Design of an

Infrastructure Sustainability Assessment Method

for application in DGBC Area

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FOR APPLICATION IN DGBC AREA

J.F. van de Pol
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Design of an Infrastructure Sustainability Assessment Method for application in DGBC Area
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SUMMARY

RESEARCH SETTING

As the intention for a transition towards more sustainable construction practices gains increasing popularity in the sector, it becomes a necessity to be able to assess sustainability of the built environment based on measurable criteria. Recently the Dutch Green Building Council (DGBC) initiated the development of DGBC Area, a new method and certificate for appraisal of sustainability in area development projects. Such a comprehensive environmental assessment method needs to consider buildings, infrastructure and public space of the area, and the interactions between these elements. However, since current research has focused on assessment of buildings, there is a lack in experience on assessment of infrastructure sustainability. The objective of this research is to design and evaluate a method for assessment of infrastructure sustainability, specifically for application in the new DGBC Area certificate.

In light of formal procedures for development of assessment methods, this research covers the first three steps, being scope definition, system analysis and indicator identification. The last step, formulation of criteria and application of the method, is outside the scope of this research. Since the DGBC seeks to harmonize their certificates with existing methods and tools that are available for sustainability appraisal. Starting point of this research thus is the identification of appropriate measures for infrastructure sustainability in scientific literature and existing practical instruments. Moreover, the DGBC has the ambition to increase potential for innovation in the methods they develop as much as possible. Since possible approaches for this purpose are case specific, the development and implementation of strategies to stimulate innovation in the environmental assessment method for infrastructure is a central aspect in this research as well.

DESIGN AND EVALUATION

The research strategy applied in this study can be characterized as design-oriented desk research. In the first phase design requirements are formulated based on a study of scientific literature and an analysis of DGBC Area. The design requirements concern both structure and content of the assessment method. First of all, the scope of the method is restricted to assessment of technical infrastructure in the context of area developments. Technical infrastructure comprises facilities that indirectly support economic production, such as roads and electricity supply networks. An Environmental Assessment Method (EAM) provides a comprehensive assessment of the environmental characteristics of such facilities. Such a method consists of an index of indicators that measure on different levels: either the stresses caused by infrastructure development processes, the condition of the natural environment or the efficiency of response strategies on reducing natural impact or increasing societal satisfaction.

Since the design is to be applied as part of DGBC Area, it should fit with structure and methodology of this certificate. Indicators are therefore clustered in the categories energy, water, materials, waste, transport, flora

and fauna and climate. Besides, the applicability of each indicator on different development process stages and area development typologies needs to be clear. Further, the design is intended to be applied in the planning stage of projects, whereas the indicators measure the estimated performance of the proposed infrastructure systems in realization and operation stages.

An initial design is developed based on the design requirements and existing measures selected from literature and practical instruments. To complete and validate the initial design, it is evaluated in interviews with experts on different fields of sustainability. Based on their remarks and suggestions several indicators are removed from the design, others adjusted or merged and new ones included. Besides, the experts suggested strategies to increase innovation potential in the method. The results of this evaluation are processed in a concept design, which is subsequently reviewed with practitioners from area development project Eeserwold. Using the proposed designs for technical infrastructure systems in this project as an example, the concept design turned out to reflect most of the relevant sustainable practices. However, this practical evaluation showed some aspects lacking in the method as well, and the practitioners suggested adjustments and new indicators to improve the design.

ISAM

Ultimately the evaluations resulted in the in this study proposed design of an Infrastructure Sustainability Assessment Method (ISAM). The central purpose of ISAM is to provide a comprehensive assessment of the environmental characteristics of infrastructure. ISAM includes a total of thirty indicators on diverse environmental aspects, which are clustered in seventeen themes, within eight categories. Each of the categories includes at least one critical indicator, representing the essence of the corresponding environmental aspect.

In short the most relevant indicators of ISAM can be described as follows. Related to the application of energy efficient systems the extent to which the need for energy is reduced and the contribution of infrastructural systems to generating renewable energy is assessed. Further the method assesses the performance of applied systems on water need reduction and local treatment of waste water. Concerning materials ISAM stimulates the choice for sustainable materials and reuse or recycling of materials. In ISAM the title of the category waste is changed in residuals, and indicators are related to the physical facilities for waste collection during operation and to waste management during realization. For assessment of the performance of transport networks ISAM assesses the quality of facilities for public transport and proposed measures for stimulating slow traffic. Besides, assessment of the spatial aspect is relevant in this category since transport infrastructure highly impacts land use. Regarding flora and fauna indicators are included that assess the measures for prevention and harmonization of ecological values and the performance of water management. Further, ISAM appraises the efficiency of practices to neutralize the impacts on climate regarding nuisance reduction and water contamination.

Three different strategies to increase innovation potential have been implemented in ISAM. These strategies comprise the performance based formulation of indicators, the set up of a separate category for assessment of innovation and the use of incentives to stimulate innovation on critical indicators. It is recommended to adopt this open option approach in DGBC Area as well and to use the weight system of the methodology to accent the relevance of the critical indicators.

Other recommendations are related to further research and implementation of ISAM. To increase reliability and validate ISAM other studies are suggested with increased numbers of experts and practitioners. Further, it is relevant to study necessary adjustments to the method, making it possible to use ISAM not only as part of DGBC Area, but as an independent method for more general infrastructure projects as well. Regarding implementation, it is recommended to perform the last step in the formal procedure of development of assessment methods: the formulation of criteria.

SAMENVATTING

CONTEXT EN OPZET VAN HET ONDERZOEK

In de bouwsector neemt de aandacht voor een transitie naar een duurzaam bebouwde omgeving toe, waardoor het noodzakelijk wordt om duurzaamheid te kunnen beoordelen op basis van meetbare criteria. Recent is de Dutch Green Building Council (DGBC) begonnen met de ontwikkeling van DGBC Gebied, een nieuwe methode en keurmerk voor het waarderen van duurzaamheid van gebiedsontwikkelingen. In een dergelijke integrale methode is het van belang dat zowel de gebouwen, infrastructuur en de publieke ruimte worden beschouwd, alsmede de onderlinge relatie tussen deze elementen. Omdat het meeste bestaande onderzoek zich heeft gericht op methoden voor gebouwen, is er een gebrek aan ervaring voor het beoordelen van duurzaamheid van infrastructuur. Het doel van dit onderzoek is het ontwerpen en evalueren van een methode voor de beoordeling van duurzaamheid van infrastructuur, die kan worden toegepast in het nieuwe DGBC Gebied keurmerk.

Dit onderzoek omvat de eerste drie stappen die in theoretische procedures voor de ontwikkeling van beoordelingsmethoden worden onderscheiden. Dit zijn definitie van de scope, systeem analyse en het identificeren van indicatoren. De laatste stap, het formuleren van criteria en het toepassen van de methode, valt buiten de scope van dit onderzoek. De DGBC heeft de ambitie om de keurmerken die ze ontwikkelen te harmoniseren met bestaande methoden en instrumenten. Uitgangspunt van dit onderzoek is daarom het identificeren van geschikte indicatoren voor duurzaamheid van infrastructuur in wetenschappelijke literatuur en bestaande praktische instrumenten. Bovendien heeft de DGBC de ambitie om in de door hen ontwikkelde methoden de potentie voor innovatie zo veel mogelijk te vergroten. Benaderingen om dit te kunnen bewerkstelligen zijn echter afhankelijk van de specifieke kenmerken van de methode. Om deze reden is een tweede centraal aspect van dit onderzoek het ontwikkelen en implementeren van strategieën om innovatie te stimuleren in de beoordelingsmethode voor infrastructuur.

ONTWERP EN EVALUATIE

De toegepaste onderzoeksstrategie kan worden gekenmerkt als een ontwerpgericht bureauonderzoek. In de eerste fase zijn ontwerpeisen geformuleerd op basis van een literatuurstudie en een analyse van DGBC Gebied. De ontwerpeisen hebben betrekking op de structuur en de inhoud van de beoordelingsmethode. Allereerst is de scope van de methode beperkt tot het beoordelen van technische infrastructuur in de context van gebiedsontwikkelingen. Technische infrastructuur omvat de voorzieningen die indirect de economische productie ondersteunen, zoals wegen en elektriciteitsnetwerken. Een Environmental Assessment Method (EAM) voorziet in een integrale beoordeling van de milieuaspecten van deze voorzieningen. Een integrale methode bestaat uit een index van indicatoren, die op verschillende niveaus zijn gericht: ze beoordelen of de mate van invloed die wordt veroorzaakt door de ontwikkeling van infrastructuur, ofwel de staat van de natuurlijke omgeving of de efficiëntie van duurzame strategieën om de invloed op de omgeving te reduceren en de bevrediging van sociale behoeften te vergroten.

Omdat het ontwerp moet worden toegepast als onderdeel van DGBC Gebied, moet het aansluiten bij de structuur en de methodologie van dit keurmerk. Indicatoren worden daarom gegroepeerd in de categorieën energie, water, materialen, afval, transport, flora en fauna en klimaat. Bovendien moet de toepasbaarheid van elke indicatoren op de verschillende fasen in een ontwikkelingsproces en op verschillende types gebiedsontwikkelingen duidelijk zijn. Het ontwerp is bedoeld om te worden toegepast in de planning fase van projecten, maar de indicatoren meten de geschatte prestatie van de ontworpen infrastructuursystemen in de realisatie- en gebruiksfase.

Een initieel ontwerp is ontwikkeld op basis van de ontwerpeisen en de bestaande indicatoren die zijn geselecteerd uit literatuur en praktische instrumenten. Om dit initieel ontwerp compleet te maken en te valideren is het geëvalueerd met experts met kennis op verschillende aspecten van duurzaamheid. Gebaseerd op hun opmerkingen zijn een aantal indicatoren uit het ontwerp verwijderd, andere aangepast of samengevoegd en nieuwe toegevoegd. De experts hebben ook strategieën voorgesteld om de potentie van het ontwerp om innovatie te stimuleren te vergroten. De resultaten van deze evaluatie zijn verwerkt in een concept ontwerp, die vervolgens is besproken met personen betrokken bij de ontwikkeling van het project Eeserwold. Met de ontwerpen voor de infrastructurele systemen van dit project als voorbeeld, bleek het concept ontwerp de meeste relevante duurzame maatregelen te reflecteren. De evaluatie toonde echter ook aan dat een aantal aspecten nog missen, en de ontwikkelaars hebben nieuwe indicatoren voorgesteld om het ontwerp te verbeteren.

ISAM

Het resultaat van de evaluaties is het uiteindelijke ontwerp voor een beoordelingsmethode voor de duurzaamheid van infrastructuur, een Infrastructure Sustainability Assessment Method (ISAM). Het doel van ISAM is om een integrale beoordeling van de milieuaspecten van infrastructuur mogelijk te maken. ISAM bevat in totaal dertig indicatoren op uiteenlopende milieuaspecten, die zijn gegroepeerd in zeventien thema's, binnen acht categorieën. Elk van de categorieën bevat minimaal een kritische indicator, die de essentie van het bijbehorende milieuaspect reflecteert.

In het kort kunnen de meest relevante indicatoren van ISAM als volgt worden omschreven. Met betrekking tot de energieprestatie worden systemen beoordeeld op de mate van reductie in energiebehoefte en de bijdrage aan het opwekken van duurzame energie. De methode beoordeelt verder de prestatie van toegepaste systemen om de totale waterbehoefte te reduceren en de inzet van technieken om lokaal afvalwater te zuiveren. ISAM stimuleert de keuze voor duurzame materialen en hergebruik en recycling. De titel van de categorie afval is in ISAM veranderd in reststoffen en indicatoren in deze categorie hebben betrekking op de fysieke voorzieningen voor afvalverzameling in de gebruiksfase en afvalmanagement tijdens de realisatie. Voor de beoordeling van de prestatie van het transport netwerk kijkt ISAM naar de kwaliteit van de voorzieningen voor openbaar vervoer en de maatregelen om langzaam verkeer te bevorderen. Daarnaast is het ruimtelijke aspect relevant omdat transport infrastructuur een grote invloed heeft op het ruimtegebruik. Met betrekking tot flora en fauna zijn indicatoren opgenomen die de maatregelen voor preventie en harmonisatie van ecologische waarden beoordelen en de prestatie van het integrale waterbeheer. Verder worden in ISAM de maatregelen beoordeeld om de invloed op het klimaat met betrekking tot hinder en watervervuiling te neutraliseren.

Drie verschillende strategieën om de potentie voor innovatie in de methode te vergroten zijn geïmplementeerd in ISAM. Deze strategieën hebben betrekking op het prestatiegericht formuleren van indicatoren, het opzetten van een aparte categorie voor de beoordeling van innovaties en het inzetten van stimuleringsmiddelen om innovatie op de kritische indicatoren te bevorderen. Het wordt aanbevolen om deze open benadering ook toe te passen in DGBC Gebied en om het wegingsysteem van deze methode te gebruiken om de relevantie van de kritische indicatoren te benadrukken.

Andere aanbevelingen hebben betrekking op nader onderzoek en de implementatie van ISAM. Om de betrouwbaarheid te vergroten en ISAM te valideren worden aanvullende studies voorgesteld met een groter aantal experts en praktijk deskundigen. Daarnaast is het relevant om de mogelijkheden te bestuderen om de methode aan te passen zodat de methode niet alleen als onderdeel van DGBC Gebied, maar ook als onafhankelijke methode voor algemene infrastructuur projecten gebruikt kan worden. Met betrekking tot implementatie wordt aanbevolen om de laatste stap van de theoretische procedure voor het ontwikkelen van beoordelingsmethoden uit te voeren: het formuleren van de criteria.

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Abbreviations

A	Adjust
B	Urban Border
C	Consequence
CD	Concept Design
CI	Critical Indicator
E	Expert
GWW	Civil engineering sector
I	Industrial estate
ID	Initial Design
II	Indicators from practical Instruments
IL	Indicators from scientific Literature
IR	Indicator Requirement
N	Non-urban area
O (1)	Overlap (Between indicators in design)
O (2)	Operation (Phase)
P	Practitioner
PD	Proposed Design
PI	Practical Instrument
R (1)	Remove (Indicator from design)
R (2)	Realization (Phase)
U	Urban area

Titles

BREEAM	Building Research Establishment Environmental Assessment Method
BREEAM Communities	Original BREEAM certificate for environmental assessment of area developments
BREEAM-NL	Dutch version of certificates for environmental assessment based on BREEAM methodology. Consists of several sub certificates (of which BREEAM-NL Nieuwbouw)
DPL	Duurzaamheids Profiel op Locatie
DGBC	Dutch Green Building Council

DGBC Area	Certificate for environmental assessment of area development projects, currently in development
EPL	Energie Prestatie op Locatie
MILO	MIlieukwaliteit n de LeefOmgeving
MIMOSA	Milieu Indicatie Model voor Optimalisatie en Samenwerking in wAterketen
VPL	Vervoers Profiel op Locatie

PREFACE

This thesis is the result of my graduation research project, the terminal assignment of the master programme of the study Civil Engineering and Management at the University of Twente. Within this programme, the last few years I have followed the courses of the department of Construction Management and Engineering with great pleasure. To be honest, finishing the programme with this master's thesis makes me delighted, and a bit proud too.

