or company level.

A representation of the categorization is illustrated in Figure 4. Some of the examples presented in the standard (ISO 14031 1999) have been collected and organized in Appendix 2.

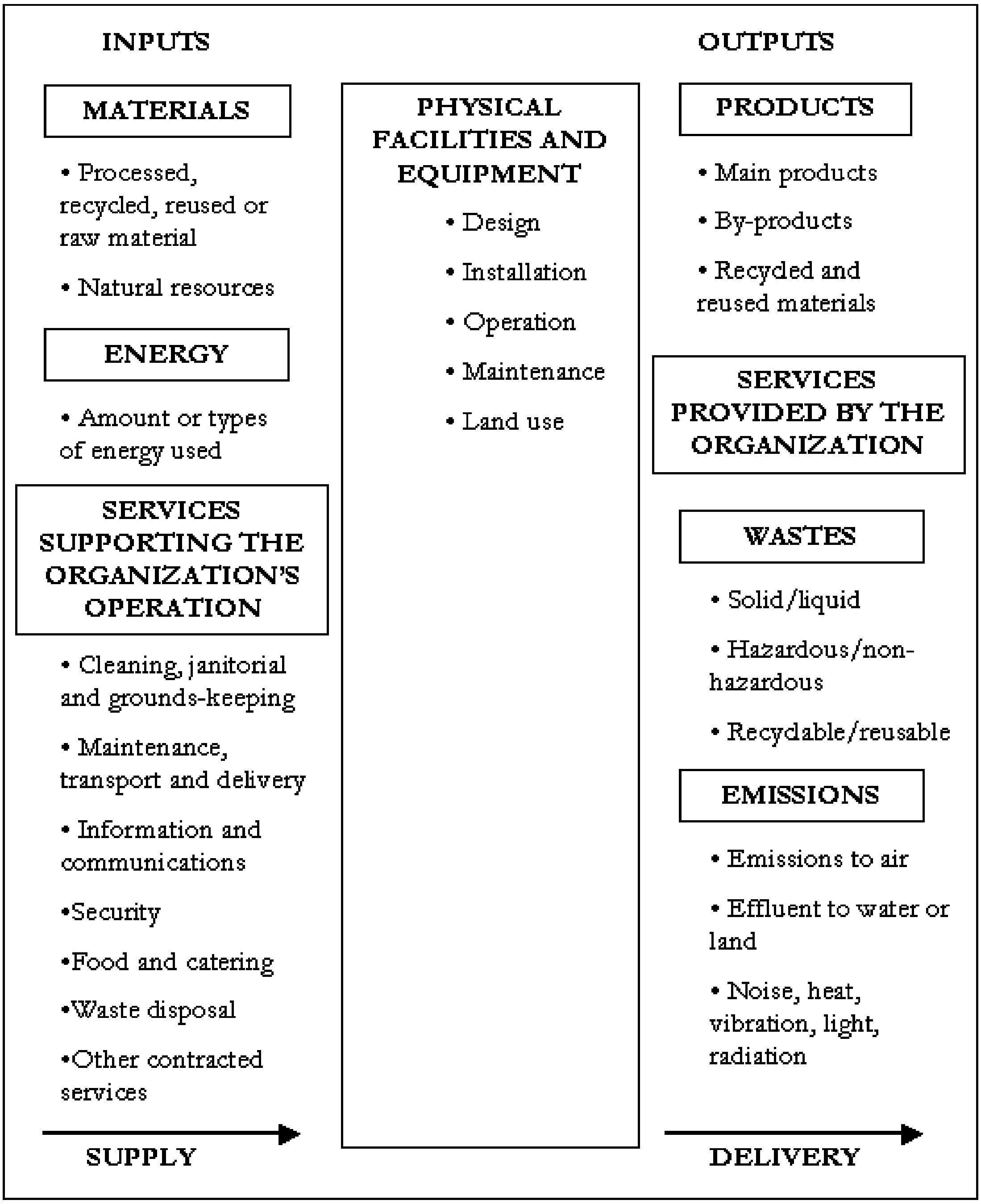

Figure 4. OPI categories according to ISO 14031 (1999, p. 41).

The Global Reporting Initiative (GRI)

The Global Reporting Initiative is "a multi-stakeholder process and independent institution whose mission is to develop and disseminate globally applicable Sustainability Reporting Guidelines" (GRI 2005). The initiative provides indicators for measuring and reporting a company's social, environmental and economic responsibility. The GRI indicators are designed solely for the company level, and they are divided into core and additional indicators. The GRI Guidelines contain 16 environmental core indicators and 19 environmental additional indicators divided into the following categories: materials; energy; water; biodiversity; emissions, effluents, and waste; suppliers; and products and services. Appendix 3 presents the core and additional environmental indicators of the GRI Guidelines. (GRI 2002).

The Eco-Management and Audit Scheme (EMAS)

The Eco-Management and Audit Scheme is "the voluntary EU scheme for organizations willing to commit themselves to evaluate, improve and report on their environmental performances." (EMAS 2005a). EMAS is a management tool that has been available for participation since 1995. To participate, an organization must comply with the following four steps:

1) conducting an environmental review;
2) establishing an environmental management system;
3) carrying out an environmental audit; and
4) providing a statement about its environmental performance. (EMAS 2005b)

Like other environmental management tools such as ISO 14031 and GRI, EMAS provides guidelines for developing EPIs and examples of such indicators.

EMAS categorizes indicators in terms similar to ISO 14031: as Operational Performance Indicators (OPIs), Management Performance Indicators (MPIs) and Environmental Condition Indicators (ECIs). The OPIs are further categorized into input indicators, physical facilities and equipment indicators and output indicators. The indicators and their dimensions are presented in Table 1. Examples of indicators in each category are provided in Appendix 4.

Table 1. EMAS indicator categories and their dimensions (adapted from Commission Recommendation 2003).

Indicator category	Input indicators	Physical facilities and equipment indicators	Output indicators
Dimensions	- Materials - Energy - Services supporting the organizations operations - Products supporting the organization's operations	- Design - Installation - Operation - Maintenance - Land use - Transport	- Products provided by the organization - Services provided by the organization - Wastes - Emissions

The indicators suggested by EMAS (Commission Recommendation 2003) provide a mix of product level, project level and company level indicators. A majority of the output indicators are most usable on a company level, whereas the input indicators consist of a more heterogeneous mix of indicators designed for different levels.

2.8 Context of environmental indicators

The context of environmental indicators can be achieved by synthesizing the two previous sections. Figure 5 depicts the field or context of environmental indicators with emphasis on the OPIs.

The figure has been generated by considering the classifications and content of environmental indicators. It is not suggested that the figure provides an exhaustive and particularly balanced view of the context of environmental indicators; rather, it is meant to summarize and depict those previously considered aspects that are especially relevant for this thesis.

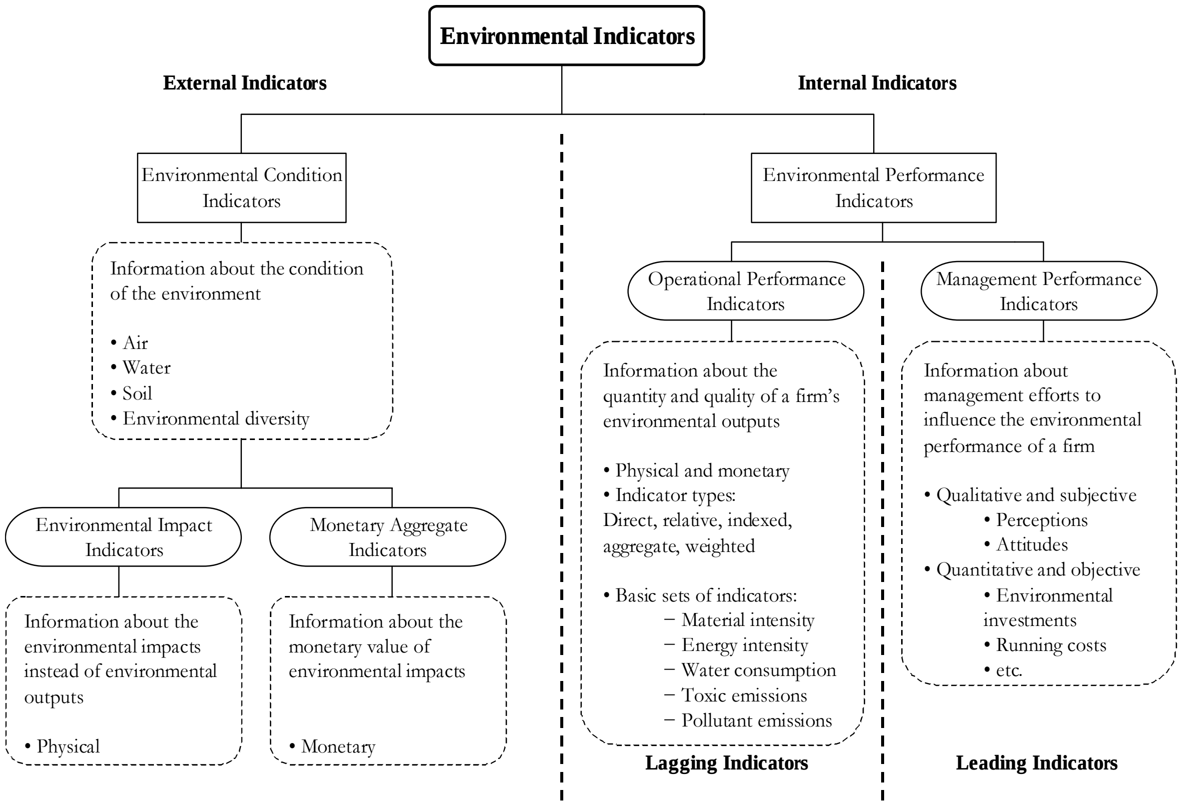

Figure 5. The context of environmental indicators.

2.9 Criteria for environmental indicators

The literature concerning environmental indicators provides numerous lists of attributes that good environmental indicators possess. Although the different attributes are numerous, they can be regarded as falling into five different categories:

1) Attributes that concern the time frame of the indicators;
2) Attributes that concern the practicability of the indicators;
3) Attributes that concern the link between the indicators and the organization;
4) Attributes that concern the objectivity and suitability of the indicators; and
5) Attributes that concern the extent and generality of the indicators.

Table 2 presents attributes that fall into the categories described above.

Table 2. Attributes of good environmental indicators.

In terms of the indicator's *time frame*, an indicator should be	▪ Continuous − indicators should be based on the same criteria and should be taken over comparable time sections or units. (Commission Recommendation 2003) ▪ Timely − indicators should be updated frequently enough to allow action to be taken. (Commission Recommendation 2003) ▪ Able to provide information on current or future trends in environmental performance. (ISO 14031 1999)
In terms of the indicator's *practicability*, an indicator should be	▪ Simple – not requiring large amounts of time or manpower to develop. (Schwarz et al 2002, ISO 14031 1999) ▪ Cost-effective in terms of data collection. (Schwarz et al 2002, Olsthoorn et al 2000, ISO 14031 1999) ▪ Protective of proprietary information. (Schwarz et al 2002) ▪ Understandable to a variety of audiences. (Schwarz et al 2002, Olsthoorn et al 2000, ISO 14031 1999) ▪ Useful to management decision making and relevant to business. (Schwarz et al 2002, ISO 14031 1999)

In terms of the *link between the indicator and the organization*, an indicator should be	▪ Responsive and sensitive to changes in environmental performance. (ISO 14031 1999) ▪ Representative of the organization's environmental performance. (ISO 14031 1999) ▪ Measurable in units appropriate to the environmental performance. (ISO 14031 1999) ▪ Consistent with the organization's environmental strategy. (ISO 14031 1999)
In terms of the indicator's *objectivity and suitability*, an indicator should be	▪ Objective. (Olsthoorn et al 2000) ▪ Robust and non-perverse – indicating actual progress toward sustainability. (Schwarz 2002) ▪ Adequate for their intended use based on the type, quality and quantity of data. (ISO 14031 1999) ▪ Significant – covering all relevant aspects. (Olsthoorn et al 2000) ▪ Balanced between problematic (bad) and prospective (good) areas. (Commission Recommendation 2003)
In terms of the indicator's *extent and generality*, an indicator should be	▪ Stackable along the supply chain. (Schwarz 2002) ▪ Reproducible. (Schwarz et al 2002, Olsthoorn et al 2000) ▪ Explicit in terms of boundary definition. (Kirchain & Atlee 2004)

2.10 Models for developing environmental indicators in businesses

2.10.1 Model of normalization and standardization

Olsthoorn et al (2000) have suggested a stepwise model for developing an organization's environmental indicators. The model contains the normalization, standardization and aggregation of data. The model is portrayed in Figure 6.

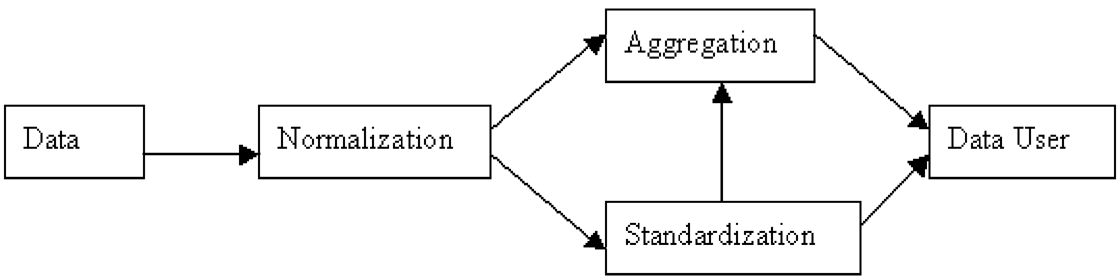

Figure 6. Stepwise approach to development of environmental indicators. (Olsthoorn et al 2000, p. 10)

Standardization refers to efforts to increase the comparability of environmental data between years, sites, functional units, products or resource uses. The most common activity to standardize is normalization, which transforms data into compatible or comparable forms. Normalization ensures that data are converted to units or to a form compatible with a chosen standard or baseline or that it has common units. (Olsthoorn et al 2000)

Aggregation transforms data into different forms or formats to allow a better understanding or interpretation of the data by different groups or for different purposes. Data aggregation should be guided by the subsidiarity principle, namely that data are to be aggregated to the lowest level of the organizational hierarchy where the decision can be made appropriately. Furthermore, indicators should be as simple as possible and only as complex as necessary. (Olsthoorn et al 2000)

The model from Olsthoorn et al (2000) concerns the process of transforming random and incommensurate data into commensurate and useful indicators. The model does not address what an organization should measure and to what ends. Hence, the model's greatest contribution concerns the very process of transforming random data into the form of indicators.