This research project has been one of the most valuable learn processes in my life. It has been interesting to study the concepts of, and relations between, construction processes and the environment. And I sincerely hope the results of this study may, as intended, somehow contribute to the big challenge of a transition towards a sustainable built environment. However, regarding my personal learning aims, process related aspects might even be more valuable. I am convinced now, even though they might be commonly known, one needs to experience certain pitfalls themselves first, to really benefit from the learning process. The first stages of a graduation project, in which one needs to formulate a problem statement and set up a research framework, really brought me significant experiences I will employ in future projects as well. Not only it learned me how to focus, it also made me aware of the endless importance of good communication.

Several persons and organizations were of great value during my whole research project. The empirical data in this research is based on interviews with experts on diverse sustainability aspects and with practitioners from the area development case Eeserwold in Steenwijk. I am grateful they have made time and effort available to provide me with valuable insights in the matters of sustainable infrastructure. Furthermore, I would like to thank Advin for their commitment to facilitate this project as a principal. More specifically, I acknowledge Jan Batelaan and Tim 't Hoen for their support during the whole research process and their feedback to keep me on track. For representing the concerns of and input from the Dutch Green Building Council, I would like to thank Martijn in 't Veld. My supervisors from the University of Twente, Joop Halman and Bram Entrop, I would like to thank for their support, critical notes and useful insights to bring this study to an higher level.

Of course, this thesis would have never been completed without the support of many people in my closest surroundings. Thanks, friends and family, for showing interest, for senseless or valuable discussions, or for just giving me the opportunity to relax and have a good time. Diane, I would like to thank you specifically for out hearing my complaints or silly disquisitions, for your patience in going to bed alone all that nights, and foremost for your loving support.

Frits van de Pol
Opheusden, January 2010

1 INTRODUCTION

This chapter first discusses recent initiatives in the Dutch construction sector to develop new methods for sustainability appraisal in the specific context of area development projects. Although infrastructure facilities are relevant aspects in such projects, there is little research available on environmental assessment methods for infrastructure. Moreover, a central concern is whether or not such methods restrict the potential for innovation in designs. The chapter concludes with an outline description of this research report.

1.1 RESEARCH SETTING

Since the eighties of the previous century sustainable development has settled as a concept in society, gaining increasing popularity across various sectors. In the construction industry sustainability is regarded a relevant aspect, since conventional construction techniques have major impacts on the natural environment. Both public and private parties have initiated programs and policies that strive for a transition towards a more sustainable built environment. As a result, the sector faces increasingly restrictive conservation and protection regulations, the emergence of environmental management standards and national consensus standards (Vanegas, 2003). In Dutch context, these initiatives have led to the incorporation of sustainability as a common aspect in project tender processes in the near future (Bouwend Nederland, 2008; Senter Novem, 2008a). For this reason it is necessary to be able to assess sustainability of construction practices based on measurable criteria. This will make it possible to evaluate the sustainability of design proposals and to incorporate environmental matters in the decision framework of projects at an early stage (Ugwu & Haupt, 2007). Moreover, the development of methods for assessment of sustainability will stimulate the construction sector to constantly strive for progress and reach for the goal of sustainability (Ding, 2008).

A widespread accepted and globally applied methodology for assessment of sustainability in the built environment is BREEAM (Building Research Establishment Environmental Assessment Method) (Ding, 2008; Seo, 2002). Originally developed in the United Kingdom, the methodology is now adjusted to specific national conditions in various countries all over the world. Recently, the Dutch Green Building Council (DGBC) developed a sustainability certificate for buildings based on BREEAM methodology, for application in Dutch context (DGBC, 2009a). The DGBC is established in 2008 on initiative of several public and private organizations, with the intention to create an independent measurement methodology for sustainability in the built environment. In the development of the certificates, the DGBC explicitly not intends to create new environmental assessment tools besides the scale of instruments that already exists. Instead, the DGBC prefers to harmonize their certificates as much as possible with existing methods, tools, databases etc.

Besides the certificate for buildings, the DGBC has decided to develop two additional rating systems: one for renovation of buildings and one for area development projects. Related to the latter, a label for assessment of housing zones in the original BREEAM methodology already exists, known as BREEAM Communities. However, the DGBC will develop a complete new certificate that can also be applied to other types of area development projects, such as industrial zones. Moreover, this new method will assess area development projects during different stages of development, from planning till operation. Since this certificate is still in development, and not yet accredited as official BREEAM methodology, this assessment method will in this study further be referred to as DGBC Area.

1.2 ENVIRONMENTAL ASSESSMENT OF INFRASTRUCTURE

Numerous environmental assessment methods, tools, techniques and databases have jet been developed (Haapio & Viitaniemi, 2008), of which BREEAM is an example. However, it is remarkable to notice that the focus of scientific literature on the assessment of sustainability of the built environment has concentrated on buildings and construction processes, and not so much on technical infrastructure. Technical infrastructure (further referred to as infrastructure) is defined as the facilities that indirectly support economic production, such as roads, sewage systems and electricity supply networks (Howes & Robinson, 2005:16). Although several authors have noticed the lack of assessment methods for infrastructure sustainability (Dasgupta & Tam, 2005; Sahely et al., 2005; Ugwu & Haupt, 2007) there is still a need for further research and experience in this field.

Infrastructure facilities may be harder to understand from a sustainability perspective than buildings, due to an extended geographical scope and the wider and more varied potential impacts (Dasgupta & Tam, 2005). More specifically, there are several differences between technical infrastructure facilities and buildings, such as the diversity in the nature of projects, variety in design standards and construction practices and a great impact on urban development (Ugwu & Haupt, 2007). The relation between infrastructure systems and urban development is further specified by Engel-Yan et al. (2005). In their view, to achieve sustainable development of urban zones, it is necessary to consider sustainability of technical infrastructure facilities, buildings and public space and the interactions between these elements. In a comprehensive assessment method for area developments, such as DGBC Area, it is thus relevant to consider sustainability of technical infrastructure facilities. Since current research has focused mainly on environmental assessment of buildings, the intention of this research is to study possibilities for sustainability appraisal of infrastructure facilities, specifically for application in the new DGBC Area certificate.

1.3 INCREASING INNOVATION POTENTIAL

Although development of environmental assessment methods is a relevant aspect of the transition towards sustainable construction practices, such methods also adhere an inevitable downside. Application of assessment methods may have a constraining effect on initiatives for innovative products or processes in planning proposals of, in this case, area development projects. Developers and principals are less stimulated to exceed the standards and minimal requirements that are set in the criteria of the assessment method, since they run a risk that their initiative for an innovative solution will not be rewarded in the assessment process (Cole, 2005). However, when this issue is recognized from the start of the development of an assessment method, it is possible to structure the method in such a manner that innovation is supported and accelerated (Kemp et al., 2000). There are numerous possible approaches to do so and optimal application varies for each specific case.

The DGBC is aware of this issue and has the ambition to try to limit the restriction of innovation or, in other words, to increase the potential for innovation in DGBC Area. Since possible approaches for this purpose are case specific, the development and implementation of strategies to stimulate innovation in environmental assessment of infrastructure facilities will be a central aspect in this research.

1.4 READING GUIDE

In light of the contextual setting and central aspects discussed above, a problem definition and research scope are formulated in the research design in chapter 2. A research framework is presented and subsequently the research strategy and methodology for each of the distinguished phases is discussed in detail. The outline of this study is to design and evaluate an environmental assessment method for infrastructure sustainability. Chapter 3 presents a theoretical framework, in which the central concepts are defined. Based on this framework several requirements regarding structure and content of the design are formulated. In chapter 4 a practical framework is provided, in which the structure and methodology of DGBC Area is discussed in detail. Besides, this chapter presents the results of an analysis of the applicability of several practical instruments for this study. Based on the practical framework, again design requirements are formulated. Chapter 5 presents the considerations on each of the design steps and on processing the results of the evaluation of the designs with experts and practitioners. Ultimately, the result of the design and evaluation steps is presented in the proposed design for an infrastructure sustainability assessment method in chapter 6. This chapter discusses the proposed design in detail, clarifying content and structure and the relation to the theoretical and practical design requirements. Finally, chapter 7 concludes this research in formulating an answer to the central research question. Several aspects regarding methodology and scope of this research are discussed and subsequently recommendations for further research and implementation are formulated.

2 RESEARCH METHODOLOGY

In this chapter the research design is presented. First the problem definition and research scope are formulated. The objective of this study is to design and evaluate a method for assessment of infrastructure sustainability. Subsequently, the outline of this study is presented in a research framework. The applied research methodology and strategy for each of the phases of the research are clarified in this section as well.

2.1 PROBLEM DEFINITION

In light of the intended transition towards more sustainable construction practices it is necessary to make sustainability measurable. Recently the DGBC initiated the development DGBC Area, a new environmental assessment method for area development projects. In such a method sustainability appraisal of infrastructure facilities is a relevant element. However, since current research has focused on environmental assessment of buildings, there is a lack in experience on assessment of infrastructure sustainability. The central problem in this study is the impossibility to assess infrastructure sustainability, specifically in a way that fits with DGBC Area methodology and structure.

2.2 RESEARCH SCOPE

This study is intended to contribute to the transition towards a sustainable construction industry. The research objective is to design and evaluate a method for assessment of infrastructure sustainability as part of the DGBC Area certificate. The central research question of this study is: How can infrastructure sustainability be assessed in DGBC Area?

With this purpose and central question as focus of this research, the scope is further defined by a number of basic principles, following from the issues discussed in the research setting. First, in line with the harmonization ambition of the DGBC, starting point of this research is the identification of appropriate measures for infrastructure sustainability in scientific literature and existing practical instruments. The design will initially be based on these measures of which applicability for use in DGBC Area will subsequently be evaluated.

Second, in the development process of an assessment method, it is important to consider possibilities to reduce constraining effects on initiatives for innovation in planning and design. The DGBC acknowledges the importance of this issue and seeks to increase potential for innovation in their certificates. Formulation and implementation of strategies to increase the innovation potential of the method are therefore a central aspect of the design process in this study.

The results of this study form a solid foundation for the DGBC to incorporate infrastructure sustainability in a first version of DGBC Area. In an iterative development process, including interaction with professionals and area development practitioners, the assessment method designed in this study will be further detailed.

Consolidation of the method, as well as formulation of standards and limits in criteria, are aspects that also will be discussed in this iterative process. These aspects are therefore outside the scope of this study.

2.3 RESEARCH FRAMEWORK AND STRATEGY

The outline of this study is to develop an initial design of an assessment method based on existing measures, and to evaluate and adjust this design based on the views of experts and practitioners. This is depicted in the research framework in Figure 2.1. In general the research strategy for this study can be formulated as a design-oriented desk research, in which the synthesis-evaluation iterations (Van Aken et al., 2007:85) can be characterized as empirical research (Verschuren & Doorewaard, 2000:152).

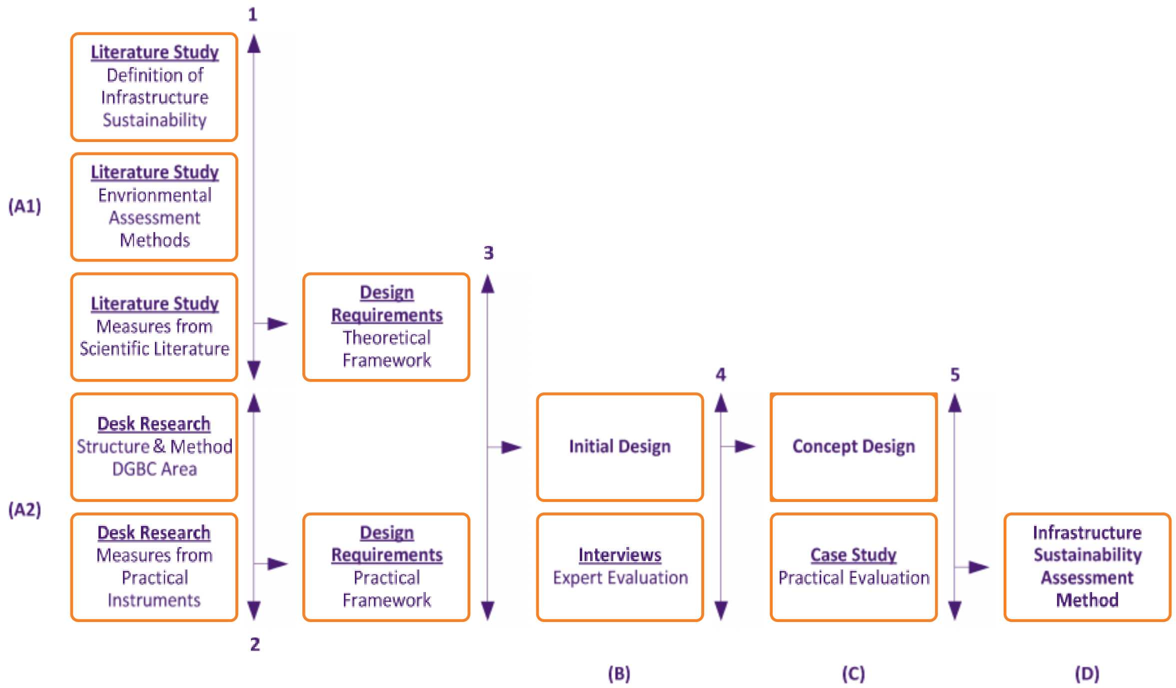

Figure 2.1 - Research framework.

The research strategy for each of the phases (A, B, C and D) distinguished in the framework will be discussed in more detail below. The numbers in the framework refer to the corresponding research sub questions (1-5) formulated for each of the phases.

2.3.1 PHASE A: DESIGN REQUIREMENTS

The objective in the first phase is to formulate design requirements for the assessment method. These design requirements are based on (A1) a study of scientific literature and (A2) an analysis of DGBC Area and other practical instruments. In this phase desk research, and more specifically literature study, is the main research strategy.

PHASE A1: DESIGN REQUIREMENTS FROM LITERATURE

The objective of the first part of phase A is to answer the following research sub questions:

1. What design requirements follow from scientific literature?
    a. What requirements follow from literature concerning infrastructure sustainability?
    b. What requirements follow from literature concerning environmental assessment methods?
    c. Which measures for infrastructure sustainability are proposed in literature?

Based on scientific literature design requirements are formulated regarding both structure and content of the assessment method. Literature on sustainable construction is used to develop a conceptualization of infrastructure sustainability as scope for the method. Other design requirements are based on theory on characteristics and development processes of assessment methods in general. Furthermore, measures proposed in existing literature are a solid foundation for the content of the design. Therefore a profound literature study on infrastructure sustainability indicators is carried out as well. The results of this part of phase A are formulated in chapter 3 of this report.

Scientific articles is search for in search engines Google Scholar, Web of Science, Scopus and Picarta, using a combination of diverse keywords related to each of the topics from the research framework. A selection is made from the search engine results based on possible relevance that proves from the article's title and abstract. After this pre-selection the articles are evaluated on usefulness. This is done using the following criteria: the article had to (i) contain relevant definitions or models within the scope of the study or specific measures for infrastructure sustainability, (ii) contain a clear description of background and research methodology, (iii) be published preferably in a well known journal and (iv) be as recent as possible. The literature study is expanded analyzing citations forward and backward from the relevant articles.

PHASE A2: DESIGN REQUIREMENTS FROM PRACTICE

The objective of the second part of phase A is to answer the following research sub questions:

2. What design requirements follow from sustainability assessment practice?
    a. What requirements follow from analysis of structure and methodology of DGBC Area?
    b. What measures for infrastructure sustainability are used in existing practical instruments?

Besides scientific literature, design requirements are also based on an analysis of the structure and methodology of DGBC Area. Moreover, in line with the DGBC's ambition to harmonize their certificates as much as possible with existing instruments, practical tools are analyzed on their potential as source for measures that can be used in the design. A selection is made of instruments, commonly used in Dutch construction setting, that incorporate infrastructural aspects, such as DPL and Greencalc+. Additionally, the original BREEAM Communities certificate and the recently introduced BREEAM-NL Nieuwbouw certificate are included in the analysis. The results of this second part of phase A can be found in chapter 4.

The analysis of DGBC Area is based on explorative interviews with contacts at the DGBC and internal documents like meeting reports. Other information is retrieved from the public websites of the DGBC and BREEAM-NL. The analysis of other practical instruments on their usefulness for the initial design is based on various sources. If available the original (demo) software and other (internal) documentation, like technical guidance manuals, reports and publications, is used. DuboCalc and BREEAM-NL Nieuwbouw are partly analyzed based on explorative interviews, because the instruments were at that time still in development and documentation was limited.

2.3.2 PHASE B: INITIAL DESIGN

The objective of phase B is to answer the following research sub questions:

3. How can the design requirements from literature and practice be combined in an initial design for an assessment method?
4. How can an evaluation of the initial design by experts be used in a concept design for an assessment method?

An initial design of an assessment method for infrastructure sustainability is developed and evaluated. The initial design is a combination of the design requirements and the measures selected from literature and practical instruments in the preceding phase. The evaluation of the initial design is done by means of interviews with several experts in the field. The goal of this evaluation is to complete and validate the assessment method. This phase of the study can be characterized as empirical evaluation research (Verschuren & Doorewaard, 2000:152, 120).

All interviewees are requested to prepare the interviews beforehand, using a preparation document sent to them by e-mail. This document gave them more information about the background of the research, DGBC Area and an explanation of what was expected from them as preparation. In short, this implied studying (a specific part of) the initial design and writing down their possible remarks on the indicators. This approach made it possible to use the available time of the experts efficiently. The design consideration preceding and following from the evaluation of the initial design are reported in chapter 5.

The interviews can be characterized as semi-structured, as beforehand is not known which information will be collected from the interviews. Standardization is strived for using an interview protocol (see Appendix 8A.IV.I) to structure the course of the interviews (Emans, 1990: 20). During the interviews the following aspects are discussed: (i) research setting, (ii) expertise of interviewee, (iii) infrastructure sustainability in general, (iv) remarks and consequences on indicators of initial design and (v) suggestions for new indicators to complete the assessment method. Further, the informants are asked to declare which indicator(s) in their opinion would represent a critical indicator for their field of expertise. This is used as a variant on the critical incident technique (Van Aken et al., 2007:131). In this study a critical indicator reflects the essence of a certain (element of a) system that is measured. Finally, possible strategies to increase the potential for innovation in an assessment method are discussed. If appropriate, the experts are asked to illustrate the suggested strategies on the identified critical indicators.

2.3.3 Phase C: Concept design

The objective of phase C is to answer the following research sub question:

5. How can an evaluation of the concept design by practitioners be used in a proposed design for an assessment method?

The concept design is based on the remarks and new suggested indicators of the experts on the initial design. In this phase the concept design will be evaluated on applicability in practice by practitioners of a specific case: the design of the infrastructure system of an area development. This part of the research can also be characterized as empirical, as practitioners from a specific case are interviewed. The results of the evaluation of the concept design are documented in chapter 5 of this report.

Using the design and planning of the technical infrastructure elements of a specific case as an example, the concept design will be evaluated in interviews with key figurants of the area development. These interviews are structured in the same way as the interviews in the initial design phase. The interviewees are requested to prepare the interview and to note their possible remarks on the indicators of the concept design. Specifically they are asked to evaluate the design on interpretation and clearness, on applicability (would assessment as suggested be possible) and on completion.

Again the course of the interviews is structured using an interview protocol, which can be found in Appendix 8A.VII.I. During the interviews the following aspects are discussed: (i) general information on the case, (ii) the sustainability ambition, (iii) remarks on indicators and (iv) suggestions for indications for infrastructural elements that are missing in the concept design. The discussion of the indicators is constantly guided by practical examples of sustainable infrastructure as practiced in the case. Of each of these examples of infrastructure sustainability is discussed whether or not it is reflected in the concept design. The strategies to increase innovation potential in the assessment method, as suggested by the experts, are presented to the practitioners. They are asked if they recognize the issue of designers using environmental assessment methods as design guideline and to illustrate specific examples of application of innovative technical solutions in the case.

2.3.4 PHASE D: INFRASTRUCTURE SUSTAINABILITY ASSESSMENT METHOD

The objective of phase D is to answer the central research question: How can infrastructure sustainability be assessed in DGBC Area?

Processing of the remarks and suggestions of the practitioners resulted in a proposed design of an assessment method for infrastructure sustainability, which is the central objective of this study. In this phase the proposed design is presented more extensively, meeting all the design requirements from the first phase. Besides, a clarification on the assessment method is formulated, to describe the intentions of and the relations between the indicators. Furthermore, the strategies to increase innovation potential are presented in relation to the structure of the proposed design. The proposed design is presented in chapter 6.

3 THEORETICAL FRAMEWORK

This chapter presents the theoretical framework for this research, in which several concepts from the research design are defined. First, the scope of the research object, sustainability of technical infrastructure, is established. Second, relevant aspects related to characteristics and development processes of an environmental assessment method are identified. Third, appropriate measures proposed in literature are selected for application in an initial design of the assessment method.

Based on the theoretical framework, as presented in this chapter, it is possible to formulate an answer to research sub question 1: What design requirements follow from scientific literature? The design requirements are formulated as a conclusion of each of the sections of this chapter.

3.1 SCOPE OF THE ASSESSMENT METHOD

This section sets the scope of the research object, it defines the concepts of infrastructure in relation to sustainability. Ultimately, it provides in a conceptualization of sustainable infrastructure that is the basis for the design of the assessment method.

3.1.1 TECHNICAL INFRASTRUCTURE FACILITIES

The word infrastructure originally is related to the foundations, or underlying base, of a system or organization. A classical interpretation considers infrastructure as the sum of all physical constructions, institutional conditions and human potential needed for an economy to function (Jochimsen et al., 1977). Howes & Robinson (2005:16) further classify the physical infrastructure based on its function in three categories:

- SOCIAL INFRASTRUCTURE. Facilities related to human and social wellbeing such as schools, health centers and housing facilities.
- MARKET INFRASTRUCTURE. Facilities directly linked to production of goods and services such as factories, offices and retail facilities.
- TECHNICAL INFRASTRUCTURE. Facilities that indirectly support economic production such as roads, sewage systems and electricity supply networks. The facilities in this category can be further divided in five domains: transport, energy, water, communication and waste.

This study focuses on facilities belonging to the category of physical, technical infrastructure. Some refer to this category of infrastructure as civil infrastructure systems (Dasgupta & Tam, 2005; Pearce, 2008). In Figure 3.1 the scope of infrastructure in this study is reflected in the highlighted path. The domains of technical infrastructure are further illustrated with specific examples of infrastructural elements that explicitly are subject in this study (Infrastructure, 2009).

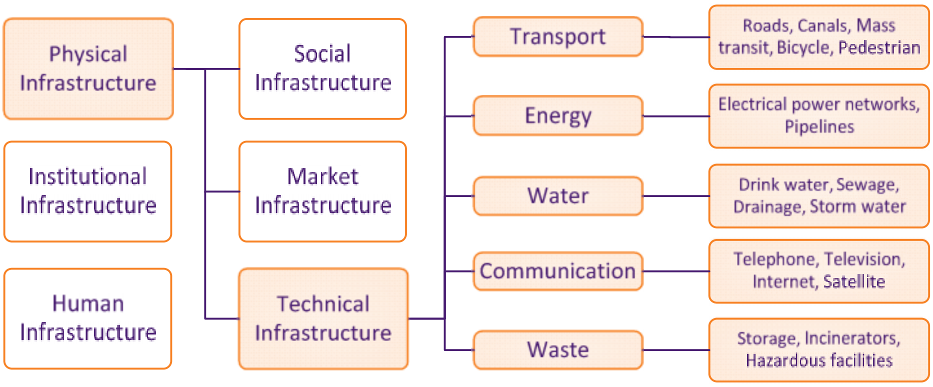

Figure 3.1 – The scope of the method is restricted to the domains of physical, technical infrastructure.

Although the scope of this study is restricted to the elements of civil infrastructure systems, it is necessary to see these elements in light of the more extensive context of area development projects. The concept of integrated area development refers to a procedural approach for complex spatial planning cases (Adviseur Gebiedsontwikkeling, 2007). In spatial and physical terms however, an area can be seen as a closed system of multiple buildings, public space and infrastructure within its boundaries. In other words, in an area development all categories of physical infrastructure (social, market and technical) are represented and intertwined (Engel-Yan et al., 2005). The technical infrastructural elements are explicitly object of study in this research, but are strongly related to the contextual elements of social and market infrastructure, as is visualized in Figure 3.2. In this light, technical infrastructure is sometimes referred to as urban infrastructure (Nielsen & Elle, 2000).

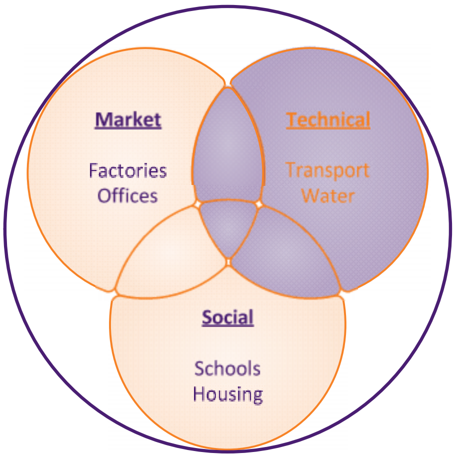

Figure 3.2 – Technical infrastructure in the context of area development projects.

3.1.2 Sustainable development of infrastructure

In order to be able to define what is understood as sustainable development of infrastructure, this section first provides an overview of basic principles of sustainable development. These are then applied to the specific context of construction industry.

The concept of sustainable development

In the seventies of the previous century society realized the seriousness of the harmful impacts on the planet due to continuous economic development. Several publications warned for the consequences of unchanged growth in population, industrialization, pollution and resource depletion (such as Carson (1962) and Meadows (1972)). However, the report Our Common Future is generally seen as the most constructive approach to handle these problems globally. In this report, sustainable development is seen as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The Triple Link Sustainability model classifies three dimensions of sustainable development (Howes & Robinson, 2005:223):

- THE ECOLOGICAL DIMENSION. The environment needs to be protected in order to preserve ecology to function in the long term. People consume resources and besides let the environment process their waste and emissions. It is relevant to respect the maximum capacity of natural systems, to recycle resources and reduce waste.
- THE SOCIAL DIMENSION. Human welfare and a sincere division of this welfare within and between generations is a central aspect. Every human being deserves a healthy, safe and valuable life.
- THE ECONOMIC DIMENSION. Development is necessary to sustain economic growth but it needs to be efficient. This dimension concerns allocating of resources in a life cycle approach for economic decisions. Stimulation of innovation is a relevant aspect of economic sustainability.

Sustainable development is depicted in Figure 3.3 as the process of integration of these three dimensions. Sustainability is an optimal balance between ecological, social and economic objectives, as is highlighted in this figure. Time is a relevant additional aspect in sustainable development, as current activities should be aimed at a goal in the future, to strive for equity between generations as well.

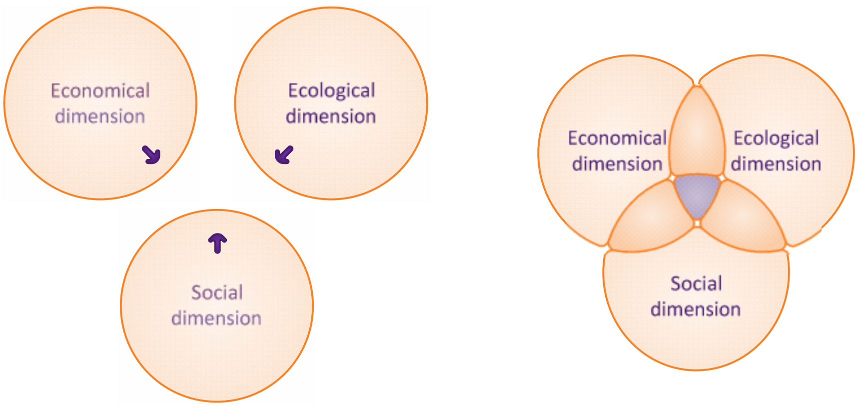

Figure 3.3 - Sustainable development is the process of integration of three dimensions, sustainability is achieved in the section where these are balanced.

SUSTAINABILITY IN CONSTRUCTION INDUSTRY

In light of sustainable development practices it is very relevant to review the construction industry. The built environment (comprising social, market and technical infrastructure) is the fundamental foundation upon which a society exists and develops (Vanegas, 2003). Infrastructure supports economic growth and responds to social demands as it connects goods to markets, workers to industry and people to services. However, it is generally accepted that the built environment and the related construction processes have direct and indirect impacts on the environment (UNESCAP, 2007:12). For example, according to Spence and Mulligan (1995), construction industry is one of the biggest consumers of natural resources such as fossil fuels, water and materials. An indirect impact of the built environment is it replaces ecological valuable land with agricultural or natural functions. Further, construction industry contributes significantly to air pollution through emission of greenhouse gasses and fine dust. The long-term time scale of projects in the built environment provides another indirect impact, as current planning and realization activities lock in consumption patterns for decades to come (UNESCAP, 2007:11). For example in infrastructure development, planning roads in preference to mass transit systems implies heavy future fossil fuel demand for personal modes of transport.

The sector thus has major direct and indirect impacts on the natural environment, contributing to resource depletion, waste generation and environmental degradation. These impacts are caused in each stage of the urban development process or life cycle, from strategic planning on the one hand to utilization of the resulting built environment, and ultimately demolition, at the other. The stresses of construction industry processes on environmental condition can be illustrated as in Figure 3.4.