2.10.2 Model for measuring sustainability

Veleva and Ellenbecker (2001) have presented a model for measuring an organization's sustainability. Although their model is originally intended for sustainable production, it can also be referred to when developing environmental indicators. In Veleva and Ellenbecker's (2001: 531) "continuous-loop model," indicators are developed and implemented in eight (8) subsequent steps. The steps are described as follows:

1) Define sustainable production goals and objectives.
2) Identify potential indicators to reflect a company's goals and targets toward sustainable production.
3) Select indicators for implementation. This step involves all employees.
4) Set specific targets after consultation with stakeholders. Examples of specific targets might concern the reduction of toxic chemicals used per unit of product or the achieving of zero work-related injuries in a year.
5) Implement the indicators. This is a key step that involves data collection, calculation, evaluation and interpretation of results. The following issues are to be clarified:

6) Monitor and communicate results. It is recommended to establish a system for regular evaluation, interpretation and presentation of results to employees and other interested parties.
7) Act on the results by taking corrective measures, for instance in terms of pollution prevention and cleaner production.
8) Review the indicators, policies and goals. (Veleva and Ellenbecker 2001).

The model is illustrated in Figure 7.

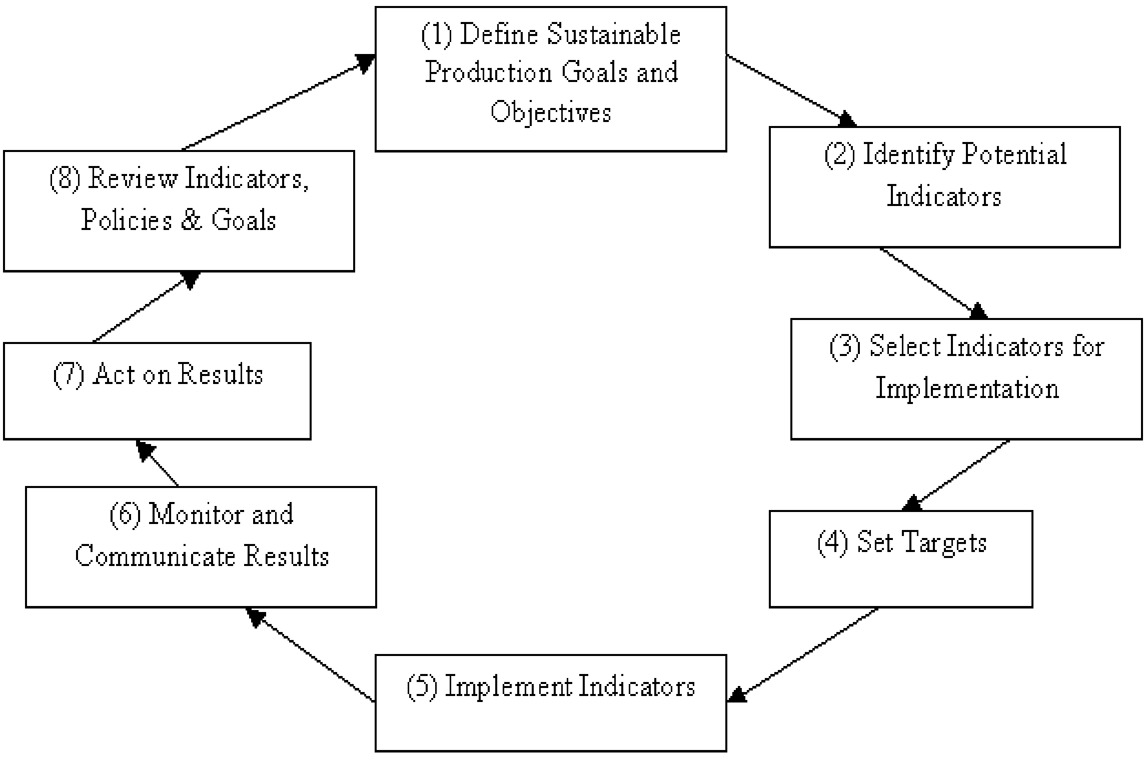

Figure 7. Continuous-loop model for defining and measuring sustainability performance in organizations. (Veleva and Ellenbecker 2001)

The model from Veleva and Ellenbecker (2001) goes further than that from Olsthoorn et al (2000) in that it gives advice on how the individual indicators should be selected. The model is lacking, however, in terms of explaining how an individual indicator should be developed from a disorganized set of data – which was the main contribution of the model from Olsthoorn et al (2000).

2.10.3 Model for planning an environmental indicator development program

The Global Environmental Management Initiative (2000) proposes an elaborate model for planning, implementing, evaluating and improving an environmental indicator development program. The emphasis of the model is on planning the program, since "careful planning will eliminate many problems in the other stages." (GEMI 2000: 19) The planning part of the model comprises 12 steps or considerations that are presented below:

1) Consider your company's operations, organization and its unique environmental impacts. Each company has its own particular products and services, organization, financial structure, legal and regulatory requirements, customer demands, data collection and management systems and environmental impacts. Indicators appropriate to one company may not be appropriate to another. In large multinational companies, indicators may even vary from one facility or division to another.
2) Determine the audience for your indicators. The most important audiences include (but are not limited to) corporate management, government regulatory agencies, the public and employees.
3) Establish goals and objectives. Many of the objectives are often related to the interests of the various audiences – internal as well as external.
4) Determine whether health and safety indicators will be included in the program.
5) Select indicators that drive performance. The indicators selected should do more than just measure environmental outputs. Scoring or indexing facilities help to measure progress from previous years and drive continuing improvements.
6) Ensure that the program is sustainable. The program must be capable of enduring if key personnel leave the company or are transferred elsewhere. Hence, adequate documentation is paramount.
7) Be consistent from year to year. The program should be reasonably consistent from year to year, although flexible enough to allow continuous improvement.
8) Select indicators that are understandable and compatible with the company's operations and information systems.
9) Use data that are already being collected for other business purposes, where possible. This will make the program more affordable.

10) Define performance expectations and identify who is accountable. Companies with successful performance measurement programs link compensation with environmental performance. Facilities that are supplying the data should also know the results of their efforts.

11) Identify clear data collection processes – when and how will data be collected and reported. Data should be collected so that they are supplied to management in time to take effective action. Regulatory requirements may also dictate when certain data are collected and reported. Other considerations are

    a. What type of information management system will be used to manage the data,
    b. What type of computer software will be used to report data,
    c. Who will collect what kind of data,
    d. How site personnel will be trained to collect data, and
    e. How the accuracy of data will be verified.

12) Normalize data. The data on environmental outputs need to be tied to a unit of production in order to clarify whether positive environmental trends are the result of pollution prevention activities or simply the effect of decreased manufacturing. (GEMI 2000)

The model does not require that the steps or considerations be taken in the aforementioned order. However, the model is illustrated in Figure 8 as a trail of subsequent steps.

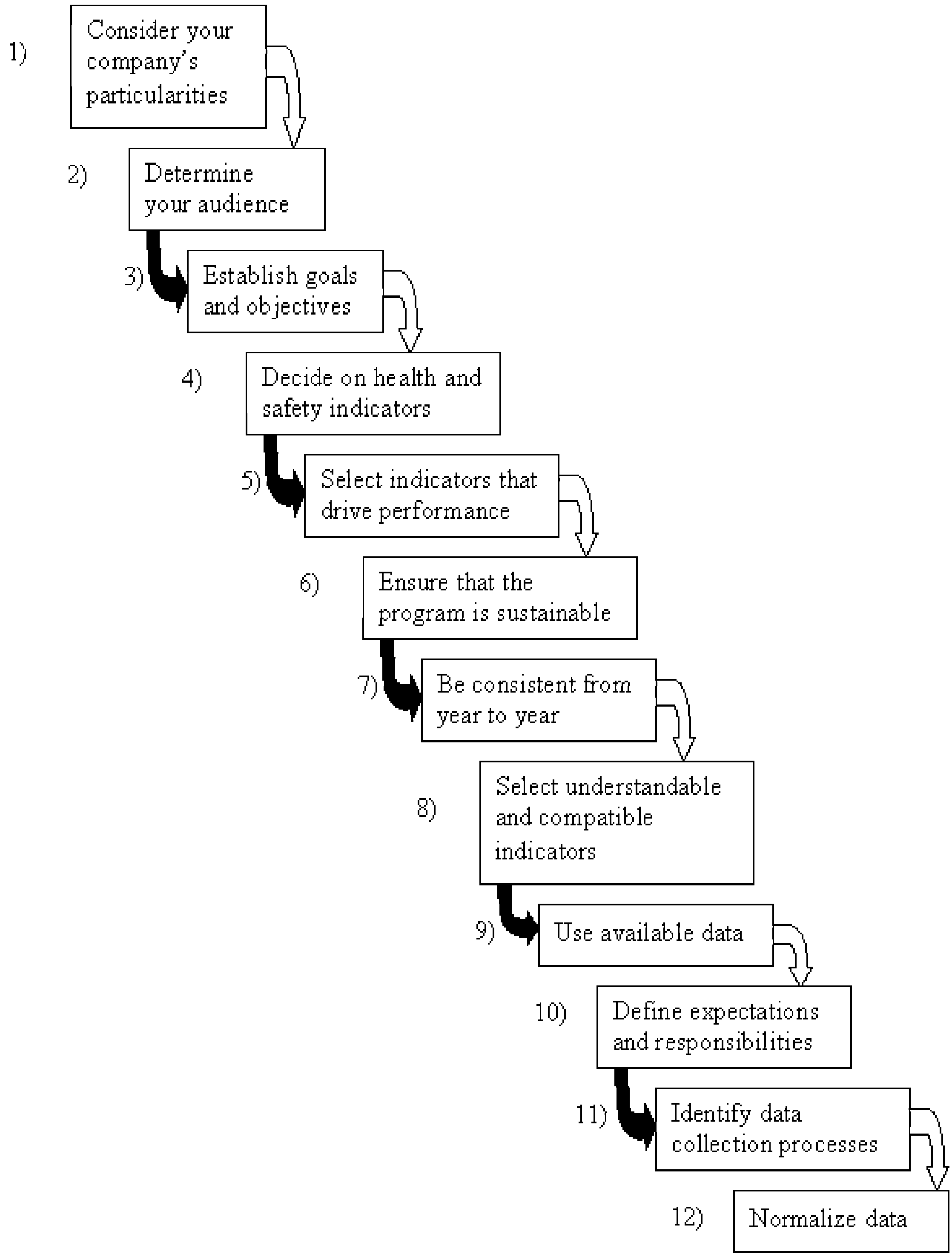

Figure 8. Model for planning an environmental indicator development program. (GEMI 2000)

2.11 Guidelines for developing EPIs for companies in the building construction industry

A number of organizations have provided input − directly or indirectly − for designing EPIs in Finnish building construction companies. Here, an input is not regarded as merely something that directly concerns the designing of EPIs. Instead, an indirect input may concern the environmental performance of a construction company in such a way that it has indirect implications on indicators concerning that performance. For instance, the national plan for waste management does not concern EPIs *per se*. Instead, it concerns the quantity of waste production of construction companies and has thus indirect implications on EPIs concerning the waste production of construction companies.

One prominent example of an organization that has provided input − direct and indirect − is the Confederation of Finnish Construction Industries (RT). Other notable organizations are the Technical Research Centre of Finland (VTT); the European Union and the Finnish government. The inputs of each of these organizations are examined in turn in the following sections.

REM

REM is a set of EPIs designed for the real estate and construction industries in Finland (REM 2005a). It was designed by the Confederation of Finnish Construction Industries (RT) with the intention of merely providing guidance; the system has no regulatory power over the actors in the Finnish real estate and construction industries. REM provides indicators for the eco-efficiency of

- Real estate ownership;
- Building construction (the customer's perspective);
- Building construction (the contractor's perspective);
- Construction design; and
- Product manufacturing.

The indicators are categorized into internal efficiency and know-how; customers, stakeholders and networking; and profitability management. A majority of the indicators are verbal statements concerning the environmental performance of the organization. However, there are also "core indicators" that are expressed numerically. For construction and construction design, the core indicators are mainly MPIs, the only OPI being the average amount of waste per constructed m^3 in a year.

The use of REM indicators in a company's operations is completely voluntary (REM 2005b). Therefore, REM may be regarded as a suggestive rather than an enforcement source when designing EPIs for a construction company.

PromisE

PromisE is an environmental classification system designed to define environmental objectives, monitor and manage those objectives and assure continuous development in the construction industry. (PromisE 2005) It was designed by the Confederation of Finnish Construction Industries (RT) as a part of the REM project. (REM 2005b) Hence, PromisE − like REM − is merely a guidance system and has no regulatory power over the Finnish construction industry.

PromisE is a system in which different EPIs are weighted in order to achieve an indexed indicator for the overall environmental performance of a building. The categories of these EPIs, and the relative weights (expressed in percents) of the indicators are presented in Appendix 5. The indicators require very little environmental accounting, since most of them are qualitative descriptions of a construction project's environmental aspects.

The RT Environmental Declaration

The Confederation of Finnish Construction Industries (RT) has developed a method for producing environmental declarations for building materials. The RT Environmental Declaration is "a voluntary and public document providing comparable and impartial information on the environmental impacts of building materials." (RT Environmental Declaration, 2005a)

An environmental declaration contains the eco-profile of a construction product. The eco-profile includes the environmental aspects of a building product's life cycle from purchase of raw materials to production to factory gate. (RT Environmental Declaration, 2005b)

The RT Environmental Declaration may be considered when designing EPIs for a construction company, since it provides a basis for the life cycle analysis of a construction project by providing life cycle information about individual building products. After all, "the purpose of the environmental profile is to provide a starting point for the environmental assessment of buildings." (Häkkinen 2005) Companies utilize the declaration system voluntarily; there is no legislation that requires it. (RT Environmental Declaration, 2005a)

The energy directive

Directive 2002/91/EC of the European Parliament and of the Council (European Council 2002) is aimed at promoting the improvement of the energy performance of buildings within the European Union. It was originally intended to become legally valid at the beginning of 2006, but its introduction in Finland has been postponed to an undefined later date. (Rantama 2005)

The directive concerns a methodology for calculating the energy consumption of buildings, the application of minimum standards for the energy performance of new buildings, energy certification of buildings and regular inspection of boilers and air-conditioning systems in buildings. (European Council 2002)

An energy certificate will be required when a new building is about to be commissioned. The certificate is expected to include key figures for standardized use and a forecast of energy consumption. Before the certificate system can be implemented in Finland, numerous questions need to be answered. Some of these questions are:

- What key energy consumption figures shall be expressed?
- How shall a building's energy classification be defined?
- Which different building types shall be assessed according to a single energy classification?
- Who shall be issuing the energy certificates? (Rantama 2005)

In short, the energy directive requires that builders provide forecasts and calculations about the energy consumption of their new buildings. Although the implementation of the directive is still incomplete, it should be taken into account when selecting EPIs for a construction company. After all, the directive − unlike REM or PromisE, for instance − will wield considerable power over construction companies once implemented. Instead of merely providing guidance, it will establish standards for the level and reporting of the energy consumption of new buildings. (See Rantama 2005 and European Council 2002)

The national plan for waste management

Finland's national plan for waste management sets objectives for waste reduction and recycling in different industries. In the building construction industry, those objectives are:

- The quantity of waste (construction, demolition waste and excavation waste) from building construction in 2005 will average 15% lower than the quantity of waste in 1995 and the quantity of waste from building construction, taking into account actual economic growth.

– The rate of waste utilization will be at least 70% in 2005.

In order to ensure that these objectives are reached, the plan defines central and non-central control mechanisms for waste production in the construction industry. The central control mechanisms consist of four administrative-judicial mechanisms and one economic mechanism. The non-central control mechanisms consist of one economic mechanism and three informational mechanisms. (Jätehuoltosuunnitelma 2005)

Although the objectives are merely advisory and suggestive, the control mechanisms may pose requirements or strong economic incentives for companies in the building industry. (See Jätehuoltosuunnitelma 2005) Hence, the objectives of the national plan for waste management should be taken into account when designing EPIs for a company in the Finnish construction industry.

The eco-efficiency of buildings and construction

The Technical Research Centre of Finland (VTT) and the Finnish Environment Institute (SYKE) have drafted a report concerning the eco-efficiency of buildings and construction. In Chapters 5 and 6 of the report, there is a discussion of eco-efficiency indicators of buildings and the construction industry. (VTT 1999)

In Chapter 5, the indicators are classified as primary and secondary indicators. Primary indicators are meant to assess the social impacts, cultural impacts and environmental load of a building or construction project. Secondary indicators are meant to assess characteristics that are known to affect the environmental load of a building or a construction project. Secondary indicators are also meant to assess different technical solutions used in buildings and construction projects. (VTT 1999)

The report contains a list of possible indicators for the eco-efficiency of buildings and construction projects. The list is presented in Appendix 6. The report was drafted with the objective of combining the functionality ideas of the construction industry and life cycle thinking. It has no regulatory power over the construction industry.

The European Union (EU) Emissions Trading Scheme

The EU Emissions Trading Scheme has direct implications for the construction industry. The first phase of the trading system (2005-2007) covers certain aspects of steel production and the CO_2 emissions of cement and lime production. Other construction materials whose production falls into the sphere of emissions trading are glass, lightweight aggregate (expanded clay aggregate), bricks, fiberglass and glass wool. (KTM 2004) Although the trading system has direct implications only on the producers of these materials, there will be indirect implications on the consumers of those materials (in this case, construction companies).

It is unknown to what extent the EU Emissions Trading Scheme will have an increased effect on the construction industry in its second phase (2008-2012). At this point, the industries that will be added to the system have not yet been determined.

2.12 Guidelines for developing EPIs for companies in the civil construction industry

Whereas there are numerous instances providing input for developing EPIs in a building construction company, there are hardly any such instances in the road construction industry. Aside from the fact that civil construction projects usually require an environmental permit and an environmental impact assessment (Hartikainen 2002), the road construction industry seems a rather unexplored field when it comes to measuring and reporting its environmental aspects.

Manual for managing environmental aspects in a civil construction project

Tuhola (1997) has designed a manual for managing environmental aspects in a civil construction project. The manual covers all the relevant environmental aspects, for example from material use and waste management to the proper use of construction and transportation machinery. However, Tuhola's manual can be seen to have little − if anything − to do with environmental indicators: The manual's sole objective is to give advice on how to deal with the environmental aspects at a construction site. The advice it provides is pragmatic and down-to-earth, and it is directed at specific working practices rather than higher-level environmental management activities. None of them concerns or has any implications on measuring environmental performance or developing EPIs.

Environmental impact assessments

An environmental impact assessment is required by law in operations where the natural environment can potentially be affected. (See Henry & Heinke 1993, Marttinen et al 2000) It is a tool primarily intended for a project-level decision making. (Munn 1979) As a result of the EIA, the company may decide whether to

1) accept the development under consideration,
2) accept an amended form of the development,
3) accept an alternative proposal, or
4) reject the development altogether. (Henry & Heinke, 1993)

An environmental impact assessment is designed to identify and predict the impact of an operation on the biogeophysical environment and on human health and well-being. (Munn 1979) In identifying and predicting such an impact, the quantity and quality of the environmental load should first be assessed. In this assessment, environmental accounting is needed, and environmental indicators may be handy. Hence, the environmental impact assessment is an indirect incentive for developing OPIs for a road-building or other civil construction company.

Environmental permit

An environmental permit is required for operations that may potentially damage the environment. Examples of such operations that are used in civil engineering are an asphalt concrete plant and a crushing plant. (SYKE 2004)

In Finland. environmental permits are generally granted by Environmental Permit Authorities and Regional Environment Centers. When applying for an environmental permit, the applicant needs to provide information about its operations, environmental load, environmental impacts and harm prevention activities. (SYKE 2004) In asphalt and aggregate production, additional attention is paid to material consumption, energy consumption and production. (SYKE 2005) The permit authority may then specify different conditions for granting the permit. (SYKE 2004)

Applying for an environmental permit often requires environmental accounting in assessing material consumption, energy consumption or production quantities. Furthermore, the conditions specified by the permit authority may also require some measure of environmental accounting. To that extent, the requirements of environmental permits should be kept in mind when designing OPIs.

3 Research

3.1 Model for developing OPIs

The empirical work of developing new OPIs for the case company was started by devising a model: a stepwise approach to selecting and designing OPIs. The model was tailored from the suggestions in Section 2.10 above to better address the needs and characteristics of Skanska Oy.

Based on the suggestions covered in Section 2.10, the model that has been most closely resembles the considerations of GEMI (1998). However, some of the steps or considerations of GEMI have been omitted, modified or combined. The order of the steps has also been revised.

The considerations that were completely omitted are numbers 6 (Ensure that the program is sustainable), 7 (Be consistent from year to year), 11 (Identify data collection processes) and 12 (Normalize data). The latter two considerations were omitted because the scope of this thesis only extends to designing the indicators; identifying data collection processes and normalizing data were viewed as steps related to actually implementing the indicators. The consideration of being consistent from year to year was omitted because it could not be concretized as an operational step. It was also decided that ensuring that the system is sustainable could not be effectively done until the data collection processes have been identified. Hence, this consideration was deemed beyond the scope of this study.

Considerations 5 (Select indicators that drive performance) and 8 (Select understandable and compatible indicators) were merged together to achieve a compact phase of indicator selection. It was also decided that the indicators should be selected on two occasions: First, there should be an identification of potential indicators. Second, there should be a selection of indicators for implementation. This kind of phasing is lacking in the considerations of GEMI (1998), but is apparent in the model of Veleva and Ellenbecker (2002) (See Section 2.10.2). The purpose of breaking the selection down into two stages was to ensure that the final indicators would be selected from a plethora of various indicators and that different possibilities would be considered before deciding on the final indicators.

The model contains two steps that have not been included in any of the models described in Section 2.10: the steps of stakeholder communications and reviewing the existing work on EPIs. The objective of stakeholder communications is to involve the relevant parties in developing new indicators. The step of reviewing the existing work on indicators was considered necessary in order to avoid overlap and to gather ideas for developing new indicators.

The tailored model for developing OPIs in this study is outlined in the following paragraphs.

Operations, organization and environmental impacts (Step 1)

In the first step, the company and its particularities are examined. This step includes a review of the company's organization and operations. It also includes an overview of the environmental aspects of Skanska Talonrakennus Oy and Skanska Tekra Oy, the two pilot cases in this study. The objective of this first step is to direct attention to the significant aspects of the company's operations in order to develop indicators that are significant and relevant.

Audience of the indicators (Step 2)

In the second step, the primary audience of the new indicators is determined. It is decided whether the indicators are mainly intended for internal or external reporting. The types of managers and stakeholders that the indicators are primarily intended for are also determined. This will guide the development and nature of the new OPIs.

Stakeholder communications (Step 3)

In the third step, the primary (and possibly secondary) audiences of the indicators are interviewed to find out what the stakeholders expect from the indicators and what kind of indicators they find particularly relevant. The aim is to ensure that the indicators that are designed meet the needs and preferences of their users rather than their designers.

Goals and objectives (Step 4)

In the fourth step, the objectives of the OPIs are established. The objectives are not specific environmental performance objectives; rather, they are goals for the indicator system itself. In other words, the objectives are meant to respond to what is expected from the indicator system.

Decision on health and safety indicators (Step 5)

In the fifth step, it is decided whether or not to include health and safety indicators in the development program. This step may be covered rather briefly.

Existing indicators (Step 6)

Since the case company has already implemented certain environmental indicators and drafted others for potential implementation, it was considered essential that the existing work on environmental indicators be reviewed. Hence, the sixth step comprises the review of indicators implemented and drafted by Skanska Oy.

Identification of potential indicators (Step 7)

The seventh step of the indicator development program concerns the identification of potential OPIs. At this stage, the practicality of the ideas should not be a limiting factor. The objective of this step is to identify a vast number of different OPIs for Skanska Talonrakennus Oy, Skanska Tekra Oy and both companies. Assessing the practicality of the identified indicators will be done later on.

Data that are already being collected (Step 8)

The eighth step involves an investigation of data that are already being collected for other business purposes and that could be utilized in new OPIs. This is an important step, since it enables the selection of indicators that require only minor modifications in the company’s operations. Utilizing such indicators will keep implementation costs down (see Section 2.9).

Selection of indicators for implementation (Step 9)

In the ninth step, the indicators for implementation are selected. There may be separate indicators for Skanska Talonrakennus Oy and Skanska Tekra Oy, and there may be indicators shared by both of them. The selected indicators should be understandable, easy to implement, and ones that drive performance − among several other aspects. (See section 2.9) This step is particularly crucial and requires a lot of consideration and probably negotiations with different parties. During this step, all the preceding steps of this plan as well as the preceding sections of this thesis need to be considered.

Definition of responsibilities (Step 10)

In the final step, people's responsibilities are defined. OPIs are, by definition, indicators that measure performance. The indicators have no way of driving performance unless people responsible for that performance are recognized. Hence, before the indicator system can be implemented, the people whose actions determine the outcome of the indicators needs to be recognized and their responsibilities defined.

The steps of the model are illustrated in Figure 9.