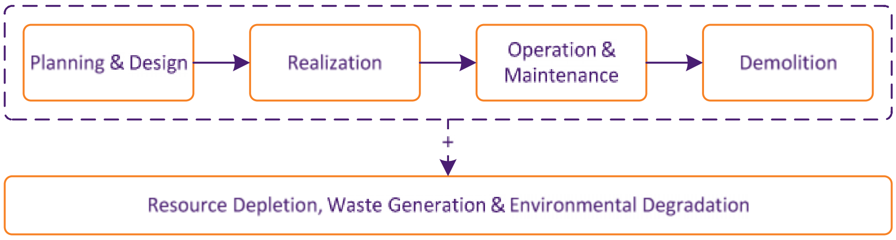

Figure 3.4 - Stresses of an infrastructure development process on environmental conditions.

Sustainable construction practices are desirable to reduce the stresses on the environment. Since the publication of the WCED report in 1987, several initiatives and envisaged policies for construction industry came to light. Principals demand achievement of higher levels of project effectiveness and efficiency, of performance in the delivery and operation of facilities over their complete lifecycle. More specific, they pay more attention to the optimization of resource use, reduction of waste, enhancement of environmental compatibility and satisfaction of needs and aspirations of stakeholders in their projects (Vanegas, 2003).

During the first international conference on sustainable building in Tampa, sustainable construction is defined as the creation and operation of a healthy built environment based on ecological principles and resource efficiency (Kibert, 1994). In the course of years, both in scientific literature and policy documents a broad spectrum of (slightly different) definitions came in to existence. The Dutch national centre for sustainable construction summarizes and merges several of these definitions in their own view on sustainable construction. Their model comprises the employment of opportunities in all stages of the construction process, to create an high spatial and architectonical quality in combination with a low impact on natural environment, that is maintained in time for future generations to profit from it as well (Nationaal DuBo Centrum, 2009).

The two mentioned definitions do show overlap with each other and with the general dimensions of sustainable development, whereas social aspects are only specifically mentioned in the latter. An unambiguous definition of sustainable construction does not exist, but Pearce and Vanegas (2002) formulate a definition that combines several central elements and is in line with basic sustainable development terminology. In this study, this definition is applied to the explicit scope of technical infrastructure domains: the realization and operation of technical infrastructure facilities, that indirectly support economic production, in a way impacts on natural resources and ecology are minimized and current and future needs of people are satisfied.

SUSTAINABLE CONSTRUCTION PRACTICES

The formulation of a definition for construction sustainability is one thing, an effective transition of traditional construction practices into sustainable construction practices is another. Specifically for the development of sustainable civil infrastructure systems Ugwu et al. (2006) concluded there are several strategies and considerations for designers to stimulate this transition. These are (i) to reckon with environmental impacts, (ii) application of innovative solutions that optimize the use of resources, (iii) material reuse, recycling and waste management, (iv) consideration of the impact of design decisions on the wider ecosystem and (v) application of innovative construction methods and technologies. The considerations (i) and (iv) are directly linked to the stresses on environmental conditions due to construction processes as depicted in Figure 3.4. The remaining strategies are in line with the mechanisms distinguished by Vanegas (2003):

- Sustainable resource management. Use of resources is actively managed in a way that ensures that supply will always exceed demand and that prevents depletion of nonrenewable resources.
- Sustainable strategies and technologies. Can be distinguished in (i) development and application of environmentally conscious alternatives and substitutes for current resources and energy sources, (ii) measures for prevention or mitigation of environmental impacts and (iii) remediation technologies to correct environmental impacts.
- Resource recovery. Pursuing recovery of resources and products through direct reuse of components, remanufacture of elements, reprocessing of materials and raw material generation.

The processes, techniques or systems in these mechanisms can reduce the negative impact of construction processes on the natural environment. The mechanisms or strategies are a classification of possible responses to unsustainable construction practices.

3.1.3 Concluding

The scope of the method is restricted to the assessment of technical infrastructure facilities as part of an area development. Figure 3.5 visualizes the final conceptualization of technical infrastructure in relation to principles of sustainable development for this research.

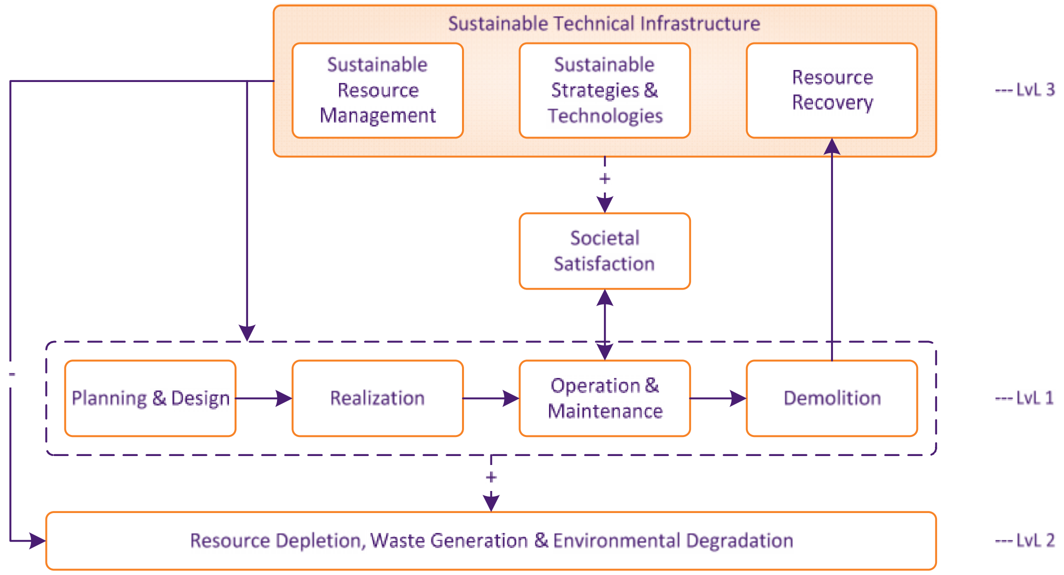

Figure 3.5 - Conceptualization of technical infrastructure in relation to principles of sustainable development (based on Vanegas, 2003).

Traditional development processes of infrastructure facilities subsequently follow the stages from design to demolition. The output of this process is the satisfaction of the user's needs and aspirations, in particularly in the operation stage. However, in all stages of the development process natural environment is impacted negatively. In other words the construction practices (level 1) stress the condition of resources, waste and environment (level 2). Sustainable infrastructure practices can be classified in three strategies (level 3). In line with the definition of sustainable infrastructure, these strategies reduce the negative impacts on natural environment and increase the satisfaction of social needs now and in the future.

Based on this conceptualization of sustainable infrastructure and the theory in this section, an answer can be formulated to research sub question 1a: What requirements follow from literature concerning infrastructure sustainability? The design requirements are formulated in the text box below.

DESIGN REQUIREMENTS

DR.1 - The method is specifically focused on assessment of physical, technical infrastructure facilities as part of an area development.

DR.2 - The method assesses the sustainability of infrastructure. This can either be done by measuring:

- The stresses of infrastructure development processes.
- The condition of the natural environment.
- The efficiency of the response strategies on reducing natural impact or increasing societal satisfaction.

3.2 ENVIRONMENTAL ASSESSMENT METHOD DEVELOPMENT

As is amplified in the research design (chapter 2), the objective of this study is to design and evaluate a method for assessment of infrastructure sustainability. In scientific literature such a method is referred to as an Environmental Assessment Method (EAM). In this paragraph the general concepts related to characteristics and development of an EAM are identified.

3.2.1 CHARACTERISTICS OF AN ENVIRONMENTAL ASSESSMENT METHOD

The primary role of an EAM is to provide a comprehensive assessment of the environmental characteristics of an object (Ding, 2008). Besides, according to Ding (2008), it enhances the environmental awareness in construction practices and directs construction industry toward environmental protection and achieving sustainability.

Cole (2005) stresses a distinction should be made between Environmental Assessment Tools (EAT) and Environmental Assessment Methods (EAM). Tools are specific techniques to predict, calculate or estimate environmental performance characteristics of a product, using methodologies such as Life-Cycle Assessment (LCA) or Analytic Hierarchy Process (AHP). Instead, EAM often have assessment of products as their core function and ultimately issue a performance rating or label to indicate extended output of the environmental assessment process. However, methods often include reference to certain assessment tools for quantitative calculation of environmental performance. The most important distinction however, is related to the organizational context. Full engagement of an environmental assessment method involves some form of registration or certification by a managing and operating organization (such as the DGBC).

In addition Haapio & Viitaniemi (2008) formulate five aspects on which EAMs can be characterized. These are (i) the type of object the method can be applied to, (ii) the users of the method, (iii) the phases of the life cycle the method concerns, (iv) the used database and (v) the forms of the results used.

Some assessment methods are concerned with a single criterion to indicate the overall performance of an object, whilst other, more comprehensive methods, are developed to provide a thorough evaluation of performance against a broad spectrum of environmental aspects (Ding, 2008). Such comprehensive methods consist of criteria, which often are clustered in categories, that represent the standard or ideal conditions against which a system is measured. Indicators reflect the relative position of the system against the yardstick set in the criteria on a given moment (Sahely et al., 2005). Indicators, or measures, together form an index that provides an integral rating of the state of the system (Munier, 2005:275).

Indicators can be typified based on their objective: what does the indicator measure? The PSR framework provides a widely applied approach for systematic analysis of systems, which makes it possible to define the objectives of indicators (Linster & Fletcher, 1999). The model helps to identify a particular chain of cause and effect for an environmental problem and the corresponding indicators in groups of Pressure, State and Response. The most serious objection to this approach is that it neglects the systemic and dynamic nature of processes, and their embedding in a larger total system containing many feedback loops (Bossel, 1999:13). For this study, the PSR approach is however regarded as relevant, since it makes it possible to relate the indicators in the design to the conceptual framework of infrastructure sustainability (see section 3.1.3):

- Indicators in the assessment method can measure the stresses of the infrastructure development process on the natural environment. Such pressure indicators are closely related to production and consumption patterns and often reflect emission or resource use intensities (Linster & Fletcher, 1999). These indicators are related to level 1 of Figure 3.5.
- State indicators measure the condition of the natural environment and its development over time. In other words, these indicators measure the extent of resource depletion, waste generation or environmental depletion related to level 2 of Figure 3.5. Often used state indicators measure the concentration of pollutants or exceeding of critical loads (Linster & Fletcher, 1999).
- Indicators can measure the efficiency of sustainability practices, or responses, to transform construction industry towards sustainable development. These response indicators are related to level 3 of Figure 3.5. Specific examples of such indicators are highly dependent on the level of abstractness the system is measured in. However, they often measure responses that are intended to either mitigate negative effects, reverse environmental damage already inflicted or preserve nature and resources (Linster & Fletcher, 1999).

3.2.2 Development processes of environmental assessment methods

Several organizations and scientists from various fields have defined principles and procedures for development of indicator indexes for sustainability assessment. General principles for sustainability assessment models are:

- Practical focus. The model will have a practical focus if current views and goals are reflected clearly in indicators and criteria (Hardi & Zdan, 1997:3). Moreover, practical focus will be enhanced if the model is developed in close cooperation with stakeholders and is formulated as specific as possible for the system being measured (Ugwu et al., 2006; Dasgupta & Tam, 2005).
- Transparency. The entire process should be open and transparent, specifically on method, data, assumptions, uncertainties and interpretations (Hardi & Zdan, 1997:3; Linster & Fletcher, 1999; Spangenberg & Bonniot, 1998).
- Representativeness. The model should be representative for a broad group of stakeholders and communicate clear and simple with its users (Hardi & Zdan, 1997:3; Ugwu et al., 2006).
- Flexibility. The model will need flexibility to be able to adjust framework and indicators in a changing environment and to make ongoing assessment possible (Hardi & Zdan, 1997:4; Linster & Fletcher, 1999).

Besides principles, procedures for development of assessment methods are defined. The processes are formulated differently but distinguish comparable steps (Sahely et al., 2005; Bossel, 1999:57, Hardi & Zdan, 1997:2-4):

1. Scope definition. The first step is to define the general purpose, the target group and the temporal and spatial boundaries of the system.
2. System analysis. The second step is the development of a conceptual understanding of the total system, including the relations and interactions between elements of the system.

3. INDICATOR IDENTIFICATION. The third step is to define sustainability criteria and the corresponding indicators. Development of a set of indicators is based on several requirements for indicator identification.
4. ANALYSIS. Indicators will be quantified and standardized as much as possible in order to be able to analyze the system. The values of the indicators will be reflected on references, goals or scales set in the criteria.

Indicators provide a simplified view on complex and detailed systems (Chambers et al., 2000:16). It is however necessary to select indicators based on predefined requirements to prevent for a fuzzy insight in the system instead (step three). Generally the number of indicators (and corresponding environmental aspects) in an assessment method should be limited to secure the quality of the analysis (Hardi & Zdan, 1997:3; Munier, 2005:294; Spangenberg & Bonniot, 1998). Reducing the number of indicators is possible assessing the system on a more abstract level and merging indicators that are overlapping. Besides, it is possible to select those indicators that represent the most useful aspects of the system (such as cause, average, minimum or weakest link). Several specific requirements for indicator selection have been formulated, in Table 3.1 the requirements used in this study are presented. The used sources and their corresponding numbers are: Chambers et al., 2000:16 (1), Munier, 2005:294 (2), Hardi & Zdan, 1997:2-4 (3), Sahely et al., 2005 (4), Dasgupta & Tam, 2005 (5), Ugwu et al., 2006 (6) en Spangenberg & Bonniot, 1998 (7).

Table 3.1 - Requirements for selection of indicators.

Nr.	Requirement	Description	Source
IR.1	Applicable	Clear, unambiguous interpretation is possible	1,2,3,4,5,6,7
IR.2	Reliable	Based on reliable data, transparent method	1,2,4,7
IR.3	Inspiring	Inspires and motivates users	1,3,6
IR.4	Representative	Specific for system being analyzed, broadly accepted	2,3,4,5,6
IR.5	Quantitative	As much as possible quantitative	3,5,6

3.2.3 INNOVATION POTENTIAL IN ASSESSMENT METHODS

Since environmental assessment methods consist of a set of indicators and corresponding criteria, they communicate to design teams and principals what aspects are regarded as the most significant environmental considerations (Cole, 2005). The effect is that EAMs are used as design tools, even though they may not have been specifically developed for this purpose. That is, since the criteria reflect the environmental demands in specific requirements, these give guidance to developers in terms of what is actually required (Kemp et al., 2000). Both scientists and practitioners have concerns regarding the extent to which this may constrain or support innovation in design.

Innovation might be constrained since EAMs can be seen as relatively rigid instruments that leave little space for assessment of practices that exceed standard requirements or that incorporate aspects which are not specifically addressed in the method (Pearce, 2008). In other words, since standards and minimal requirements are set in the criteria for environmental assessment, a limited definition of environmentally responsible practices might be institutionalized (Cole, 2005). Hence, there is a possibility that initiatives for innovative solutions incorporated in planning and design of a system will not be awarded in the assessment process. In practice, the rigidity of an assessment method might thus provide an additional risk for innovation processes, since developers cannot be ascertained their efforts will be credited.