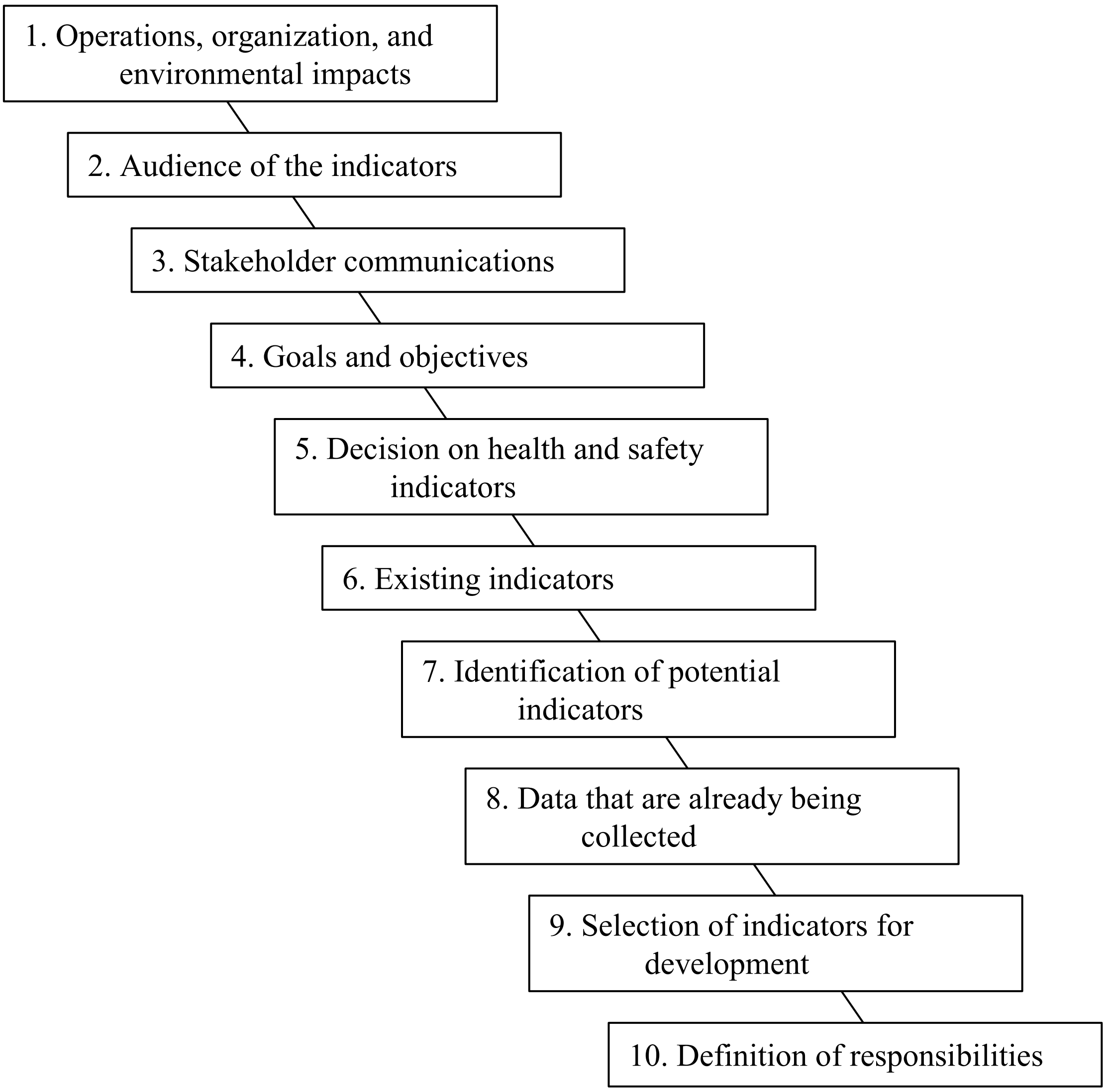

Figure 9. The model for developing OPIs.

The practical implementation of the model is depicted in the following sections.

3.2 Step 1: Operations and organization of the company

Skanska Oy is a Finnish construction corporation. It is a subsidiary of the Skanska Group, which operates in numerous other locations including Sweden, Norway, Denmark, Poland, the United Kingdom, the United States and Latin America.

Skanska Oy is involved in three branches of business: building construction (housing and commercial construction), civil construction and building services. Most of Skanska Oy's revenue is generated by building construction (58% of revenue), while civil construction accounts for 23% of Skanska Oy's revenue. Skanska Oy's market area comprises Finland and Estonia. (Vuosikatsaus 2004)

Skanska Oy's organization is depicted in Figures 10 and 11.

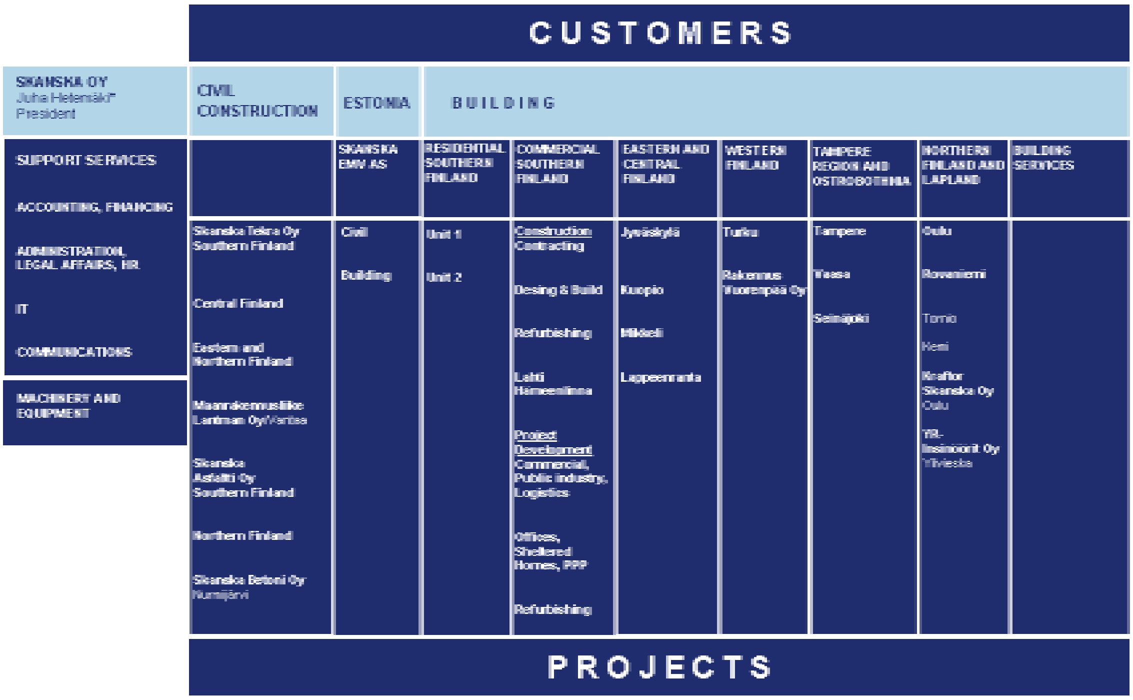

Figure 10. Construction services of Skanska Oy.

Figure 11. Skanska Oy in Finland and Estonia.

The figures highlight the polarization of Skanska Oy's operations into building and civil construction. They also demonstrate that building services, albeit considered a separate branch of business, is often viewed as part of building construction. Similarly, the figures indicate that the civil construction business is operated by three subsidiaries of Skanska Oy: Skanska Tekra Oy, Skanska Asfaltti Oy and Skanska Betoni Oy. PDR Finland is a customer of the building construction unit.

Skanska Oy and the environment

Skanska Oy has set for itself the following environmental objectives (Kihlman 2005):

- Minimization of environmental impacts during the life cycle of products
- Minimization of material loss and streamlining of waste management
- Increase in material knowledge
- Consideration of the immediate surroundings and minimization of disturbances caused by construction sites.

The Skanska Group has also applied a Code of Conduct (2005), a set of ethical principles to guide its operations around the world. The Code includes an environmental perspective. In the environmental section, the following statements are made:

- Caring about environment permeates all of Skanska's work.
- Compliance with legal and other environmental requirements provides the foundation for Skanska's environmental ambition.
- Skanska is committed to preventing and continually minimizing adverse environmental impact and to conserving resources.
- Skanska thinks ahead to determine how its work affects the environment and bases its decisions on available relevant facts.
- Skanska avoids materials and methods with environmental risks when there are suitable alternatives available. Skanska strives to recommend that clients use environmentally better alternatives whenever the circumstances permit.
- Skanska does not engage in activities that have unacceptable environmental and social risks. Skanska aims to identify such risks as early as possible to facilitate timely and adequate actions and decisions. (Code of Conduct 2005)

Environmental aspects of building construction

Skanska Talonrakennus Oy has defined and rated the environmental aspects of its operations. The most significant aspects were found to be (in the order of importance)

1) Energy consumption (construction, utilization, maintenance, energy sources, energy efficiency);
2) Consideration of significant aspects in strategies, goals and design;
3) Material loss;
4) Logistics (transportation);
5) Waste management (demolition waste, efficiency, separation of waste, collection and disposal of waste, hazardous waste). (Management system 2003a)
6) Land use planning; and
7) Impact of materials on human health and environment.

Section 2.2 provides a theoretical and generic view of the environmental aspects of building construction.

Environmental aspects of civil construction

Skanska Tekra Oy has defined and rated the environmental aspects of its operations. The most significant aspects that Tekra has control over were found to be

1) Management (principles of operation, objectives),
2) Risk assessment,
3) Competency of staff,
4) Material selection,
5) Stakeholder communications,
6) Use of machinery on site (logistics on site, construction machinery),
7) Material transportation,
8) Service life and maintenance of the final product, and
9) Primary raw materials and auxiliary materials. (Management system 2003b)

When the aspects are viewed in terms of EPIs, numbers 1-3 and 5 can be considered to be MPIs, whereas numbers 4 and 6-9 can be viewed as OPIs (see section 2.6.1). Section 2.3 provides a theoretical and generic view of the environmental aspects of civil construction.

3.3 Step 2: Audience of the indicators

The indicators are primarily intended for internal use: to help managers at different levels make decisions that include environmental aspects. (Kekki 2005a) Goals and objectives of the indicators will be discussed in greater detail in the following section (Step 3) and have already been considered to some extent in Section 1.2.

There is a wide range of potential users of the indicators. At one end of the spectrum, there are the CEOs of Skanska Oy, Skanska Talonrakennus Oy and Skanska Tekra Oy, along with vice presidents and other high-ranking managers. At the other end there are controllers, project managers, quality managers etc. The aim is to include everyone who has control over decisions that affect Skanska's environmental performance. As the range of such individuals is large and continually changing, it is not purposeful to identify every one of them at this point. There will be a closer look at the potential users in the next step (stakeholder communications).

3.4 Step 3: Stakeholder communications

The interviewees for stakeholder communications were primarily selected from within the company, as the new OPIs are primarily intended for in-house decision-making. However, representatives of both Skanska Tekra Oy's and Skanska Talonrakennus Oy's significant customers were interviewed as well.

When selecting the in-house interviewees, the aim was to achieve a sample that would cover the organization horizontally as well as vertically. Simultaneously, an effort was made to include most of the significant users of the OPIs in the research. The interviewees were selected in cooperation with Skanska Oy's Environmental Manager.

When selecting the external stakeholders for interviews, the aim was to include only a limited sample of such persons that could be expected to have genuine preferences concerning Skanska's OPIs. The interviewees were suggested by individuals at Skanska Talonrakennus Oy and Skanska Tekra Oy.

When conducting the interviews, the interviewees were contacted on three occasions. First, they were contacted face-to-face or by telephone to request permission for an interview and to set up a date for the interview. Second, they were e-mailed a covering note that contained the questions and a brief introduction to the interview, usually about a week prior to the meeting. Third, the actual interview was carried out.

The interviewees were asked three questions:

1) What objectives and expectations does the interviewee have concerning the new OPIs?
2) Which environmental aspects should the indicators deal with?
3) Should the indicators be in physical units, in monetary units or a mix of both?

Although the questions were pre-set, the interviewees were allowed to discuss them freely and in any order they saw fit. Answers to the questions are discussed in the following step (goals and objectives).

The stakeholder interviews, along with other encounters with the company's employees, also brought out views and perspectives concerning the research subject. One aspect that especially became apparent was skepticism toward the research objective: Many believed that designing functional and efficient indicators would be extremely difficult for various reasons. For one, construction projects were believed to differ too greatly to establish target values for the indicators. As a result, the indicators were believed to have little if any influence on the company's operations. Secondly, the economic aspect of corporate responsibility seemed to greatly overshadow the environmental aspect in many people's mindset. Some claimed that any environment-related activities would only be a burden if they did not directly benefit the economic performance of the company.

3.5 Step 4: Goals and objectives

The research was initiated with the intent of selecting OPIs that would have influence on the company's operations. Hence, one of the OPIs' objectives is their applicability for decision making. This objective was also brought up by a majority of the stakeholder interviewees. (See Maikola 2005, Lamminaho 2005, Hetemäki 2005, Toivola 2005, Pernaa 2005 and Nikula 2005)

Other goals and objectives were established through the stakeholder interviews. Most of the interviewees concluded that the information in the indicators should be in monetary units or that the monetary dimension should at least be included in one way or another. (See Maikola 2005, Tammivuori 2005, Lamminaho 2005 and Hetemäki 2005) However, some also felt that the physical dimension should not be entirely forgotten. (Lamminaho 2005, Toivola 2005, Pernaa 2005 and Maikola 2005) The importance of the physical dimension was especially stressed by the environmental department (Kekki 2005a) and external stakeholders (Heinonen 2005 and Soini 2005).

Another widely mentioned objective concerns the straightforwardness and simplicity of the indicators. The interviewees stated that the indicators should immediately and straightforwardly indicate when something is not right, and, preferably, also immediately indicate what aspects are causing the abnormality. (Hetemäki 2005, Tammivuori 2005, Nikula 2005, Maikola 2005, Heinonen 2005 and Soini 2005) Information for the indicators should also be simply and inexpensively collected (Hetemäki 2005, Toivola 2005, Pernaa 2005 and Maikola 2005), and the indicators should be similar to other indicators that may exist in the construction industry (Nikula 2005 and Toivola 2005). It was especially stressed that the indicators should correlate with the general strategy of the company. (Kekki 2005a and Toivola 2005)

The interviewees also defined objectives concerning the types of environmental aspects that should be monitored. One aspect rose above all others: the loss of construction materials during construction. (See Maikola 2005, Lamminaho 2005, and Tammivuori 2005) In building construction, the main focus was on the consumption and loss of construction materials (Lamminaho 2005), whereas in civil construction, the focus was on the re-use rate of excavated land (Maikola 2005, Pernaa 2005 and Heinonen 2005).

Other suggestions included humidity management (Tammivuori 2005), energy consumption at a construction site (Maikola 2005, Lamminaho 2005 and Soini 2005), recycled materials (Nikula 2005 and Soini 2005), and transportation of goods (Lamminaho 2005). Top management (Hetemäki 2005 and Tammivuori 2005) expressed a wish that the PromisE system could somehow be connected to the indicators.

Top management also stated that in order to maintain simplicity, only a few indicators should be developed − possibly even only one. (Toivola 2005) In the case of multiple indicators, their implementation should be scheduled to take place over a time span of several years. (Hetemäki 2005)

3.6 Step 5: Decision on health and safety indicators

The case company already places great emphasis on health and safety issues. Safety of construction workers, for instance, is at the forefront of the company's priorities. (Kekki 2005a) Every employee of Skanska Oy receives safety training in numerous forms, and managers' performance is partially assessed according to the health and safety statistics of their subordinates.