On the other hand, if the issue is taken into account from the start of the development of the assessment method, innovation might as well be stimulated. In the view of Kemp et al. (2000) environmental labels, such as DGBC Area, will support and accelerate innovation, if only they are shaped and employed properly. A prerequisite for this positive effect is that the instrument consists of a catalogue of criteria that are regularly revised and developed further. It should however be noted that, besides shape and structure of an instrument, wider economical and political conditions (which cannot be influenced in the design of an assessment method) have effects on the innovation processes as well.

CHARACTERISTICS OF ENVIRONMENTAL INNOVATIONS

It is relevant to further define the concept of innovation, in the specific setting of environmental assessment, since the characteristics of the innovations may have consequences for the implementation of strategies to increase innovation potential in an assessment method. The innovations can be characterized as environmental (or sustainable) innovations, representing subsets of innovation systems (Horbach, 2005:3). Environmental innovations consists of new or modified processes, techniques, systems and products to avoid or reduce stresses on the natural environment (Kemp et al., 2000). These innovations are only successful if they allow for the same use value at lower environmental cost, irrespective of whether they are introduced for environmental protection reasons.

Different types of innovations may have different requirements for implementing strategies to improve the innovation potential in the method for infrastructure sustainability. Continuity (incremental) changes improve the performance of existing technologies, whereas discontinuity (radical) changes lead to the replacement of existing technologies by superior alternatives. In light of environmental innovation, incremental solutions address the stresses on the natural environment through adjustments to the input mix, process changes or through end-of-pipe treatment methods (Könnölä & Unruh, 2006). Since these innovations improve existing technologies, the assessment method for infrastructure sustainability will most likely already incorporate measures that cover the technologies. It might however be necessary to adjust the requirements or standards since the performance of the technologies is improved. Radical environmental innovations seek the replacement of existing components, or entire systems, which often require transformation of production systems, services etc. (Könnölä & Unruh, 2006). It is most likely an existing instrument for sustainability appraisal will not include any measures to reward the environmental performance of such innovations.

Another dimension to categorize types of innovation is related to the nature of the innovation. Generally these are product and process innovations, which can be for example respectively a new material or technique. These different types of innovations require different indicators for assessment (Horbach, 2005:10). For example, for assessment of a new product it is necessary to have insight in the environmental characteristics of the new products with respect to comparable products. For innovations in techniques it is important to know the improvement in energy intensity or reduction of material use.

3.2.4 CONCLUDING

The characteristics and definitions of aspects related to EAMs can be specified for the design of such a method for infrastructure. The objective of this study is to design and evaluate an environmental assessment method (EAM) that provides a comprehensive assessment of the environmental characteristics of infrastructure. As it is comprehensive, the method will consist of several indicators that form an index for environmental assessment. The different types of indicators can be related to the three levels in the conceptualization of infrastructure sustainability (section 3.1.3). Specification of the criteria, the yardstick of the method, is outside the scope of this study.

The general principles for assessment methods are also valid for the design in this study. Practical focus and representativeness are to some extent implicitly guaranteed in the research methodology (evaluation-iterations with experts and practitioners). The first step of the process for development of assessment methods is reflected in the theoretical and practical frameworks (chapter 3 and 4). The second step, system analysis, is only incorporated on an abstract level, referring to the conceptual framework of infrastructure sustainability in section 3.1.3. Furthermore, it is assumed the objective of this step is accounted for in this study, since the initial design is based on existing measures, which will then be evaluated by interviewing experts with knowledge of the system. The result of this study is related to the third step, since the design of the assessment method is an identification of relevant indicators. The last step, formulation of criteria and application of the method, is outside the scope of this research. The criteria will be formulated in an iterative process with stakeholders from area development practice by the DGBC.

In this research, strategies to increase the potential for innovation in the assessment method for infrastructure sustainability will be developed (based on empirical data) and implemented in the resulting design. The strategies need to reckon with the characteristics of environmental innovations, such as the difference between incremental and radical innovations and process or product innovations. Indicators for assessment of sustainability of innovations need to measure the environmental performance in relation to use value.

Based on this specification of relevant aspects of EAMs in relation to the design in this study, an answer can be formulated to research sub question 1b: What requirements follow from literature concerning environmental assessment methods? The design requirements are formulated in the text box below.

DESIGN REQUIREMENTS

DR.3 - The design is an environmental assessment method (EAM).

DR.4 - The method consists of several indicators that together form an index for comprehensive environmental assessment.

DR.5 - The method incorporates potential to assess environmental innovations, such as new or modified products or processes that exceed standard criteria.

3.3 MEASURES PROPOSED IN SCIENTIFIC LITERATURE

Much of the scientific literature on assessment of sustainability of the built environment has been focused on buildings and construction processes, and less on technical infrastructure systems (Dasgupta & Tam, 2005; Ugwu & Haupt, 2007). Specific characteristics of infrastructure projects make assessment of sustainability complex. In recent years however, the lack on assessment methods of infrastructure has been noticed and several studies on this issue are published. Some of these articles differentiated indicators that are specifically applicable for assessment of sustainability of infrastructure systems. By means of a literature study four articles are selected of which the indicators are used as a basis for the initial design of the assessment method in this study. Below, these articles are discussed in short on content, method and specifically on the way indicators are identified.

Dasgupta & Tam (2005) develop a decision support tool that can be used to measure sustainability of infrastructure and decide on the best alternative. Their article develops a set of civil infrastructure system (CIS) indicators and proposes a layered framework for their use. In the first layer of their framework they distinguish between regulatory and project specific indicators, which all differ for each project and environment. The indicators in the second layer can be used for judgment and incorporate environmental and technical issues. The authors propose several indicators as examples, based on other scientific literature they selected.

Sahely et al. (2005) present a framework that is seen as a practical tool for measuring and enhancing the sustainability of urban infrastructure over its life cycle. The framework focuses on key interactions and feedback mechanisms between infrastructure and surrounding environmental, economic and social systems through the use of sustainability criteria and indicators. A generic set of sustainability criteria is put forward and system specific (transportation and water system) indicators are formulated as examples.

Whereas these both papers focus on the development of frameworks for sustainability assessment and choose indicators as examples, Ugwu and Haupt (2007) focus on the development of key performance indicators in interaction with stakeholders from construction practice. They generate indicators based on governmental guidelines, literature and experiential knowledge and then validate these in construction practice.

The integral research project CRISP also focuses on development of indicators (Bourdeau & Nibel, 2004). The Construction and City Related Sustainability Indicators Project (CRISP) is aimed at joining indicators with respect to urban development from 16 different European countries. The project provides a database with more than 500 indicators for assessing sustainability which are categorized in product, process, buildings, urban and infrastructure.

3.3.1 CONCLUDING

The selection of these articles provides an answer to research sub question 1c: Which measures for infrastructure sustainability are proposed in literature? The measures and indicators suggested in these articles are listed in 8Appendix I. The table in this appendix also shows which of the indicators are selected for use in the initial design, based on the criteria for indicator identification formulated in paragraph 3.2.2.

DESIGN REQUIREMENTS

DR.6 - The indicators for assessment of infrastructure sustainability selected from existing scientific literature are a basis for the initial design.

4 PRACTICAL FRAMEWORK

This chapter provides the practical framework for this research. First, the background and characteristics of BREEAM methodology in general are presented. Second, the structure and methodology of DGBC Area are discussed in detail. Third, several existing practical instruments are analyzed on applicability to be used as a basis for the design.

Based on the practical framework, as presented in this chapter, it is possible to formulate an answer to research question 2: What design requirements follow from sustainability assessment practice? The design requirements are formulated as a conclusion of each of the sections of this chapter.

4.1 BACKGROUND OF BREEAM

In 1990 the Building Research Establishment first implemented their Environmental Assessment Method. BREEAM has been developed in the United Kingdom in cooperation with the private sector (BREEAM, 2009). The first edition of the label was specifically aimed at assessment of new office buildings. Since then, the method has been revised and expanded several times, and to date it is possible to assess buildings in all sectors using BREEAM methodology.

4.1.1 ANALYSIS OF BREEAM METHODOLOGY

BREEAM has been the first comprehensive method, assessing on a broad range of environmental aspects (Haapio & Viitaniemi, 2008). Environmental performance is assessed on several criteria that are subdivided in nine categories: management, health and comfort, energy, transport, water consumption, materials, land use, site ecology and pollution. Assessment credits are awarded reflecting the environmental performance of the building under assessment, leading to a single score on these categories. A weighting system is then applied across the categories to determine the final BREEAM score (Seo, 2002). The final score is expressed in a single rating using pass, good, very good, excellent or outstanding. BREEAM is applicable to almost all kinds of buildings, can be applied by diverse stakeholders and considers all phases of the lifecycle from production till disposal (without the demolition stage) (Haapio & Viitaniemi, 2008).

4.1.2 BENEFITS AND CRITIQUES

This paragraph considers several benefits and critiques on BREEAM methodology based on scientific literature. An overview of the critical analysis is given in Table 4.1 and a positive view on BREEAM methodology is adapted for this study.

An important benefit of BREEAM methodology is the integral assessment on different environmental aspects (Ding, 2008). The method is applicable to all phases of the lifecycle from production till disposal (without the demolition stage) and considers both general and specific issues in the assessment (Ding, 2008; Haapio &

Viitaniemi, 2008; Van den Dobbelsteen, 2008). Using BREEAM methodology the environmental performance of an object is mostly assessed based on qualitative criteria, although some criteria are founded on quantitative assessment, to some extent using scientifically based methods such as LCA (Ding, 2008; Van den Dobbelsteen, 2008). Since the method can be applied in the design stage of a project, it is possible to incorporate recommendations in the further design and planning stage (Ding, 2008). The final result of a BREEAM assessment is presented in a single grade for the whole system. This is beneficial compared to instruments that separate scores in categories, since restriction of developers in their design liberties is limited (Haapio & Viitaniemi, 2008; Van den Dobbelsteen, 2008). Besides, the BREEAM rating is also founded in an assessment report to give users insight in the structure of the analysis and in the bottlenecks of the design or object (Haapio & Viitaniemi, 2008). According to Ding (2008), BREEAM is flexible for adaptation to changing conditions. It is possible to adapt the model based on national or regional differences in, for example, climate, materials and techniques. This can either be done by changing the criteria itself or adapting the weight system.

On the other hand, in light of the basic triple link sustainability model, it is remarkable that BREEAM does not include any financial aspects (Ding, 2008). For environmental issues and financial considerations to go hand in hand in an evaluation framework is particularly important in the design stage, where alternative options for development are assessed. Another critique is related to the process of determination on weight factors (Ding, 2008). In BREEAM methodology it is possible to adapt the factors to national or regional conditions based on, for example, an analysis of stakeholders preferences. On the contrary, Ding (2008) favorites a project based approach for setting weight factors to achieve an optimal reflection of project specific characteristics. Others also formulated more general and subjective critiques on BREEAM methodology. The method would be less robust, since users have the opportunity to manipulate the results of the analysis (Senter Novem, 2008b; Van den Dobbelsteen, 2008). Also, the method is experienced being relatively complex by users (Senter Novem, 2008b). The benefits and critiques are summarized in Table 4.1.

Table 4.1 - Overview of benefits and critiques BREEAM methodology.

Benefits	Disadvantages
Integral, comprehensive assessment	No financial aspects included
Both qualitative and quantitative criteria	No project based approach for setting weight factors
Analysis in design stage	Less robust
Performance reflected in a single rating	Relatively complex
Flexibility for changing conditions	

In general this critical analysis gives a paramount positive view on BREEAM methodology. It should however be noticed it is impossible to validate the method compared to other instruments, since the characteristics of different methods are to diversified to do so (Van den Dobbelsteen, 2008; Haapio & Viitaniemi, 2008).

For this study a positive view on BREEAM methodology is adapted, the benefits are considered more relevant than the critical considerations. Financial issues can be considered as fundamental to all projects and are generally monitored by the principal. Moreover, contradictory to general BREEAM methodology, such aspects are intended to be incorporated in the criteria of DGBC Area (see also section 4.2.1). Although Ding (2008) favors a project based approach for setting weight factors, arguments for a national approach can also be formulated. For example, a project based approach consequences a costly and thorough analysis before each project. After all, a positive validation of BREEAM is only confirmed by the international recognized status the methodology has acquired, since it is applied in many different countries all over the world.

4.2 Structure and Methodology of DGBC Area

To date BREEAM methodology is used in several countries as the leading assessment methodology for the built environment. In 2008 the Dutch Green Building Council was established to develop BREEAM-NL, a version of BREEAM methodology specifically adjusted to national characteristics of Dutch context. BREEAM-NL differentiates on three certificates, being one for new buildings, one for renovation projects and one for area development projects (the latter is referred to as DGBC Area). Since this study is intended to contribute to the assessment of infrastructure sustainability in DGBC Area, the structure and methodology of this certificate will be further analyzed in this section (based on internal documentation: DGBC, 2009b).

4.2.1 Objective and scope of DGBC Area

The objective of the DGBC Area label is to stimulate sustainable area developments. This goal is in line with the DGBC's mission to stimulate construction industry towards a sustainable built environment via the development and management of certificates for sustainability (DGBC, 2009a). The scope of DGBC Area is comprehensive, including the assessment of environmental performance of physical infrastructure facilities to be realized in the area, as well as on social and economical aspects such as social cohesion and business potential. DGBC Area can be applied to different types of area development projects. Four typologies are distinguished specifically (non-urban area, urban area, urban border and industrial estates), but the certificate is flexible to be adjusted for additional area types. Further, the intention is to apply the DGBC Area certificate in several stages of a project life cycle, thus making it possible to monitor an area development on sustainability aspects in the initial planning stage, during realization and in operation. This approach is desirable since the time horizon of area development projects is commonly long. Finally, the rating system is intended to be used by BREEAM Experts, independent and certified professionals that apply the assessment method on a specific case, by order of a principal (such as an area development organization).

The DGBC has made the deliberate choice to create a new area development certificate, instead of adjusting the existing original BREEAM Communities system for this purpose (BRE, 2009). The above described characteristics of DGBC Area therefore show several differences with basic BREEAM methodology (and specifically with BREEAM Communities). First of all, DGBC Area incorporates financial aspects, such as assessment of business potential and stakeholder agreement. Secondly, the certificate can be applied on different area typologies, instead BREEAM Communities is only suited for housing zones. Third, DGBC Area will be applied multiple times during the development project, whereas basic BREEAM methodology is generally applied once (for example in the planning stage).

4.2.2 Structure of DGBC Area

Although the DGBC creates a complete new certificate, the structure of DGBC Area is based on several existing instruments. Besides the original BREEAM Communities scheme, these are DPL (IVAM, 2009a) and One Planet Living (WWF & BioRegional, 2009). A first important characteristic of DGBC Area structure is the used classification of criteria in several categories. Figure 4.1 visualizes these categories and their mutual relations.

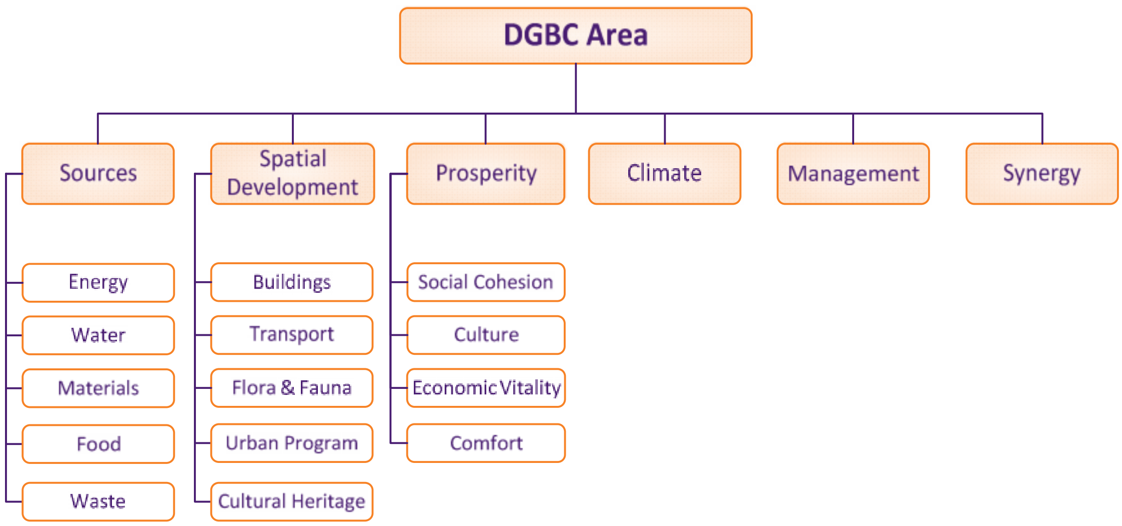

Figure 4.1 - Categories for criteria and indicators in DGBC Area.

In DGBC Area six central categories are distinguished, of which three are separated in subcategories. In the following descriptions of the categories the content and scope are clarified, as well as the relation with infrastructure:

- Sources. This category contains criteria for assessment of the use and consumption of natural sources in the realization and operation of the area development. The objective of the criteria in this category is to stimulate developers to close the cycles of sources within the areas boundaries. Regarding infrastructure facilities it is therefore necessary to assess efficiency in self-supporting and consuming behavior regarding each of the sources: energy, water, materials and waste.
- Spatial Development. The sources provide the area with a body. A morphological design for spatial structure will be made that combines the physical elements of the zone: buildings, transport facilities and ecology. Since the certificate can be applied to different types of area developments, these elements can either be new or existing. Important specified issues for the sustainable assessment of the transport system are emission and safety. The subcategory flora and fauna specifically reflects the open water and greenery of the area.
- Prosperity. The people that live and work in the area represent the social structure and this sets the cultural needs and identity of an area. Social cohesion of the area is reflected and criteria deal with housing issues. When facilities (like groceries, catering, businesses) are well attuned on each other, economic vitality will be high. Finally, comfort represents the mutual fine tuning of all these subcategories.
- Climate. In this category all negative impacts on (micro) climate due to the development and use of the area are clustered, even if the cause of the impact is assessed in another category. The negative impacts can be separated in light, sight, noise, air, water and soil. An example of a negative impact on climate is the emission of greenhouse gasses due to energy consumption. (Emissions due to transport are an exception, these will be assessed in the subcategory transport.)
- Management. Criteria in this category assess the coordination of the aspects in the four main categories. Planning and design of the area development should balance interests, cost and benefits of different stakeholders. Furthermore, policy on management of system maintenance and facility operation control during realization and operation stage of the development should be incorporated in the planning stage.
- Synergy. The relation between different disciplines and elements of an area development is very important using an integral development approach. Synergy can be created if all elements represented in all categories are combined in an optimal sense.

Besides categories for clustering of the criteria two other characteristics of the scope of DGBC Area are comprised in the structure. These aspects are the variation in lifecycle stages and in area development typologies. Both these variables are relevant for structure, since not all indicators are applicable to all of the lifecycle stages and area typologies. Figure 4.2 illustrates these two dimensions in relation to criteria.

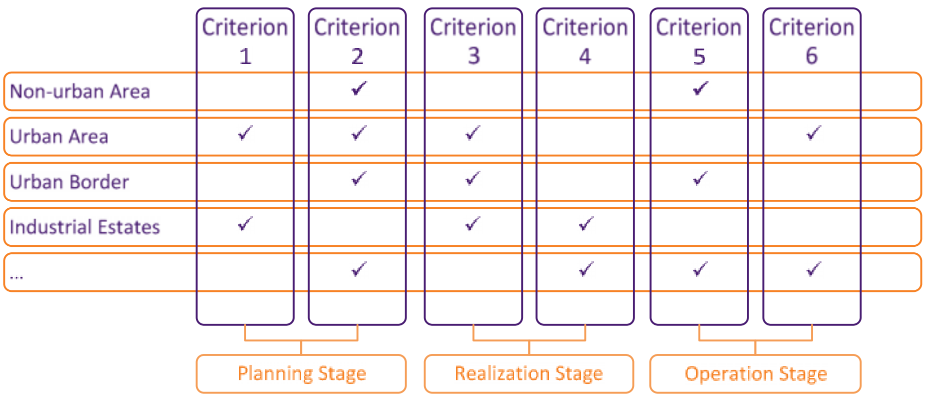

Figure 4.2 - Different lifecycle stages and area development types in relation to criteria.

4.2.3 RATING METHODOLOGY

In general terms DGBC Area methodology is in line with overarching, original BREEAM methodology. DGBC Area is also a typical example of a comprehensive EAM, incorporating a broad range of environmental aspects to assess. The desired state of each of the aspects is reflected in criteria, specifically for BREEAM-NL these are called creditcriteria. The certificate measures the relative position of a specific area development, on a certain moment in the lifecycle, in proportion to the criteria using an index of indicators (see also section 3.2.1 for definitions of this terminology). Application of the certificate delivers a single score on each of the categories, on which the weighting system of the method is then applied. This results in a final score that will be presented in a single rating.

4.2.4 CONCLUDING

Several design requirements follow from the characteristics of DGBC Area, since the design for infrastructure sustainability assessment should fit with this structure and methodology. In line with DGBC Area, the design needs to make comprehensive assessment of infrastructure sustainability possible. Further, it needs to be possible to apply the method to different area typologies and it has to be clear which indicators of the design refer to which area types. Since the users of the method are educated and licensed BREEAM Experts, no further requirements for the design related to users are formulated. DGBC Area differentiates criteria for the planning, realization and operation stages of an area development (see section 4.2.1). Regarding this extensive scope, this study is focused on the identification of indicators that are intended to be applied only during the planning phase of an area development. Although applied in the planning phase, the measures will assess estimated environmental performance of design proposals for infrastructure systems in realization and operation stages. Thus, the method will assess design intentions and potential as determined through prediction instead of actual real world performance (Cole, 2005).

Based on these concluding remarks on relevant aspects from the analysis related to the design of an assessment method, an answer can be formulated to research sub question 2a: What requirements follow from analysis of structure and methodology of DGBC Area? The design requirements are formulated in the text box below.

DESIGN REQUIREMENTS

DR.7 - The indicators of the method assess the potential of a design of infrastructure facilities in realization and operation stages, but are applied in the planning stage.

DR.8 - The structure of the method clusters indicators in the categories energy, water, materials, waste, transport, flora and fauna and climate.

DR.9 - The design gives insight in the applicability of each indicator on the development stages realization and operation.

DR.10 - The design gives insight in the applicability of each indicator on the area typologies non-urban area, urban area, urban border and industrial estate.

4.3 MEASURES FROM PRACTICAL INSTRUMENTS

In line with the intention of the DGBC to harmonize as much as possible with existing instruments, a selection of existing practical instruments that concern (elements of) infrastructure systems is analyzed on applicability for this study. This analysis delivered an extensive list of relevant measures that are used as input for the initial design in this study.

In construction practice there is a big amount of broadly accepted instruments available that can support in sustainable development processes. Consequently a selection is made of instruments that are analyzed. First, the choice is made to only examine instruments that are used in the Dutch construction setting. Analysis of instruments used in other countries is not possible in the limited time available for this study. Besides, this is not desirable, since the assessment method will be designed for application in the Dutch context. Second, to make a selection off the instruments used in Dutch construction practice, the extensive description and categorization published by the Dutch national centre for sustainable building is used (Nationaal DuBo Centrum, 2009). The selection of instruments from this inventory is based on the (i) extend to which an instrument is specifically applied to infrastructure systems and the (ii) type of instrument (so called communication- and ambition tools are not selected because they commonly do not contain any measures). Third, at request of the DGBC three other instruments are added to this list (DPL, BREEAM-NL Nieuwbouw and BREEAM Communities).

The result of the analysis of the selected practical instruments is an insight in general characteristics such as the methodology and historical and recent developments of the instruments. These results are presented in the description of the instruments in 8Appendix II. However, the most relevant result for this study is the potential applicability of (elements of) the instruments for the initial design. These results are presented in short in Table 4.2, a more extensive formulation can also be found in 8Appendix II. If appropriate the measures or indicators used in the instruments are (re)formulated for usage in the initial design of this study. Table 4.2 shows a checkmark in the column ID if any measures from the corresponding instruments are used in the Initial Design.

Table 4.2 - Results analysis of existing practical instruments.

Nr.	Title (in Dutch)	ID	Application in this study
PI.1	Nationaal Pakket Duurzaam Bouwen GWW	×	Not applicable. The instrument is focused on specific examples of infrastructure sustainability, but does not provide any measures to assess presence or performance of such practices in a design.
PI.2	Energie Prestatie op Locatie (EPL)	✓	The instrument provides a useful methodology for calculating energy performance on an area scale. Indicators are formulated for energy consumption of, and energy generation by, infrastructure facilities for the initial design.
PI.3	Verkeers Prestatie op Locatie (VPL)	✓	Indications for energy consumption and emission as effect of transport mobility can be calculated using VPL-Kiss model.
PI.4	DuboCalc	✓	The environmental cost indicator (in Dutch: Milieu Kosten Indicator, MKI) is a measure for material use and embedded energy consumption in a project's life cycle. Based on a mature methodology to calculate shadow prices.
PI.5	Greencalc+	✓	Regarding infrastructure systems this instrument assesses material use, energy performance and mobility. However, sources and methods used in Greencalc+ are overlapping EPL, VPL and DuboCalc.
PI.6	Milieukwaliteit in de LeefOmgeving (MILO)	×	Not applicable. Does not contain specific indicators for sustainability assessment. It gives relevant insights in minimal norms and values for different area development types, regarding several sustainability aspects.
PI.7	Energiescan GWW	×	Not applicable. Instrument gives insight in average figures for energy consumption of infrastructural facilities but does not value or reference this.
PI.8	MIMOSA	✓	This instrument is developed to measure sustainability of a full water cycle , this overdraws the scope of an area development. However, indicators differentiated in this instrument can be used as examples of relevant aspects.
PI.9	DuurzaamheidsProfiel op Locatie (DPL)	✓	Several specific indicators with respect to technical infrastructure of an area can be used as input for the initial design. The proposed indicators are however almost all qualitative.
PI.10	BREEAM-NL	✓	This certificate for sustainable buildings contains several criteria that have interfaces with infrastructure systems. Relevant indicators are reformulated to be used in the initial design.
PI.11	BREEAM Communities	✓	This original certificate for sustainable developing of housing areas contains several criteria for infrastructure sustainability. Relevant indicators are selected to be used in the initial design.

4.3.1 CONCLUDING

The analysis of existing practical instruments that are related to the scope of infrastructure, delivered several measures that can be used as a basis for the initial design in this study. An answer can thus be formulated to research sub question 2b: What measures for infrastructure sustainability are used in existing practical instruments? All specific measures are listed in 8Appendix II.

DESIGN REQUIREMENTS

DR.11 - The indicators for assessment of infrastructure sustainability selected from existing practical instruments are a basis for the initial design.

5 EVALUATION OF INITIAL AND CONCEPT DESIGN

This chapter is structured following the design steps of phases B and C of the research framework. Of both the initial and concept design, the considerations in preceding design steps are presented, as well as a summary of the results of the evaluation with experts and practitioners. Finally the considerations towards the proposed design are reported.

5.1 TOWARDS AN INITIAL DESIGN

The initial design is a combination of the structural design requirements and the selected measures following from scientific literature and practical instruments. Three aspects regarding preceding steps towards this initial design are relevant to discuss.

First, merging indicators is one possible strategy for reducing the number of indicators in an assessment method (see also paragraph 3.2.2). Thus, indicators selected from scientific literature and practical instruments that showed overlap in both goal (what is measured) and method (how is this measured) are merged in one indicator for the initial design. The concerning indicators are listed with a reference to the new merged measure in Appendix I and II. However, indicators with just an overlap in goal are not merged, but instead next to each other included in the initial design to ask the experts view on which method to prefer.

Second, the indicators are categorized following DGBC Area structure. This is basically done following the description of the category the measure belonged to in the original source. That is, if an indicator in the original source belonged to the category waste management, it would most likely fit with the category waste in DGBC Area. If the original source did not contain the required information, logical reasoning is used to categorize that particularly indicator. The classification is evaluated comparing it with classifications made by two independent persons. After the classification in categories of DGBC Area the indicators were further grouped by formulating different themes per category. This is done in order to cluster the indicators and to structure the method.

Third, in the initial design the indicators are described more extensively, based on the explanations and clarification in the original sources. That is, relevant information concerning the proposed method and aspects that define the scope and objective of the indicator are incorporated in the formulation.

The above formulated preceding design steps and the resulting initial design together form an answer to research sub question 3: How can the design requirements from literature and practice be combined in an initial design for an assessment method? The initial design of the assessment method is presented in Appendix 8A.III.I.

5.2 INITIAL DESIGN EVALUATION

The initial design is evaluated in interviews with experts on different fields of sustainability. In this paragraph first the selection of experts is presented, including the formulation of criteria used for this selection. Next, the results of the evaluation of the initial design are reported.

5.2.1 SELECTION OF EXPERTS

The selection of experts is based on the structure of DGBC Area, as for each of the categories one interview with an expert took place. Moreover, two additional interviews are conducted with persons who have a more general expertise in sustainability, consequently all indicators of all categories were discussed with them. The experts were selected based on (i) publically known expertise, (ii) specialism in a particular category, (iii) availability and (iv) relation with the DGBC. Table 5.1 represents a list of the interviewed experts, their function, organization and specialism. More information about the specific expertise of the interviewees can be found in the job descriptions in Appendix IV.

Table 5.1 – List of the selected experts, their functions, organizations and specialisms.

Nr.	Function	Organization	Specialism
E.1	Advisor Environment and Ecology	Rijkswaterstaat Dienst Infrastructuur	General
E.2	Manager Sustainability	Bouwend Nederland	General
E.3	Program Manager	Senter Novem – Programma Energiebesparing GWW	Energy
E.4	Expert Urban Water Management	Tauw	Water
E.5	Prof. Materials and Sustainability Managing Director	TU Delft Nederlands Instituut voor Bouwbiologie en Ecologie	Materials
E.6	Key Account Manager Benelux	Van Gansewinkel Groep	Waste
E.7	Consultant Mobility & Logistics	TNO Mobiliteit	Transport
E.8	Managing Director	ES Consulting	Climate

5.2.2 RESULTS

The main results of the interviews with experts are remarks on the measures proposed in the initial design and suggestions for new ones. Besides, the experts appointed critical indicators and gave their view on possible strategies to increase innovation potential in the assessment method. A report of each of the interviews is given in Appendix IV, all remarks and suggestions made by the individual experts are listed in this appendix as well.