Environmental aspects, on the other hand, generally receive far less attention than health and safety issues. (Kekki 2005a) For instance, health and safety issues are more closely measured and observed than environmental issues: Skanska Oy has already rather extensive methods for assessing its performance in health and safety aspects. (See Koponen 2002)

To that end, limiting the development of new indicators solely to the environmental aspects was considered appropriate. As the objective of this study is to come up with a suggestion for new OPIs, it was feared that the environmental perspective would have been overshadowed by the health and safety perspective. Incorporating health and safety indicators into the project would also have massively expanded the scope and extent of the study.

3.7 Step 6: The company's current environmental indicators

The case company already has some EPIs in place. Some of the indicators are OPIs and some are MPIs. In addition to these indicators, the company has sought to develop other EPIs. The existing indicators as well as work on new possible indicators are discussed in the following paragraphs.

Indicators reported to Skanska AB

Skanska Talonrakennus Oy provides annual information for Skanska AB's environmental report. The following information is reported to Group headquarters in Sweden:

1) The percentage of personnel that has participated in basic environmental training and the number of employees who have participated in advanced environmental training.
2) The number of major suppliers that have a certified environmental management system and the classification of suppliers.
3) Information about internal and external audits: Their number and the most common causes of non-conformities.
4) Environmental requirements for projects, and the environmental objectives that exceed legal requirements.
5) Restoration of polluted soil.
6) Sorting of waste: The percentage of those projects where waste is sorted into at least three different components.
7) The number of suppliers' employees who have participated in environmental training.
8) The number of employees who have participated in auditing training.

As is apparent, majority of the information is in the form of EPIs. MPIs are represented by numbers 1, 2, 4, and 6-8. Number 3 can be regarded as an MPI or an OPI. Number 5 − if reported in the form of an indicator − represents an example of an OPI.

The Ecometer

Skanska Talonrakennus Oy has a software system called the Ecometer for calculating the quantities of certain environmental aspects of a building's life cycle. This software calculates the environmental aspects for three stages of a life cycle: construction, maintenance and service life. For each stage, the Ecometer calculates the following environmental load:

- Use of non-renewable and renewable energy (MJ/m^2);
- Emissions into the atmosphere (kg/m^2);
- Production of wastes (kg/m^2);
- Hidden streams of material production (kg/m^2); and

- Use of renewable and non-renewable natural resources (kg/m^2).

To calculate the quantity of the aforementioned environmental aspects in the maintenance and service phases, a building must be assigned a time span for the review (usually 50 years). The Ecometer bases its calculations on the environmental declarations (see Section 2.11) of building materials and products. Hence, the actual energy consumption of construction machinery, for instance, is not considered.

The Ecometer also produces relative indicators for the quantity of energy that the finished building consumes. The indicators are expressed in kWh/a/m^2. Such indicators are calculated for heating, electricity for common areas, hot water and apartment electricity. Energy consumption for heating and electricity for common areas are also combined to form an indicator for total energy consumption during service life.

Waste indicators

Skanska Talonrakennus Oy has OPIs that measure the production of waste at the company's construction sites. Total production of waste and the percentage of recyclable waste are measured on a monthly basis. Information for the indicators is collected from waste management bills and reports, and the indicators can be viewed in the scorecard section of the management system. The indicators are relative calculations, where the production of waste is expressed in relation to the volume (m^3) of the building under construction. Hence, the unit of the indicators is kg/m^3.

Construction sites measure their total waste production and recyclable waste production. The production of recyclable waste is compared to total waste production, which results in an indexed indicator where recycled waste is the nominator and total waste is the denominator. The production of recyclable waste is divided into subcategories: combustible waste, rock material, scrap, cardboard, wood and other recyclable waste. Skanska Talonrakennus Oy sets different waste production objectives for different types of construction, since waste production differs among these.

Energy consumption

Skanska Talonrakennus Oy has tested indicators for measuring electricity use at its construction sites. The indicators were tested at nine pilot sites. At the pilot sites, energy consumption was determined from electricity, gas and district heating bills. Energy consumption (kWh) at each of the sites was divided by the volume (m^3) of the building under construction. The outcome was a relative indicator, where energy use was the nominator and the volume of the building was the denominator. Hence, the unit of the indicator was kWh/m^3.

The use of the energy indicator was discouraged when the pilot sites − despite their similarities in construction type and time − produced incoherent results. Since the sites displayed no coherence or consistency in their energy use, the indicator value for an optimal or a normal site could not be reasonably determined. Hence, the indicator was deemed ineffective, and further testing and research is needed to fully utilize the benefits of the indicator.

The environmental index of a construction site

Skanska Oy has drafted environmental indices to reflect the overall environmental performance of construction sites. According to the plan, each site would have its own index for which the information would be collected on-site via a simple form. Although the index is not yet in use, the form has already been developed.

The form has six categories (protected locations, storing of chemicals, waste containers, use of energy on site, cleanliness of site and obstructions of passage), and each of the category is assigned positive points for instances of proper operation and negative points for instances of inappropriate operation.

The value of the index is obtained by dividing the number of positive points by the sum of positive and negative points and multiplying the ratio by 100. Hence, the maximum value of the index is 100% (no instances of inappropriate operation; the nominator equals the denominator) and the minimum value is zero (no instances of appropriate operation; the nominator is zero). The environmental index is analogical to the TR indicator used in safety inspections.

Potential EPIs for Skanska Oy

Skanska Oy has drafted a set of EPIs for a potential future utilization in construction. The indicators are designed to address the environmental aspects of building and road construction. Most of the indicators are OPIs, and they are divided into direct, relative and economic indicators. The OPIs concern such aspects as waste production and material consumption, and there are indicators for different phases of a building's life cycle.

EPIs drafted in cooperation with U.K. and Norwegian operations

Skanska Oy and its British and Norwegian counterparts in the Skanska Group have sought to draft EPIs that could be utilized throughout the Group. The indicators have been designed to reflect the GRI Guidelines, and they are divided into the following categories:

- Waste
- Construction materials
- Energy
- Biodiversity
- Disturbance to local community
- Unplanned pollution incidents
- Water
- Greenhouse gases
- Training.

Depending on the category, the indicators are either OPIs or MPIs. For instance, the training category contains MPIs whereas the categories for water, energy and waste contain OPIs. The OPIs are either physical indicators or combined physical and monetary indicators, where the nominator is in physical units and the denominator is in monetary units (contract sum).

3.8 Step 7: Identification of potential indicators

The objective of this step was to come up with as many OPIs relevant to Skanska Talonrakennus Oy or Skanska Tekra Oy as possible. A list of potential indicators is provided in Appendix 7. The indicators are categorized in two ways: first, in terms of the ISO 14031 (1999) categorization of an organization's operations. (See Figure 4) Second, they are categorized in terms of indicator types. The types selected for this research were

1) *Absolute indicators*, where the data or information is expressed directly, such as metric tons of contaminants emitted in a project. In ISO 14031 (1999), these indicators are referred to as *direct measures or calculations.* (See Section 2.6.2). The term "absolute indicator" was chosen in order to avoid confusion regarding the nature of the indicator: in environmental management, the words "direct" and "indirect" are already strongly

linked with, for instance, environmental impacts. Hence, the term "absolute" was considered more apt when describing the type of the actual indicator, whereas the term "direct" might be mistaken as concerning the subject of the indicator (direct environmental impact, for example).

2) *Relative indicators*, where the absolute value is compared to another parameter, physical or monetary.

3) *Indexed indicators*, where the data or information are converted to basic units or to a form that relates the information to a chosen standard or baseline.

4) *Aggregated indicators*, where lower-level (such as project level or unit level) indicators are combined to form a higher-level (such as company level) indicator by aggregating them.

The categorization outlined above closely resembles the categorization of ISO 14031 (1999) (See Section 2.6.1), with the clear distinction that the ISO 14031's weighted indicator category is missing altogether. The reason for this omission is the complexity of the category: weighted indicators combine different parameters while assigning them different weights, and defining different weights for any chosen parameters would substantially increase the complexity and extent of this thesis.

In the list of potential indicators, most of the indicators are expressed in a generic fashion: for instance, potential relative indicators are often expressed as an *absolute indicator divided by a physical or monetary parameter* (such as brm^3 or project sum, €). The indicators are not always specified any further, as the number of potential indicators would then grow exponentially.

Hence, the greatest informational value of the list is primarily located in the first two columns (environmental aspect column and absolute indicator column). The environmental aspect column is especially significant, since therein lies the specificity of the potential indicators' focus. The environmental aspects of Skanska Talonrakennus Oy were determined according to Sections 2.2 and 3.2 of this thesis, and in cooperation with Kolhonen (2005) and Kekki (2005c). The environmental aspects of Skanska Tekra Oy were determined according to Sections 2.3 and 3.2, and in cooperation with Kemppainen (2005a) and Kekki (2005b).

The absolute indicator column is significant, because it contains specific suggestions for potential absolute indicators. It is particularly significant, since it has definite implications as to the types of data that are required. The other types of indicator are mostly modifications and derivations of absolute indicators, and therefore do not usually have additional implications as to the types of data that are required.

The relative indicator column is also somewhat significant, since it contains suggestions for potential denominators that can be used when forming relative indicators.

The indexed indicator and aggregated indicator columns have the least significance at this point, since they primarily contain generic derivations of absolute and relative indicators, which are expressed more precisely. There are some exceptions, however, such as the indexed indicator for material efficiency.

3.9 Step 8: Data that are already being collected

3.9.1 Data in data systems

Skanska Oy has data systems for storing and processing different kinds of data. The expenditures of different projects are recorded in the system of denominations and electronic invoice checking. The product modeling system processes information about the physical inputs of a building construction project. The Ecometer (see Section 3.7) focuses on the environmental aspects of a building construction project, basing its calculations on the environmental declarations of building products and materials.

The system of denominations and electronic invoice checking is a way of allocating costs by different denominations. In practice, the monetary values of bills and other expenditures are typed into the system, and each item of expenditure is assigned a relevant denomination. For instance, there can be denominations for different material procurements and labor costs, and all respective expenditures are allocated to those denominations.

Construction sites may use the denominations differently. For instance, one project may have separate denominations for concrete procurements, rock material procurements and labor costs, whereas another project may have a joint denomination for all material procurements and respective labor costs. The system of denominations and electronic invoice checking only concerns monetary information (costs); it does not concern any physical information such as material quantities or working hours.

The product modeling system is used for modeling a building by using models of different building products. It is possible to use the system in retrieving the number of different building products used in a project. Furthermore, the quantities of the products can also be obtained via simple calculations. However, the quantity of a given building material cannot be directly obtained, because the models of different building products often contain more than one building material. Hence, the product modeling system cannot be used as such in determining the consumption of different building materials − additional calculations and operations would be required.

3.9.2 Data at construction sites

Construction sites receive large amounts of data that could be collected and utilized for OPIs. A majority of that data is in the form of delivery notes, energy bills and waste management bills. There are two aspects, however, that hinder the immediate exploitation of most of the data for OPIs.

First of all, the data is not being collected or stored systematically, and the types of collected data as well as the data collection methods differ greatly from site to site. (Koivumäki 2005, Mikkonen 2005) Furthermore, a great deal of the data is received and handled on pieces of paper, which hinders its processing in Skanska's data systems.

Second of all, the data that the construction sites receive are not readily normalized. For instance, the overall quantity of wooden products that has been brought to a building construction site cannot be directly determined, because the quantity of some products is expressed in running meters, and the quantity of some other products may be expressed in pieces or kilograms. In order to determine the quantity of all wooden products, for instance, the quantities of different products should be available in matching units. Similarly, different suppliers provide different types of data about their products. For instance, one supplier of a given product may express the quantity of the product in kilograms, whereas another supplier of the same product may express the quantity in cubic meters. This becomes evident from the delivery bills at a construction site.

According to Koivumäki (2005), the construction sites of Skanska Talonrakennus differ greatly in terms of the information they collect and observe. However, each site keeps track of its waste production (measured as kg/m^3). At the case site (Vallesmanni), the consumption of concrete is also systematically monitored.

The site has a bookkeeping system for monitoring and managing its concrete pouring. The system simply comprises a notebook and a pencil for recording the concrete pours. In the notebook, there are columns for the date and object of the pouring as well as for the individual and cumulative volumes of poured concrete. Rötsä (2005) argued that the system might be improved by adding a column for the volume of purchased concrete.

Hence, the loss of concrete at a site could theoretically be determined by subtracting the volume of the poured concrete from the volume of the purchased concrete. However, problems would arise, since the surplus of a concrete batch is sometimes used elsewhere than originally planned and is not transferred directly into a loss of concrete.

The case site in Arabianranta keeps a record of excavated soil and rock haulage. The system concerns only haulage from the site to outside dumping locations and excludes soil and rock imports to the site. The information is recorded on an Excel spreadsheet, which automatically calculates the cumulative values of transported soil and rock. The system separately considers haulage of polluted soil and unpolluted soil.

Loads hauled are categorized according to their destination. The distance (in kilometers) between the site and the destination has been recorded on some occasions, but not every time. The system currently uses the recorded distances in calculating the ton-kilometers of contaminated soil haulage, but not of uncontaminated soil haulage. Aside from soil and rock haulage, no other environmental aspects are systematically monitored at the case site.

3.10 Step 9: Selection of indicators for development

3.10.1 Environmental aspects to be measured

For Skanska Talonrakennus Oy, the environmental aspects selected for measurement were material consumption, energy consumption, waste production and material haulage. Different material types to be measured are concrete, steel, plasterboard, pre-cast concrete, rock material, untreated wood, impregnated wood and plaster.

For Skanska Tekra Oy, the aspects to be measured were consumption of recycled soil and rock materials, the re-use rate of soil and rock extracted from construction sites, energy consumption, water consumption and soil and rock haulage.