REMARKS

The first main data obtained in the interviews are remarks on the measures. Based on the remarks the (C) consequences for the measures in the initial design can be to (R) remove directly, (O) remove because of overlap or (A) adjust. All remarks and consequences are listed in the interview reports in Appendix IV. For each indicator of the initial design the considerations are summarized and clustered in Appendix 8A.III.II. These considerations contain a summary of the remarks of the exerts and, if appropriate, concluding consequences for this study. The final consequence is assigned based on the considerations and may vary from the consequence formulated by independent experts, since their opinions may differ. Based on the remarks 34 indicators are removed from the initial design directly and 27 indicators are merged or removed because of overlap.

SUGGESTIONS

The second main category of results are suggestions for new measures. Some interviewees suggested another way of measuring a certain theme than was proposed in the initial design. Other noticed that certain aspects of infrastructure sustainability were lacking in the initial design. All suggestions are listed in the interview reports in Appendix A.IV. Some of these suggestions are outside the scope of this study and therefore not included in the concept design. The considerations regarding the selection of the suggestions are summarized in Appendix 8A.III.III. Other suggestions are merged and formulated in new indications based on fit with the design requirements. The results of the suggested measures are listed in Table 5.2, a reference number to the concept design (CD) is included.

Table 5.2 - Suggestions from experts during evaluation of the initial design.

Nr.	Theme	Suggestion of measure	CD
SI.1	Waste facilities	Facilities for collection of public waste (not bounded to households or industry).	10
SI.2	Transport system flexibility	Relativity in intensity and capacity of roads to measure if new solutions like dynamic traffic lanes are practiced.	19
SI.3	Storm water capacity	Surface of paved or build-on land that can be used occasionally as storm water capacity is seen as open water.	26
SI.4	Water quality	Assume that a profound study on water quality in the design stage delivers a sustainable solution.	27
SI.5	Water treatment	Local treatment and infiltration of waste water and runoff.	28
SI.6	Neutralisation	Use planting structure as a technique to neutralize negative impacts on climate in the area.	35

Critical indicators

Besides remarks and suggestion, the experts appointed indicators than can be regarded as critical for the assessment method, reflecting the essence of a certain environmental aspect. The experts appointed these critical indicators for their own category of specialism. The references for the critical indicators are listed in Table 5.3 – List of appointed critical indicators. It should be noticed that the experts consider these appointed indicators critical, assuming their remarks and suggestions on the indicators are incorporated in a new formulation. For this reason, Table 5.3 represents a reference to the critical indicators in both the initial and concept design.

Table 5.3 – List of appointed critical indicators.

Category	Energy	Water	Materials	Waste	Transport	Flora & Fauna	Climate
Reference ID	ID.2 ID.3	ID.5	ID.17	ID.30	ID.42 ID.59	ID.68 SI.3	SI.6
Reference CD	CD.1 CD.2	CD.4	CD.6	CD.9	CD.13 CD.14	CD.25 CD.28	CD.35

Innovation strategies

The experts gave their opinion on possible strategies, that can be implemented specifically in the assessment method for infrastructure sustainability, to increase the potential for innovation practices. This paragraph summarizes their general considerations on this issue and presents a rephrased formulation of three different suggested strategies. The specific suggestions of each of the experts are reported in Appendix IV.

First of all, most of the experts recognized the relevance of the issue and confirmed that application of assessment methods might influence the application of innovative solutions or strategies that exceed standard requirements. Several experts noted that this is an inevitable consequence of developing models, since these tend to give a simplified representation of (a part of) reality. It is however stressed that one should accept the limitations and try to convert these in positive effects. To do so, in the specific case of an assessment method, it is necessary to adapt an open option approach and incorporate as much flexibility in the method as possible. The purpose of increasing flexibility is to stimulate designers, instead of remaining within the limits, to reach for and beyond the edge of standards.

Based on the interviews, three different strategies for increasing innovation potential can be formulated. These are:

1. FLEXIBILITY IN INDICATOR AND CRITERIA FORMULATION. The central purpose of this strategy is to avoid rigid formulation of indicators and criteria. Rigid formulations prescribe, for example, specific techniques, systems or materials and validation is based on the presence or absence of these specific observable design features. Instead, flexible formulations assess the ability of the techniques, systems or materials to meet or exceed specified performance thresholds. This performance can either be tested when the system is in use, or be predicted beforehand using models and calculation instruments.
2. SEPARATE ASSESSMENT OF INNOVATION. This strategy affects the structure of the certificate, since it proposes to create a separate category for innovation assessment. Innovative processes or technical solutions exceeding standard criteria in the method can be appraised in this category. If appropriate, a neutral commission of experts can be used to assess the innovations on sustainability and to formulate new criteria. Using the weight system of the methodology, designers can be stimulated to innovate additionally, making the category a relevant part of overall assessment.
3. INCENTIVES ON CRITICAL ENVIRONMENTAL ASPECTS. In this strategy designers are encouraged to exceed the standard requirements of the assessment method, specifically on the critical environmental aspects. Since the critical indicators reflect the essence of sustainability on certain environmental aspects, it is desirable to innovate on these aspects specifically. A premise for this strategy is that critical indicators and criteria are formulated flexible (see strategy 1). The incentives can be allocated using the weight system of DGBC Area or by awarding additional credits for innovation in each of the criteria for critical aspects.

5.3 FROM INITIAL TO CONCEPT DESIGN

Based on the evaluation the initial design is revised. Some measures are removed, other merged and new measures included. An overview of the final considerations for the revision of the initial design is presented in Table 5.4. These considerations refer to the initial design matrices in Appendix III and the interview reports in Appendix IV.

Table 5.4 - Considerations for revision of the initial design.

Category	Summary of design considerations
Energy	Energy consumption is starting point of the calculation for energy performance which is considered to be a critical indication. The EPL as methodology for the calculation is made explicit and the indication remains separated in two parts (CD.1 and CD.2), to stimulate initiatives on both fields. An additional measure for public lighting is still included (CD.3), because this aspect comprises the biggest potential for energy reduction in infrastructure.
Water	Indications for water use and reuse are joined in a single indicator that assesses the systems efficiency. This critical indicator (CD.4) implicitly includes reduction of the need for water, reuse of water and local collection of water. Local treatment of waste water is possible, however efficiency is doubted. It is reflected in an indication for use of chemicals (CD.5), because this is related to the applied treatment technique. Emission and contamination is in the scope of this study only related to surface water runoff and therefore reflected in CD.32.
Materials	The environmental cost indication (CD.6) is regarded the most valuable and mature methodology for material sustainability assessment. It includes several other proposed indications of the initial design and is preferred to the relative classification of low environmental impact. Reuse of moulds is too specific and reuse of soil is guarded in Dutch construction law. Reuse of aggregates is common practice in civil engineering sector. Only the percentage of reused and recycled materials that can be ascertained in the design stage is assessed (CD.7), the potential for reuse and recycling in the future is not. Origin of materials (CD.8) is regarded relevant and can be assessed with demonstrable certificates.
Waste	Waste production is only measurable in realization stage, therefore included in CD.11. Organic residuals are reused more efficiently if collected centrally. Facilities for separated storage are becoming a central theme in waste management (CD.9) and is therefore regarded critical. Residuals separated during construction will consequently be recycled or reused (CD.12). Planning of routes for waste transport is common practice. An indication for collection of public waste is added (CD.10).
Spatial	Both indications are relevant, but repositioned in category transport in CD.19 and CD.20 (as all other

Category	Summary of design considerations
Development	indicators are in sub categories too). Floor space index as reference is removed, because infrastructural use of land is standard aspect of this index.
Transport	Mobility is the covering aspect of this category, the performance of transport, but should not be measured directly. Stimulating cleaner transport modalities (CD.14) and pedestrian and cyclist traffic (CD.15 and CD.16) should be the central aspects of sustainability assessment. Emission and energy consumption (CD.13) of traffic are directly linked to mobility and in addition give an indication of the extend of clean modality use. Traffic information is not regarded as relevant by experts. Several indicators for safety are standard procedure in Dutch context, but assessment of extra initiatives remains relevant (CD.17). Stimulation of restricted traffic areas (CD.18) is however an indication related to safety and emission, that is not incorporated in the standard planning procedures. A suggested indication for flexible use of land is added to the index (CD.19).
Flora & Fauna	The indications for flora and fauna are joined in assessment of a study for preservation of local valuable ecological elements (CD.21). The indications for felled trees, biodiversity and green areas are slightly adjusted (CD.22, CD.23 and CD.24). Protected areas are covered in the indication for location choice (CD.20). Storm water management is related to the extent of open water (CD.26), covering several indicators from the initial design. Indications for water quality (CD.27) and local treatment and drainage (CD.28) are added.
Climate	The indications for emissions are adjusted to incorporate the capacity for absorption (CD.29 and CD.30). The indications for noise, smell and light are adjusted to harmonize in the proposed method of measurement (CD.31, CD.33 and CD.34). The indication for treatment of surface water runoff (CD.32) is adjusted to make assessment of specific practices possible. Heating of the area can be prevented with planting structures (CD.35), but the indication is extended for all negative impacts.
Management	All indications of the category management are removed from the assessment method, or overlapping indications in other categories. The argument to remove the category is twofold. First, some indications are relevant for sustainable development, but need to be expanded with much more indications for a solid reflection of the aspects. Second, some indications are near the edge of the specific scope of infrastructure sustainability in this study.

The result of the revision is the concept design, which is the basis for the practical evaluation. The revision of the initial design thus answered research sub question 4: How can an evaluation of the initial design by experts be used in a concept design for an assessment method? The concept design is presented in Appendix 8A.VI.I.

5.4 CONCEPT DESIGN EVALUATION

The concept design is evaluated in interviews with practitioners from a specific case of an area development project. In this paragraph first the selection of the case and the practitioners is presented, including the formulation of criteria used for this selection. Next, the results of the evaluation of the concept design are reported.

5.4.1 CASE SELECTION

The case that is subject for the practical evaluation should be an area development project that is suited to test the concept design on. For selection the following criteria are used: the case should (i) be at least in a definitive design phase, (ii) have a clear formulated sustainability ambition and (iii) be more than standard with respect to infrastructure elements.

The selected case is Eeserwold, an area development project in the Dutch municipality Steenwijk. Eeserwold is the name of a complete new area that will be realized, containing an industrial and a housing zone. The design and planning of the area development are almost finished and the zoning scheme is already ratified. In general the developers have declared sustainability and quality as two keywords that are central in the development. A more extensive description of the selected case can be found in 8Appendix V.

Using the proposed designs for the technical infrastructure elements of the industrial zone of project Eeserwold as an example, the concept design is evaluated in interviews with key figurants of the development. Three main parties are involved in the design phase of Eeserwold: the municipality Steenwijkerland, the planning department of construction company Roelofs and real estate developer Geveke. The latter is not invited for an interview because this company is only involved for realizing and selling the private housing part of the development. Table 5.5 represents a list of the interviewed persons involved in the area development, their functions and organizations.

Table 5.5 - List of the selected practitioners, their functions and organizations.

Nr.	Function	Organization
P.1	Project Manager Spatial and Economic Development	Gemeente Steenwijkerland
P.2	Project Manager Public Works	Gemeente Steenwijkerland
P.3	Project Manager Planning Development	Roelofs Planontwikkeling

5.4.2 Results

The results of the practical evaluation are clustered in different categories. Specifically with respect to the Eeserwold case it became clear that infrastructure sustainability practices were reflected in the concept design. Besides, some general remarks on the measures proposed in the concept design can be formulated. The practitioners also suggested several new measures for infrastructural elements that are lacking in the concept design.

Reflection of sustainable infrastructure practices

Eeserwold is selected as case for its application of several infrastructure elements that can be characterized as representing more than standard practices in sustainability terminology. In the extensive case description in Appendix V these specific examples of infrastructure sustainability are described in detail. During the interviews reflection of these aspects in the concept design is evaluated. Table 5.6 gives a short description of the aspects and summarizes the views of the practitioners on the reflection in the concept design.

Table 5.6 - Reflection of sustainable infrastructure practices in concept design.

Sustainable practice	Reflection
Lake Cooling System	A system is developed to use cold water from Eeser Lake to cool the buildings of the area. The advantages of this system are reflected in the indications for energy performance.
LED public lighting	In Eeserwold LED technique will be applied for public lighting. As LED is an energy efficient lighting technique this is reflected in the indications for energy performance and besides in the indication for public lighting.
Accessibility	The area is situated near several public transport facilities. The practitioners are convinced this is reflected in the concept design. However, it is noted that project developers have little impact on the availability of the facilities.
Glass fibre connection	For communication the area is provided with a glass fibre connection. The concept design lacks any indication for communication infrastructure.
Park management	A park management organization is established for maintenance of Eeserwold. Such practices for maintenance management initiated in the design stage are not reflected in the assessment method.
Low density	The ambition is to realize a low building density and a lot of green planting in the development. This is not directly reflected in the assessment method. The formulation of the indication for green areas should be reformulated.

Remarks

Besides reflection on specific sustainability practices, the case managers also reflected the concept design more generally. The remarks are listed in the reports of the interviews in Appendix VII. In Appendix 8A.VI.II the remarks are clustered and summarized, and a final consequence is formulated. Based on the remarks three indications are removed from the concept design directly.

Suggestions

Since the interviewees were asked to evaluate the completeness of the concept design, they also suggested some relevant aspects of infrastructure sustainability that are not reflected in the concept design. A complete list of these suggested elements is presented in Table 5.7. However, none of these suggestions are used in the proposed design, since they exceed the scope of the assessment method or are overlapping existing indicators. See for a specific formulation of the underlying considerations Appendix 8A.VI.III.

Table 5.7 - Suggestions from practitioners during evaluation of the concept design.

Nr.	Theme	Description of missing element
SP.1	Maintenance management	Planning and establishment in design stage of a management organization for maintenance during operation.
SP.2	Land use flexibility	Multifunctional use of elements of the areas infrastructure.
SP.3	Communication infrastructure	Planning for installation of state of the art communication infrastructure facilities.
SP.4	Violence safety	Realization of infrastructural facilities to prevent violence and crime in the area.

EVALUATION INNOVATION STRATEGIES

The practitioners recognize the issue of possible restriction of innovation when designers use assessment methods as a design guideline. In some cases this is a well considered and deliberate approach in planning and design. For example, at Roelofs Planontwikkeling they have developed their own design guideline, based on the criteria that are set in multiple sustainability regulations and certificates. Their ambition is to go further than these standard requirements in their own projects. In such cases the issue is therefore not seen as a limitation for innovation, but a guarantee for minimal sustainability performance.