For both companies, energy consumption comprises site electricity as well as the fuel consumed by construction machinery. Since the building construction unit already measures its waste production in physical units, waste production refers here solely to measurements in monetary units.

3.10.2 Denominators for relative indicators

The process of selecting denominators has already been outlined in Step 7 (Section 3.8). In effect, the volume of construction (brm^3) was selected for the building construction unit. For the civil construction unit, the following denominators were selected:

1) For rock excavations, the volume (m^3) of the finished tunnel or cave.
2) For road construction, the area (m^2) of constructed road.
3) For bridge construction and demanding concrete structures, the volume (m^3) of steel or concrete required for the construction.
4) For foundation engineering, the volume (m^3) of the excavated soil and rock.

Different project types have such individual characteristics that more than one denominator is needed. Since the relative indicators are mainly for in-house use, this was not considered a problem. Given that different project types need to be considered separately in any case, it was decided to have numerous descriptive denominators rather than one or two inaccurate denominators. (See Kekki 2005c, Kemppainen 2005b and Savola 2005)

3.10.3 Specific indicators

The following energy consumption indicators were selected for the building construction as well as the civil construction unit:

1) Amount of electricity consumed on-site. Units of measure: € and kWh. Measured at the project level as well as at the company level.
2) Amount of electricity consumed at a site divided by the size of the structure. Units of measure: €/denominator and kWh/denominator (selection of denominators has been discussed above).
3) Quantity of fuel consumed by construction machinery. Units of measure: € and liters. Measured at the project level as well as at the company level.
4) Quantity of fuel consumed by a machine divided by the duration of the machine's operation. Units of measure: €/h and l/h.

The following water consumption indicators were selected for the civil construction unit:

1) Quantity of water consumed. Units of measure: € and m^3. Measured at the project level as well as at the company level.

2) Quantity of water consumed at a site divided by the size of the structure. Units of measure: €/denominator and m^3/denominator.

The following material loss indicators were selected for the building construction unit:

1) Quantity of materials consumed in a project and overall in the company. Units of measure: €, m^3 and t.
2) Quantity of consumed material excluding material loss divided by the quantity of consumed materials including material loss. A project level indicator. Units of measure: %.

The following soil and rock use efficiency indicators were selected for the civil construction unit:

1) Quantities of recycled soil and rock inputs and overall soil and rock inputs in a project and in the business unit. Units of measure: m^3.
2) Quantities of recycled soil and rock outputs and overall soil and rock outputs in a project and in the business unit. Units of measure: m^3.
3) Quantity of recycled soil and rock inputs divided by the overall quantity of soil and rock inputs. A project level indicator. Units of measure: %.
4) Quantity of recycled soil and rock outputs divided by the overall quantity of soil and rock outputs. A project level indicator. Units of measure: %.

The following transportation indicators were selected for the building construction as well as the civil construction unit:

1) Soil and rock as well as material haulage in a project and in a business unit. Units of measure: €, kilometers [km] and ton-kilometers [tkm].
2) Soil and rock as well as material haulage in a project divided by a denominator. Units of measure: €/denominator, km/denominator and tkm/denominator.

The following waste indicator was selected for the building construction industry:

1) Waste costs of a project divided by the size of the project. Units of measure: €/ m^3.
2) The already existing indicator of the amount of waste (kg) divided by the size of the project (m^3).

3.11 Step 10: Definition of responsibilities

The people best able to affect on-site energy consumption are project managers and pre-construction engineers. Pre-construction engineers are responsible for designing the project in such a way that its execution does not require excess amounts of energy. In effect, pre-construction engineers should consider such aspects as construction materials and the construction period. Project managers, on the other hand, are responsible for carrying out the plans in such a way that excess energy consumption is avoided. Project managers should thus consider such aspects as proper utilization of machinery and proper use of electricity on site. It is the task of analysts to pinpoint the extent to which pre-construction engineers and project managers are responsible for any given indicator result. However, the pre-construction engineers should be aware of the framework their design establishes for energy consumption in a project, and whether that framework is desirable or not. Similarly, project managers should be aware of the energy consumption goals and limits in that framework.

Project managers are responsible for the level of water consumption in a project. Hence, they should monitor water consumption and be held accountable for any excess use of water. Should there appear to be consistently excessive water consumption, it should be assessed whether the pre-construction engineers also share responsibility for the excess.

Project managers are the primary group responsible for efficiency in material consumption, since they control the activities that generally lead to lost materials (such as timing procurements and deciding on batch size). Planners, on the other hand, are responsible for the amount and type of materials consumed in a project.

Pre-construction engineers are the primary group responsible for the soil and rock use efficiency indicators. The pre-construction engineering stage includes a plan for soil and rock procurements and internal soil and rock reutilization. In the construction stage, soil and rock use efficiency cannot be effectively influenced.

Project managers are responsible for the logistics indicators, because they make the final call on what product is procured and from whom. They have some control over delivery times and distances, although some product procurements may be predefined by seasonal contracts.

Project managers are also responsible for the monetary waste indicators, just as they are responsible for the physical waste indicators currently in place.

4 Results

4.1 Model for designing OPIs

The research was initialized by constructing a model for selecting new OPIs. The constructed model closely resembles similar models presented in the literature, but it also entails certain unique aspects. The model's ten steps are briefly summarized as follows:

1) The case company's operations, organization and environmental aspects are examined in order to obtain an understanding of its particularities and individual characteristics.
2) The primary audience of the indicators is identified.
3) Significant stakeholders are incorporated into the program by consulting them about the new OPIs.
4) Goals and objectives for the indicator system are established.
5) It is decided whether the health and safety indicators will be included in the program.
6) The company's existing work on relevant indicators is reviewed.
7) Potential indicators are identified. At this stage, the practicality of ideas should not be a limiting factor, as the objective is to come up with an exhaustive selection of indicators.
8) Existing data collection systems are reviewed to find out if information for new OPIs is readily available.
9) New OPIs are selected for implementation.
10) Those responsible for the indicators' output are identified.

The nature of the model is generic in the sense that it can be applied in practically any organization in any industry. However, the results of the model can be expected to be industry-specific as well as company-specific.

4.2 OPIs selected for implementation

The OPIs that were selected for implementation are reviewed in Table 3. The indicators are primarily intended for project level utilization, although it is suggested that the information be collected at company level as well. Hence, each indicator would have a project-level as well as a company-level application.

There are four types of indicators: absolute, relative, indexed and aggregate. Absolute indicators concern the subject of measurement directly and exclusively; no other aspects are involved. The suggested indicators include an absolute indicator for each subject of measurement, because the information obtained from absolute indicators is needed for all the other indicators.

In relative indicators, the subject of measurement is divided by the size of the structure. In building construction, the size of the structure is measured in brm^3. In civil construction, there are four different dimensions for measuring the size of construction: For rock excavations, it is the volume (m^3) of the finished tunnel or cave. For road construction, it is the area (m^2) of constructed road. For bridge construction and demanding concrete structures, it is the volume (m^3) of steel or concrete required for construction. For foundation engineering, it is the volume (m^3) of excavated soil and rock. The size of measurement signifies the denominator in relative indicators. In the 'Units of measurement' column in Table 3, the denominator is marked by 'x'.

Indexed indicators are represented by those of material loss and soil and rock use efficiency. In both instances, the result of the indicator is expressed in percent (%). The indicators are constructed in such a way that 100% is the best possible result and that the greater the percentage, the better.

As has been mentioned earlier, each indicator selected for implementation is also aggregated into a company-level indicator. Hence, every indicator in Table 3 represents a project-level as well as a company-level indicator.

In material consumption, different material types to be measured are concrete, steel, plasterboard, pre-cast concrete, rock material, untreated wood, impregnated wood and plaster. Wood is measured in m^3, while other material types are measured in metric tons.

Table 3, Indicators selected for implementation

Subject of measurement	Business unit	Indicators	Units of measurement
Energy consumption	Building and Civil	Site energy consumption	€ and kWh
		Site energy consumption / size of structure	€/x and kWh/x
		Construction machinery's fuel consumption at a site	€ and l
		Quantity of fuel consumed by a machine / duration of the machine's operation	€/h and l/h

Water consumption	Civil	Water consumption at a site	€ and m^3
		Water consumption at a site / size of structure	€/x and m^3/x
Material consumption	Building	Material consumption at a site	€, m^3 and t
		(Material consumption excl. losses / total material consumption) * 100	%
Earth use efficiency	Civil	Quantity of recycled soil and rock inputs	m^3
		Quantity of recycled soil and rock outputs	m^3
		(Quantity of recycled soil and rock inputs / overall quantity of soil and rock inputs) * 100	%
		(Quantity of recycled soil and rock outputs / overall quantity of soil and rock outputs) * 100	%
Transportation	Building and civil	Overall soil and rock plus other material haulage	km and tkm
		Soil and rock plus other material haulage / size of project	km/x and tkm/x
Waste	Building	Waste production / size of project	kg/m^3
		Waste costs / size of project	€/m^3

5 Analysis of Results

5.1 Quality and functionality of the model

The model that was generated proved useful in developing a suggestion for new OPIs in the case company. First of all, applying the model broke the development process down into smaller and more manageable pieces. As a result, the focus and direction of developing the indicators became gradually clearer and more precise over time.

Assessing the company's organization and operations made its environmental values and aspects evident. The research project for developing new OPIs is in line with the company's environmental objectives and its views on corporate responsibility. Identifying the company's environmental aspects provided further direction for selecting new indicators.

Identifying the audience of the indicators was critical in terms of establishing stakeholder communications, which, in turn, was a key factor in defining goals and objectives for the new OPIs. The objectives themselves were not surprising: the indicators were expected to be objective, simple and appropriate for guiding the company's operations. Information for the objectives should be easily and inexpensively collected, and the indicators should generally contain information in monetary units rather than in physical units. The indicators should concern such aspects as the loss of materials, energy consumption at construction sites, and haulage of construction materials as well as soil and rock.

Reviewing the company's existing work on OPIs was an important phase in terms of avoiding unnecessary duplication and obtaining guidance for selecting new indicators. Identifying potential OPIs took the research project closer to its ultimate objective: the selection of new indicators for implementation. Research on data that the company already collects helped narrow down the pool of indicators and focus on aspects for which the information was readily available.

Since the model has certain unique aspects (See Section 3.1) in respect to other similar models, it can be considered to withhold some scientific novelty value. Since showing the solution's connections to theory and demonstrating its scientific novelty value is an essential phase of the constructive research methodology, the methodology's utilization has been successful to some extent.

5.2 Quality and functionality of the selected indicators

5.2.1 Energy

There are a number of reasons for selecting site electricity indicators for implementation: First of all, the information for such indicators is readily available in electricity bills. Although designing data collection methods is beyond the scope of this study, it is evident that the energy bills provide an easy and economical source of information, thus meeting the stakeholders' request for indicators with easily and inexpensively collectable data. Secondly, it is relatively easy to conduct energy indicators in monetary units as well as in physical units, as the bills contain monetary as well as physical information about energy consumption. Hence, the stakeholders' demand for physical and monetary indicators can be met in a single stroke. Thirdly, electricity constitutes the bulk of energy consumption on a construction site (See Sections 2.2 and 2.3 and Kemppainen 2005a) and is therefore a significant environmental aspect of construction. Measuring and analyzing site electricity may also become beneficial during possible future developments related to emissions trading and the energy directive (See Section 2.11).

However, the indicators' applicability in decision-making is not quite clear-cut. Especially in building construction, even seemingly similar projects may have different demands for site electricity. For instance, the amount of electricity required for heating depends on outdoor temperature and air humidity, which differ greatly geographically as well as seasonally. Nevertheless, site electricity consumption should be measured at least for the sake of external reporting, and possibly for in-house decision making as well. As the data pile up, conclusions and regularities may emerge that could be used in decision making and performance evaluation.

The fuel consumption of construction machinery can be a useful indicator in analyzing the machinery's operation and condition: Deviations in oil consumption may indicate that a given machine is either incorrectly operated or in poor condition. Observing the oil consumption is also beneficial in terms of assessing the life cycle impacts of a construction project and preparing for possible modifications in the EU Emissions Trading Scheme.

5.2.2 Water

For water indicators, basically the same conclusions apply as for site electricity indicators, with some adjustments. Like site electricity consumption, water consumption is easily measured via water bills. And, like site electricity indicators, water indicators may be challenging to utilize in decision making. The greatest difference between site electricity and water indicators is that water consumption is a far less significant environmental aspect in the construction industry, except for rock excavations. Hence, water indicators' most significant input would be in external reporting.

5.2.3 Material consumption

The quantity of materials consumed in building construction projects is measured for two reasons: to obtain data for external reporting and to obtain data for material loss indicators. The most important indicator concerning material consumption is the indicator for material loss. The indicator has four good qualities:

1) It concerns a significant environmental aspect of building construction (material consumption).
2) It is directly linked with the profitability of the company, since material losses are a result of inefficient resource use. Improving production efficiency is a focal point of Skanska Oy's operations.
3) It has total material consumption (instead of the size of the project) as a denominator. Therefore, the indicators can be expected to provide comparable results among different types of project. This is not always

the case with indicators that have the size of the project as the denominator (See Section 3.7 about energy indicators).

4) The unit is %, which can be transferred into monetary as well as physical information, hence meeting the demands of different stakeholders.

Measuring material consumption also provides basis for further indicators and analyses. For instance, measuring material consumption is a step toward assessing the environmental load of a building's entire life cycle, as environmental declarations for construction products and materials increase in number. Similarly, the information obtained may become especially useful if the EU Emissions Trading Scheme evolves in a direction where the greenhouse gas emissions of construction material production increase in importance.

5.2.4 Soil and rock use efficiency

The indicators for soil and rock use efficiency in civil construction are somewhat analogous to the material loss indicators in building construction: The indicators concern a major environmental aspect of civil construction (soil and rock use); they are directly linked with the economic performance of a project; and since the outcomes of the indicators are expressed in %, the indicators can be used in comparing different types of projects and in obtaining monetary as well as physical information about soil and rock use efficiency. The indicators for soil and rock use efficiency and material consumption differ in the sense that the efficiency of material consumption is primarily affected in the construction site, whereas the efficiency of soil and rock use is primarily affected in the planning phase.

Measuring the efficiency of soil and rock use potentially opens up opportunities for direct and substantial economic benefits, since soil and rock use comprises the largest single item of expenditure in a civil construction project. Implementation of the indicator is also encouraged by external stakeholders, especially the Finnish Road Administration.

5.2.5 Transportation

The transportation indicators have potential to reveal opportunities for economic gain, because the costs of material and soil and rock haulage are currently hidden and embedded in overall material costs. Measuring and analyzing the monetary value of haulage provides a means to assess the cost structure of material procurements, and hence an opportunity to affect that structure.

Measuring and analyzing the physical dimension of haulage provides a means to assess the environmental load incurred by logistics. This, in turn, is beneficial in terms of assessing the environmental load incurred over a project's life cycle. Furthermore, keeping track of one's haulage may prove beneficial if the EU Emissions Trading Scheme adds emphasis to emissions from logistics.

The possible shortcoming of the relative transportation indicator is the same as with energy and water indicators: Because the absolute indicator is divided by size of project, different types of projects may provide incommensurable results.

5.2.6 Waste

The monetary indicators for waste production are useful in terms of realizing the economic losses that the wastes generate, which could help motivate project managers to decrease waste production. The indicators should be easy to implement, since they already have physical counterparts and the data collection methods can be directly transferred to the monetary indicators.

One disadvantage of the indicators might be that, if the costs of waste treatment are trivial, the indicators might in fact discourage the prevention of waste production. Furthermore, the costs of waste treatment do not take into account the economic value of material that goes into waste.

5.2.7 Scientific novelty value

The indicators can be considered to have some scientific novelty value in the sense that OPIs are scarcely utilized in the construction industry, and there are no specific standards for OPIs in that line of business. However, the results are company-specific and therefore cannot be extended to all other companies in the industry. Nevertheless, the indicators have such novelty value that the requirements of constructive research methodology (See Section 1.5) are met.

6 Conclusions

6.1 Assessment of the research project

This research project set out to develop a suggestion for OPIs in the case company, Skanska Oy. To achieve that objective, the relevant literature was reviewed, and a model for designing OPIs was developed and carried out. As a result of the research, the objective was met and a list of new OPIs was suggested.

The model developed was a key factor in the success of the research project. It had a decisive role in breaking the overall task into smaller and more manageable pieces, and gradually directing and specifying the focus of the research into the most significant aspects. Perhaps the greatest contribution of the model was the fact that it ensured key people's continuous involvement: As a result, the indicators were developed to meet the needs of their users instead of the expectations of their developer.

The research results cannot be considered a wild success in all aspects, however. The most significant limitation is the fact that the suggested indicators do not fulfill all the goals and objectives assigned for them − instead, they even contradict some of the objectives. One such objective concerned the number of the indicators: Only a very few were originally requested, whereas a large number of them were actually designed. Another such objective concerned the indicators' applicability in decision making: The indicators were primarily expected for in-house use, whereas some of the suggested indicators are more applicable in external reporting.

The limitations, however, may not be as severe as they seem. First, indicators applicable to external reporting were suggested because the information for them seemed to be readily available, and the indicators' implementation costs were expected to be low. Second, the number of suggested indicators expanded as external indicators were included in the selection. In effect, the suggested indicators serve more purposes than was originally planned, which does not necessarily lessen the value of the indicators designed primarily for in-house use.

Another general limitation of the research project concerns one of its very strengths: key personnel involvement. Although the potential users of the indicators were consistently referred to for opinions and information, a great number of decisions were made without consulting all the relevant people involved. However, it is safe to say that such decisions were secondary as much as they were numerous. Nevertheless, the subjective decisions ensure that the research findings do not solely represent the mindsets of the indicators' users.

6.2 Findings

During the research project, some hindrances to selecting and implementing new OPIs surfaced. One such hindrance is the fragmentary nature of the construction industry: Construction projects are often geographically dispersed and different from one another in numerous respects, which makes it difficult to design common indicators that would objectively and straightforwardly reflect the operational performance of different projects. The outcome of an indicator may be difficult to interpret when there are numerous variables, ranging from geographic location to the time of year, affecting the efficiency of construction operations. Construction companies also deal with a great number of subcontractors and products, which makes it difficult to collect normalized data. Subcontractors provide information in various forms, and the industry does not yet have a standardized format for reporting or collecting information concerning, for instance, construction products.

Another hindrance is posed by attitudes toward the environmental perspective. The economic aspect of corporate responsibility seems to greatly overshadow the environmental aspect in many people's mindset. Some of the interviewees maintained that any environment-related activities would only be a burden if they did not directly and significantly benefit the economic performance of the company.

Many also believed that environmental indicators could have little effect on the company's operations. A common view was that environmental aspects were already considered to an appropriate extent and that any additional considerations would only be uneconomical. Hence, there was a general disbelief toward obtaining effective OPIs.

6.3 Recommendations

It is recommended that the case company take the implementation of the suggested indicators under consideration. While doing so, the company should investigate possible data collection methods and weigh the implementation and maintenance costs against the potential benefits of the indicators.

In weighing the costs and benefits of the indicators, the company should take into account that some of the energy, water and material indicators are primarily intended for external reporting and do not have direct effect on the efficiency of the company's operations. In those cases, evaluating the benefits should concern such aspects as the indicators' effect on the company image and its desirability to investors.

It is strongly recommended that the case company implement the indicators for material use efficiency and soil and rock use efficiency. These indicators directly concern the efficiency of the company's operations and are therefore tightly linked with the company's strategy of maximizing profitability. The indicators also concern major environmental and economic aspects of building and civil construction.

Finally, it is recommended that the case company implement the selected indicators in phases. For instance, it may take time before all the relevant material types can be included in the material consumption indicators.

In terms of the scientific community, some suggestions for further research topics are made. First, it could be researched whether the generated model for developing OPIs has any applicability in other fields of business. The model was intended to be generic, and its applicability has now been validated in a Finnish construction company, but there is no scientific evidence of its applicability in other industries or geographic areas. Second, it could be researched whether the suggested indicators bear any potential for a widespread implementation in the construction industry, or whether they are advantageous for the case company alone. Third, the changing age structure of the Finnish construction industry and its effects on the attitudes toward environmental and social responsibility could be researched in order to assess the future of the industry's environmental development.

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8 Appendices

Appendix 1. Operational indicators (derived from Krajnc & Glavič 2003).

Indicator type	Indicator category	Indicator, unit
Input indicators	Energy use indicators	Total energy consumption, J
		Energy intensity (Total energy consumed / Value of product sold or value added), J/€
		Average costs of energy source, €/J
	Materials use indicators	Total material consumption, kg
		Raw materials efficiency, kg/kg = 1
		Hazardous materials input mass, kg
	Water use indicators	Total water consumption, m^3
		Specific water consumption, m^3/UP
		Water cost fraction, €/€ = 1
Output indicators	Product indicators	Product durability, days, d
		Total packaging mass, kg
		Mass fraction of products from recyclable materials, kg/kg = 1
	Solid waste indicators	Total solid waste mass, kg
		Recycling mass fraction, kg/kg = 1
		Total solid waste costs, €
	Liquid waste indicators	Specific liquid waste volume, m^3
		Specific pollution mass ratio, kg/UP
		Liquid waste cost fraction, €/€ = 1
	Air emissions indicators	Mass fraction of greenhouse gases, kg/kg = 1
		Greenhouse gas intensity, kg/€
		Acidification mass fraction, kg/kg = 1

Appendix 2. Examples of OPIs (ISO 14031: 1999).

Category	Indicator
Materials	Quantity of materials used per unit of product
	Quantity of packaging materials discarded or reused per unit of product
	Quantity of water per unit of products
Energy	Quantity of energy used per year or per unit of product
	Quantity of energy used per service or customer
	Quantity of each type of energy used
Services supporting the organization's operations	Amount of hazardous materials used by contracted service providers
	Amount of recyclable and reusable materials used by contracted service providers
	Amount or type of wastes generated by contracted service providers
Physical facilities and equipment	Number of hours per year a specific piece of equipment is in operation
	Number of emergency operations or non-routine operations per year
	Total land area used for production purposes
Supply and delivery	Average fuel consumption of vehicle fleet
	Number of freight deliveries by mode of transportation per day
	Number of business trips by mode of transportation
Products	Number of recyclable products
	Duration of product use
	Number of units of energy consumed during use of product
Services provided by the organization	Amount of fuel consumption (for a transportation organization)
	Quantity of materials used during after-sales servicing of products
Wastes	Quantity of waste per year or per unit of product
	Quantity of waste stored on site
	Quantity of waste controlled by permits
Emissions	Quantity of specific emissions per year or per unit of product
	Quantity of waste energy released to air
	Noise measured at a certain location

Appendix 3. The core and additional environmental indicators (GRI 2002).

Core Indicators	Additional Indicators
Materials	
1. Total material use other than water, by type.	
2. Percentage of materials used that are wastes (processed or unprocessed) from sources external to the reporting organization.	
Energy	
3. Direct energy use segmented by primary source.	17. Initiatives to use renewable energy sources and to increase energy efficiency.
4. Indirect energy use.	18. Energy consumption footprint (i.e., annualized lifetime energy requirements) of major products.
	19. Other indirect (upstream/downstream) energy use and implications, such as organizational travel, product lifecycle management, and use of energy-intensive materials.
Water	
5. Total water use.	20. Water sources and related ecosystems/habitats significantly affected by use of water.
	21. Annual withdrawals of ground and surface water as a percent of annual renewable quantity of water available from the sources.
	22. Total recycling and reuse of water.
Biodiversity	
6. Location and size of land owned, leased, or managed in biodiversity-rich habitats.	23. Total amount of land owned, leased, or managed for production activities or extractive use.
7. Description of the major impacts on biodiversity associated with activities and/or products and services in terrestrial, fresh water, and marine environments.	24. Amount of impermeable surface as a percentage of land purchased or leased.
	25. Impacts of activities and operations on protected and sensitive areas.
	26. Changes to natural habitats resulting from activities and operations and percentage of habitat protected and restored.
	27. Objectives, programs, and targets for protecting and restoring native ecosystems and species in degraded areas.
	28. Number of IUCN Red List species with habitats in areas affected by operations.
	29. Business units currently operating or planning operations in or around protected or sensitive areas.

Emissions, Effluents, and Waste	
8. Greenhouse gas emissions.	30. Other relevant indirect greenhouse gas emissions.
9. Use and emissions of ozone-depleting substances.	31. All production, transport, import, or export of any waste deemed “hazardous” under the terms of the Basel Convention Appendix I, II, III and IV.
10. NOx, SOx, and other significant air emissions by type.	32. Water sources and related ecosystems/habitats significantly affected by discharges of water and runoff.
11. Total amount of waste by type and destination..	
12. Significant discharges to water by type.	
13. Significant spills of chemicals, oils, and fuels in terms of total number and total volume.	
Suppliers	
	33. Performance of suppliers relative to environmental components of programs and procedures described in response to Governance Structure and Management Systems section (Section 3.16).
Products and Services	
14. Significant environmental impacts of principal products and services.	
15. Percentage of the weight of products sold that is reclaimable at the end of the products’ useful life and percentage that is actually reclaimed.	
Compliance	
16. Incidents of and fines for non-compliance with all applicable international declarations/conventions/treaties, and national, sub-national, regional, and local regulations associated with environmental issues.	
Transport	
	34. Significant environmental impacts of transportation used for logistical purposes.
Overall	
	Total environmental expenditures by type.

Appendix 4. Examples of OPIs (Commission Recommendation 2003, pp. 23-24).

Input indicators		
Indicator category	**Examples of indicators**	**Examples of measurement units**
Materials	Raw materials, operating and auxiliary materials, ground water, surface water, fossil fuels, wood.	Metric tons per year Tons per ton of product per year Tons of hazardous substances per year Cubic meters per year
Energy	Electricity, gas, oil, renewables, etc.	Megawatt hours per year Kilowatt hours per metric ton of product
Products	Preliminary products, auxiliary and office products, etc.	Metric tons per year Kg's of harmful material per ton of product Percentage of products with eco-labels
Services	Cleaning, waste disposal, catering, haulage, financial services, etc.	Metric tons per year Kg's of harmful material per service unit Percentage of services with eco-labels
Physical facilities and equipment indicators		
Design	Buildings, machinery, equipment, etc.	Heat loss of buildings in Watts per m^2 Percentage of equipment with reusable parts
Installation	Buildings, machinery, equipment, etc.	Percentage of machinery parts designed for reuse Percentage of equipment with eco-labels
Operation	Buildings, machinery, equipment, etc.	Hours per year specific machinery is in operation Metric tons of substances used for operation
Maintenance	Buildings, machinery, equipment, etc.	Hours per year specific machinery needs maintenance
Land use	Green area, paved area	Km^2 per year
Transport	Fuel consumption, emissions, business travel by mode of transportation etc.	Fuel consumption in metric tons per year Greenhouse gas emissions in tons per year Person/kilometers per year
Output indicators		
Emissions	Air emissions, effluents, waste.	Metric tons per year Kg's per ton of product Decibels (at specific location)
Products	Substances in products, packaging material, energy consumption of appliances	Metric tons of hazardous material per product unit Percentage of product parts designed for reuse Percentage of products with eco-labels
Services	Cleaning, waste disposal, catering, transport, financial services, etc.	Fuel consumption in liters per service unit Percentage of services with eco-labels

Appendix 5. The indicators of PromisE and their relative weights (%) (REM 2005b).

	Ofice buildings			Apartment buildings			Stores		
User health	25			25			20		
Management of microclimate of room		35			35			35	
Setting and the level of objectives			35			35			35
Content of plans			25			25			25
Monitoring and documenting			20			20			20
Objectives in real estate management contracts			20			20			20
Quality of indoor air		30			30			30	
Extent of ventilation			40			40			40
Cleanliness of incoming air			30			30			30
Material emissions			30			30			30
Management of humidity		30			30			30	
Planning of structural physics			40			40			40
Humidity management of construction site			45			45			45
Manuals and service instructions			15			15			15
Lighting		5			0			0	
Intensity and uniformity			55			0			0
Prevention of reflection and glare			45			0			0
Use of natural resources	30			30			35		
Energy consumption		45			40			45	
Setting energy consumption objectives			15			15			15
Heat consumption			25			40			25
Electricity consumption			35			20			35
Management of energy consumption during use			15			15			15
Receiving			10			10			10
Water consumption		5			10			5	
Water systems			100			40			100
Water consumption monitoring			0			60			0
Land use		10			10			10	
Utilization of existing constructions			55			55			55
Utilization of existing networks			45			45			45
Materials		20			20			20	
Overall use of parent stock			70			55			70
Degree of recycling			30			20			30
Space saving with common facilities			0			25			
Operating life		20			20			20	
Planned value of operating life			20			55			20
Meticulousness of operating life planning			30			20			30
Adaptability			50			25			50
Ecological impacts	35			35			35		
Emissions into the atmosphere		50			50			45	
Environmental impact of structural components			25			25			25
Environmental impact of energy consumption			75			75			75
Wastes		20			20			20	
Waste management of the building			50			50			50
Waste management of construction project			50			50			50
Sewerage wastes		0			5			0	
Handling of rainwater on site			0			100			0
Diversity of site and its surroundings		10			10			10	
Covering of soil			30			30			30
Removal of soil			30			30			30
Constructing on conservation areas			30			30			30
Incidence of uncommon species on site			10			10			10
Environmental impacts of traffic		20			15			25	
Connections of public transportation			50			45			60
Connections of bicycle and pedestrian traffic			35			25			30
Accessibility of services			15			31			10
Environmental risks	10			10			10		
Environmental risks of site		35			35			35	
Cleanliness of site			100			100			100
Environmental risks of construction		65			65			65	
Environmental risks of construction materials			40			40			40
Environmental risks of refrigerants			0			0			0
Managing of construction site's risks			30			30			30
Managing of health risks			30			30			30

Appendix 6. Eco-efficiency indicators for buildings and construction projects (VTT 1999).

Assessment area	Aggregated indicators	Indicators
Use of energy and materials	Emissions	Global Warming, GWP
		Ozone layer depletion, POCP
		Acidification
		Eutrophication
		Ground level ozone
		Eco-toxicity
	Waste	Construction and demolition waste
		Nuclear waste
		Slag and ashes
		Hazardous waste
	Natural resources	Fuels
		Metals
		Minerals
		Bio-fibers
Indoor environment	Health	Allergy
		Sick Building Syndrome
		Cancer
		Infections
		Spec. Environmental Sensibility
		Joint problems
		Poisoning, caustic, reproduction
	Comfort	Noise
		Thermal comfort
Outdoor environment (on the estate)	Health	Air pollution
		Ground pollution
		Electromagnetic fields
	Comfort	Noise
		Wind
		Shade
		Odor
	Biological diversity	Vegetation
		Water
	Biologic production	Natural soil
		Added soil
Temporary (will be moved to material use when calc. of impact is settled)	Eco-cycling	Source separation of waste
		Composting
	Impacts on recipient	Storm water pollution

Appendix 7: List of potential indicators

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Inputs	Indicator type			
Materials	Absolute	Relative	Indexed	Aggregated
Construction materials (concrete, steel, wood, satiated wood, plasterboards, elements, rock materials, plaster)	Quantity of material used in a project (m^3, kg)	[Direct indicator] / brm^3 (m^3/brm^3, kg/brm^3)	[Direct indicator] / Overall quantity of material (%)	Sum of [direct indicator] in all projects in a year (m^3, kg)
Recycled/reused materials (crushed concrete)	Quantity of recycled materials used in a project (m^3, kg)	[Direct indicator] / value added (m^3/€, kg/€)	Raw materials efficiency (%)	- Aggregate of [relative indicator] in all projects in a year (m3, kg)
Recycleable/reusable materials (wood, stel, concrete, rock material)	Quantity of recycleabee materials used in a project (m^3, kg)	[Direct indicator] / cost of [Direct indicator] (m^3/€, kg/€)	[Direct indicator] / [Direct indicator] of a typical project	- Aggregated [indexed indicator] in all projects in a year
Hazardous materials (satiated wood, cooling agents, possibly paints, varnishes etc.)	Quantity of hazardous materials used in a project (m^3, kg)	[Direct indicator] / Revenue of project (m^3/€, kg/€)	[Relative indicator] / [Relative indicator] of a typical project	
	Quantity of water used in a project (m^3)		[Aggregated indicator] / [Aggregated indicator] of a base year	
	Material/water costs in a project (€)			
Energy	Absolute	Relative	Indexed	Aggregated
Types of energy use on site (electricity, oil, district heating, gas)	Quantity of each type of energy used in a project (MJ, kWh)	[Direct indicator] / brm^3, hrs of machines used (MJ/brm^3, kWh/brm^3, MJ/h)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
Energy used by tools and machinery	Quantity of energy used by machinery in a project (MJ, kWh)	[Direct indicator] / Revenue of project (MJ/€, kWh/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
Energy used by construction cabins	Quantity of energy used by construction cabins in a project (MJ, kWh)		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
	Total quantity of energy used in a project (MJ, kWh)			
	Energy costs of a project (€)			
	Hours of machines used (hrs)			
Services supporting the organization's operations	Absolute	Relative	Indexed	Aggregated
Transport and delivery	Kilometers of import transportation in a site (km)	[Direct indicator] / brm^3 (tkm/brm^3, kg/brm^3, etc.)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
	Kilometers of export transportation in a site (km)	[Direct indicator] / value added (tkm/€, kg/€, etc.)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
	Kilometers of total transportation in a site (km)	[Direct indicator] / cost of service (tkm/€, kg/€, etc.)	[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
	Ton-kilometers of import/export/total transportation in a site (tkm)	[Direct indicator] / Revenue of project (m^3/€, kg/€)		
	m^3-kilometers of import/export/total transportation in a site (m^3-km)	Emissions of transportation / kilometers of transportation (kg/km)		
	Fuel consumption of import/export/total transportation in a site (MJ, l, m^3)	Transport expences / tkm (€/tkm)		
	Emissions of import/export/total transportation in a site (kg, kg CO_2-ekv.)			

- Subcontractors' operations	Number of subcontractors that meet the criteria of a good subcontractor	[Direct indicator] / All subcontractors	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
	Number of subcontractors with environmental certificates		[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
			[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
Physical facilities and equipment				
Land use				
Operation				
Outputs				
Products	Absolute	Relative	Indexed	Aggregated
Buildings	Calculated energy consumption of a building (kWh)	Calculated energy consumption / brm^2 (kWh/brm^2)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (kWh)
	Calculated heat loss of a building	Calculated heat loss / brm^3)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (kWh/brm^3)
	Energy classification of a building		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
	PromisE classification of a building			Number of buildings with A or B classifications (energy or PromisE)
Wastes	Absolute	Relative	Indexed	Aggregated
Construction wastes (combustible waste, wood, metal, rock, cardboard, plasterboard, plastic, miscellaneous)	Quantity of construction/hazardous/ recyclable waste in a project (kg, m^3)	[Direct indicator] / brm^3 (kg/brm^3, m^3/brm^3)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (kg, m^3, €)
Hazardous waste	Cost of construction/hazardous/ recyclable waste in a project (€)	[Direct indicator] / Revenue of project (kg/€, m^3/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (kg/brm^3, etc.)
Recyclabe/reusable waste (construction wastes save for miscellaneous waste)	Total quantity of waste in a project (kg, m^3)		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
Municipal waste	Total costs of waste in a project (€)			
Emissions	Absolute	Relative	Indexed	Aggregated
Emissions to air (CO_2, CO, NO_x, CH_4…)	Quantity of emissions/effluents in a project (kg, m^3)	Quantity of emissions/effluents / brm^3 (kg/brm^3, m^3/brm^3)	[Direct indicator] / [Direct indicator] of a typical project	Total quantity of emissions/effluents in a year (kg, m^3)
Effluent to water or land (oil spills, wastewater, stormwater)	Volume of noise outside the site's perimeter (dB)	Quantity of emissions/effluents / Revenue of project (kg/€, m^3/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (kg/brm^3, m^3/brm^3)
Noise, vibration	Number of occurrences when noise / vibration regulations have not been met		[Aggregated indicator] / [Aggregated indicator] of a base year	

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Inputs	Indicator type			
Materials	Absolute	Relative	Indexed	Aggregated
Construction materials (Asphalt, rock materials, concrete, cement, steal, ferroconcrete, wood)	Quantity of material used in a project (m^3, kg)	[Direct indicator] / ha (m^3/ha, kg/ha)	[Direct indicator] / Overall quantity of material (%)	Sum of [direct indicator] in all projects in a year (m^3, kg)
Recycled/reused materials (fly ash, crushed concrete, furnace slag, rubber granules)	Quantity of recycled materials used in a project (m^3, kg)	[Direct indicator] / value added (m^3/€, kg/€)	Raw materials efficiency (%)	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
Recycleable/reusable materials (wood, rock materials, concrete, steel)	Quantity of recycleable materials used in a project (m^3, kg)	[Direct indicator] / cost of [Direct indicator] (m^3/€, kg/€)	[Direct indicator] / [Direct indicator] of a typical project	Aggregated [indexed indicator] in all projects in a year
Hazardous materials (curing agents, grout, oil)	Quantity of hazardous materials used in a project (m^3, kg)	[Direct indicator] / Revenue of project (m^3/€, kg/€)	[Relative indicator] / [Relative indicator] of a typical project	
Water use	Quantity of water used in a project (m^3)		[Aggregated indicator] / [Aggregated indicator] of a base year	
	Material/water costs in a project (€)			
Energy	Absolute	Relative	Indexed	Aggregated
Types of energy use on site (electricity, oil, gas, etc.)	Quantity of each type of energy used in a project (MJ, kWh)	[Direct indicator] / ha (MJ/ha, kWh/ha)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m3, kg)
Energy used by tools and machinery	Quantity of energy used by machinery in a project (MJ, kWh)	[Direct indicator] / Revenue of project (MJ/€, kWh/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m3, kg)
Energy used by construction cabins	Quantity of energy used by construction cabins in a project (MJ, kWh)		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
Fuel consumed by construction managers	Total quantity of energy used in a project (MJ, kWh)			
Fuel consumed by personnell logistics	Energy costs of a project (€)			
	Hours of machines used (hrs)			
Services supporting the organization's operations	Absolute	Relative	Indexed	Aggregated
Transport and delivery	Kilometers of import transportation in a site (km)	[Direct indicator] / ha (tkm/ha, kg/ha, etc.)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
	Kilometers of export transportation in a site (km)	[Direct indicator] / value added (tkm/€, kg/€, etc.)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
	Kilometers of total transportation in a site (km)	[Direct indicator] / cost of service (tkm/€, kg/€, etc.)	[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
	Ton-kilometers of import/export/total transportation in a site (tkm)	[Direct indicator] / Revenue of project (m^3/€, kg/€)		
	m^3-kilometers of import/export/total transportation in a site (m^3-km)	Emissions of transportation / kilometers of transportation (kg/km)		
	Fuel consumption of import/export/total transportation in a site (MJ, l, m^3)			
	Emissions of import/export/total transportation in a site (kg, kg CO_2-ekv.)			

Subcontractors' operations	Number of subcontractors that meet the criteria of a good subcontractor	[Direct indicator] / All subcontractors	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
	Number of subcontractors with environmental certificates		[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (m^3, kg)
			[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
Physical facilities and equipment				
- Operation (construction machines)	Absolute	Relative	Indexed	Aggregated
	Fuel consumption (l)	[Direct indicator] / operating hours		
	Oil consumption (l)			
Outputs				
Products	Absolute	Relative	Indexed	Aggregated
Roads	Area of construction (m^2, ha)		[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (m^3, kg)
Bridges	Volume of construction (m^3)		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
Wastewater treatment plants				
Wastes	Absolute	Relative	Indexed	Aggregated
Construction wastes (exported land, mixed construction waste, other demolition waste, sludge)	Quantity of construction/hazardous/ recyclable waste in a project (kg, m^3)	[Direct indicator] / ha (kg/ha, m^3/ha)	[Direct indicator] / [Direct indicator] of a typical project	Sum of [direct indicator] in all projects in a year (kg, m^3, €)
Hazardous waste	Cost of construction/hazardous/ recyclable waste in a project (€)	[Direct indicator] / Revenue of project (kg/€, m^3/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (kg/ha, etc.)
Recyclabe/reusable waste (wood, metal, concrete, combustible waste)	Total quantity of waste in a project (kg, m^3)		[Aggregated indicator] / [Aggregated indicator] of a base year	Aggregated [indexed indicator] in all projects in a year
	Total costs of waste in a project (€)			
Emissions	Absolute	Relative	Indexed	Aggregated
Emissions to air (CO_2, CO, NO_x, CH_4…)	Quantity of emissions/effluents in a project (kg, m^3)	Quantity of emissions/effluents / ha (kg/ha, m^3/ha)	[Direct indicator] / [Direct indicator] of a typical project	Total quantity of emissions/effluents in a year (kg, m^3)
Effluent to water or land (oil spills, stormwater)	Volume of noise outside the site's perimeter (dB)	Quantity of emissions/effluents / Revenue of project (kg/€, m^3/€)	[Relative indicator] / [Relative indicator] of a typical project	Aggregate of [relative indicator] in all projects in a year (kg/ha, m^3/ha)
Noise, vibration	Number of occurrences when noise / vibration regulations have not been met		[Aggregated indicator] / [Aggregated indicator] of a base year	