The practitioners confirmed the relevancy of the strategies suggested by the experts. Some of the technical innovations applied at Eeserwold are discussed, but the practitioners could not imagine possible limitations for these innovations related to the different strategies. Moreover, the little number of interviewed practitioners, and their limited affinity with the innovation processes of the specific examples at Eeserwold, makes it impossible to formulate valid consequences regarding the suggested strategies.

5.5 FROM CONCEPT TO PROPOSED DESIGN

Based on the remarks on the indicators and suggestions of missing infrastructural elements the concept design is adjusted. Some measures are removed and other are adjusted in formulation. An overview of the final considerations for the revision of the concept design is presented in Table 5.8. These considerations refer to the concept design matrices in Appendix VI and the practitioner interview reports in Appendix VII.

Table 5.8 - Considerations for revision of the concept design

Category	Summary of considerations
Energy	In the indications related to EPL methodology (FD.1 and FD.2) the impact of applied infrastructure systems is made explicit, instead of just asking if infrastructure facilities are part of the calculation. The indication for efficient public lighting (FD.3) is extended with expected reduction in energy usage.
Water	The formulation of the indication for water need in the concept design is extending the scope of the assessment method, for it is an indication for the integral area development. This indication is adjusted to make the impact of infrastructural systems on the water need explicit (FD.4). Indication FD.5 is only adjusted in formulation.
Materials	There are no remarks on the indications for material choice and reuse, these are slightly adjusted in formulation (FD.6 and FD.7). The measure for origin of materials is removed from the method, because according to the practitioners origin of all materials is always demonstrable.
Waste	Facilities for separated collection of waste (FD.8) and for public waste (FD.9) are regarded essential, the indications are slightly changed in formulation. This is also valid for waste minimization (FD.10). Separation of waste on construction site, is adjusted towards measurement of the intended goal of this indication: the extent of reuse and recycling of residuals (FD.11). The dimension locally is added to this indication, to stimulate reuse and recycling of residuals of the construction process on site.
Transport	Indications for transport are not adjusted much, they turned out clear on interpretation, however some are slightly changed in formulation. The indications to assess 'more than standard' facilities or practices are removed from the method. First, these indications are too subjective, and second, such indications can be formulated for all relevant themes.
Flora & Fauna	According to the practitioners, indications in this category are to some extent part of standard planning procedures, this needs to be noticed when formulating norms for the criteria. Moreover, planning for preservation of trees is overlapping with the ecological study (FD.18). Green areas are considered

Category	Summary of considerations
	outside the scope of infrastructure. The assessment of biodiversity is reformulated to measure efficiency of the proposed measures (FD.19). The indications for water management are only adjusted in formulation.
Climate	The only remark of the practitioners is to make sure assessment exceeds standard regulations and norms. Moreover, in line with FD.19, the indications for noise, smell and light (FD.25, FD.27 and FD.28) are adjusted to assess efficiency of initiated practices. Further, the indications for emission of greenhouse gasses and fine dust (FD.24) are joined.

The result of this revision is the proposed design, which is the central result of this study. The evaluation and revision of the concept design answered research sub question 5: How can an evaluation of the concept design by practitioners be used in a proposed design for an assessment method? The proposed design is presented and clarified in more detail in chapter 6.

6 INFRASTRUCTURE SUSTAINABILITY ASSESSMENT METHOD

The in this study proposed design of an Infrastructure Sustainability Assessment Method (ISAM) is presented In this chapter. General characteristics of the assessment method, related to the design requirements, are described first. Next, the actual proposed design is presented and clarified in detail for each category. The suggested strategies to improve innovation potential in the method are then applied in relation to the structure of the design. Finally, several aspects of the design are discussed in the last paragraph.

6.1 CHARACTERISTICS

In the here proposed assessment method, the design requirements related to scope (paragraph 3.1.3) are fulfilled. The central purpose of ISAM is to provide a comprehensive assessment of the environmental characteristics of infrastructure. The scope of infrastructure is, for this method, limited to physical, technical infrastructure facilities as part of integral area developments. The indicators in ISAM differ in intended purpose, related to the conceptualization of infrastructure sustainability (section 3.2.34). That is, indicators can measure either the stresses caused by infrastructure development processes, the condition of the natural environment or the efficiency of response strategies on reducing natural impact or increasing societal satisfaction.

The structure of ISAM makes it possible to use it as part of the certificate for sustainable are developments, DGBC Area (paragraph 4.2.4). The intended users of the method are BREEAM Experts, educated and certified assessment professionals. With respect to different development stages of area development projects, ISAM is intended to be applied in the planning stage, whereas the indicators measure estimated performance on environmental aspects in the realization and operation stage. Besides, in ISAM it is possible to assess infrastructure systems of different area typologies. Not all indicators of the method are applicable to all types of area development projects.

6.2 PROPOSED DESIGN

This environmental assessment method is originally based on indicators proposed in scientific literature and on indicators used in existing instruments. An initial and concept design based on these indicators is evaluated by experts and practitioners. The here presented design is a result of the revision based on these evaluations. The presentation of the proposed design in this section is clustered following the categories of the assessment method. The proposed design is also presented in total in an external appendix (in Dutch).

Structure of the Design Matrices

ISAM consists of eight categories, in which thirty indicators are further clustered in seventeen themes. For each category of ISAM the measures are listed in a matrix, and provided with a proposed design number (PD). The indicators in the categories are further clustered in themes to improve the overview of the assessment method. A description of the indication is given in which a formulation of the objective and proposed method for measurement is included. If appropriate, the table shows insight in indicators that are regarded as critical (CI) for the design. Further, some indicators are only applicable to either the realization (R) or the operation (O) phase of an area development. Moreover, the design differentiates on area types non-urban (N), urban (U), urban border (B) and industrial zone (I). Finally, the relation of the measures to the distinguished levels (1, 2 and 3) of the conceptualization of sustainable infrastructure is made visible.

Besides the presentation of the measures in a table, a clarification is given for each category. This clarification describes the measures in more detail and gives insight in mutual relations between measures. It also details the proposed method of measurement and the minimal information required for assessment. In some cases specific examples of sustainable practices are presented to illustrate the indicators (examples mainly based on Senter Novem, 2008c).

6.2.1 Energy

The application of efficient infrastructural systems improves the energy performance of an area. It can reduce the need for energy or increase the contribution of renewable energy sources. The measures for infrastructure sustainability on the category energy are presented in Table 6.1.

The instrument EPL provides a methodology to calculate the reduction on fossil fuels for an area. In this calculation the energy performance of the location is reflected on a reference project and scaled in a ten point range. The EPL score can be increased in two ways: (PD.1) either reduce the need for energy or (PD.2) use more renewable energy. In ISAM this is reflected in the first two indicators, which are regarded as critical for this category. A prerequisite for adequate application of these measures is that all infrastructure elements that use or generate energy are incorporated in the EPL calculation (which is not standard procedure). Together, measures PD.1 and PD.2 will give insight in the improvement of energy performance of the area due to application of efficient infrastructure systems. Users of ISAM will need insight in the energy consumption of the planned infrastructure facilities and in the ratio between different (fossil and renewable) energy sources for the area.

(PD.3) Since several experts stressed the high energy reduction potential of public lighting, a separate indication is included in ISAM. Although the efficiency of public lighting will also be reflected in the EPL score, a separate indication will stimulate initiatives on the application of new techniques. The measure will assess on technical characteristics of the planned public lighting systems in criteria for power, energy consumption, automatic management systems and others.

Table 6.1 - ISAM on Energy.

Category Energy			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.1	Energy performance	Extent of energy need reduction for infrastructure facilities in proportion to standards as calculated with EPL methodology	CI		✓	✓	✓	✓	✓	✓		
PD.2		Extent of renewable energy generated by infrastructural systems in proportion to total	CI		✓	✓	✓	✓	✓			✓
PD.3	Public lighting	Extent of achieved energy reduction on public lighting			✓	✓	✓	✓	✓	✓		

6.2.2 WATER

This category is only concerned with water as source in the area, the scope is restricted to (potable) water supply. The method assesses the performance of applied infrastructural systems on water need reduction and local treatment. Open water, decoupled rain water and filtered waste water for drainage are included in the categories Flora and Fauna and Climate. The measures for infrastructure sustainability on the category water are presented in Table 6.2.

(PD.4) The total water need of the area reflects the extent to which the area is not self-supporting in water supply, it thus reflects the quantity of purified water that needs to be imported from outside the boundaries of the area. The water need can be reduced by application of efficient systems, local water collection and reuse. The critical indicator measures the extent to which application of sustainable infrastructural techniques contribute to this reduction. Examples of such techniques are systems for leak detection, water collection and the use of gray water for irrigation. Users need to have insight in the efficiency or capacity of the planned systems for assessment.

(PD.5) Local treatment of waste water is possible and reduces the stresses for transport to central treatment facilities. The purified water can either be drained locally or (re)used for purposes such as irrigation. In the indication the extend and use of chemicals is explicitly included to stimulate the application of more sustainable techniques. The use of chemicals is directly related to different water treatment techniques and therefore a proper foundation for formulation of criteria. Insight in the intended treatment technique is required for measurement of this aspect.

Table 6.2 - ISAM on Water.

Category Water			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.4	Water need	Extent of total water need reduction due to application of specific techniques or systems	CI	✓	✓	✓	✓	✓	✓			✓
PD.5	Local treatment	Extend and use of chemicals for local (waste) water treatment			✓	✓	✓	✓	✓			✓

6.2.3 MATERIALS

Sustainable use of materials is related to the choice between materials with different environmental effects and the possibilities for reuse or recycling of materials. The measures for infrastructure sustainability on the category materials are presented in Table 6.3.

(PD.6) The environmental cost indicator (in Dutch: Milieu Kosten Indicator (MKI)) provides a mature methodology for assessment of sustainability of materials. In this methodology, effects of materials on environmental aspects, such as emission, embedded energy consumption and nuisance, are expressed in an economical value based on lifecycle analysis. The method is broadly accepted and applied and several instruments are developed to calculate the shadow price based on extensive databases that contain characteristics of materials (such as DuboCalc). Since the indicator assesses the improvement in environmental cost as a critical indicator, users are stimulated to choose for more sustainable materials. Users of ISAM will need insight in the type and quantity of materials for the assessment.

(PD.7) Besides, application of reused and recycled materials in realization stage is stimulated in PD.7. The scope of the indicator is explicitly restricted to the extent of reuse of materials during construction, since this weight percentage can be ascertained in planning stage. In contrast, the potential of a design for actual reuse of materials after demolition cannot be calculated with enough certainty in planning stage. Again, users will need to have insight in the type and quantity of materials to be able to calculate the weight percentage for reuse.

Table 6.3 - ISAM on Materials.

Category Materials			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.6	Material choice	Percentage improvement of environmental cost (shadow price) due to material use in proportion to a reference situation	CI	✓	✓	✓	✓	✓	✓		✓	
PD.7	Material reuse	Ascertained weight percentage of reuse and recycling of materials in proportion to total use of materials		✓		✓	✓	✓	✓			✓

6.2.4 RESIDUALS

In ISAM the title of the category waste is changed in residuals, since this better reflects the intention of the indicators to stimulate (re)use of waste as a resource for raw materials or energy. Indicators in this category are related to the physical facilities for waste collection during operation and to waste management during realization. The measures for infrastructure sustainability on the category residuals are presented in Table 6.4.

The physical facilities for waste collection in the area can be characterized as infrastructure by definition. (PD.8) Separation at the source is a prerequisite for efficient processing of waste in resources, hence provision of facilities for separate collection of waste is regarded a critical indication. Centralization of these facilities within the boundaries of the area (and within the regulations for maximal distances) reduces the cost for transport. (PD.9) Besides, the area needs to provide facilities for collection of waste that is not produced in households or industry. For assessment with ISAM, users need insight in the type of facilities that will be realized and in the spatial planning.

(PD.10) Regarding waste management during realization, contractors are stimulated to minimize waste production. The estimated waste production can be reflected to average numbers in the criteria. The objective of PD.11 is to stimulate contractors to separate their waste and use residuals in the same project again. This is for example possible with rubble that can be used as granulate for foundation of roads. The indication thus is an extension of PD.7, as the locally applied portion (PD.11) of the total reused or recycled materials (PD.7) is measured. Users will need to calculate the potential for local reuse of materials in their specific area development and intend to optimally use this potential.

Table 6.4 - ISAM on Residuals.

Category Residuals			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.8	Collection	Provision of central facilities for separate collection of (recyclable) waste	CI		✓	✓	✓	✓	✓			✓
PD.9		Provision of facilities for collection of public waste			✓	✓	✓	✓	✓	✓		
PD.10	Minimization	Percentage of achieved waste minimization during realization in proportion to average waste production numbers		✓		✓	✓	✓	✓		✓	
PD.11		Extent of locally applied reused or recycled residuals		✓		✓	✓	✓	✓			✓

6.2.5 TRANSPORT

A well-considered planning of an area development can contribute to the use of cleaner transport modalities. The quality of facilities for public transport and practices for the slow traffic group need to be assessed. Besides, assessment of the spatial aspect is relevant in this category, because of the big impact of transport infrastructure on land use. The measures for infrastructure sustainability on the category transport are presented in Table 6.5.

A general indication for the performance of transport infrastructure is mobility. Since it is also possible to stimulate mobility in ways that are not regarded as sustainable, this indication is not directly included in ISAM. Instead, several measures are included to assess the potential of the area to stimulate the choice for cleaner and efficient transport modalities. (PD.12) A broad range of planning practices can contribute to the reduction of energy consumption and related CO_2 emission by traffic. Application of the instrument VPL-Kiss provides an easy methodology for calculation of the energy reduction based on data of population characteristics, social and market infrastructure facilities and spatial planning of road networks. (PD.13) Public transport is seen as the modality with the highest potential for energy reduction without decreasing mobility. To stimulate people to use it, quality of public transport should be high. Assessment of this quality based on public transport schedules and bus routes is a often applied methodology.

Stimulation of pedestrian and cyclist traffic does not only reduce energy consumption, but increases public health as well. In Dutch context, the standards on sustainability aspects on this topic are high, due to the implementation of regulations in planning procedures (such as, in Dutch, Duurzaam Veilig Verkeer). However, the importance of two additional indicators, that exceed common practices, is stressed in this study. (PD.14) The morphology of the area (the situation of blocks, roads and buildings) is assessed in a measure for reduction of barriers. (PD.15) Areas with a restriction for motorized traffic increase safety for the slow traffic groups (and besides reduce energy consumption and emission). Insight in the spatial planning of all roads and road categories is required for assessment.

Of all domains of technical infrastructure, transport facilities have the biggest impact on land use. Since transport is a sub category of spatial development in DGBC Area structure, indications on this aspect are included here. (PD.16) Flexible use of road infrastructure is a measure for the efficiency of land use. Well known applications are rush-hour lanes, multifunctional use of parking areas and others. Users will need to know what part of the total planned infrastructure can be used for multiple purposes. (PD.17)In the choice of locations for development of infrastructure facilities the impact on natural and ecological values should be leading. A classification in land use can be based on the actual presence of natural and ecological values on a specific location or other characteristics, such as the land being contaminated or used before. Again, insight in the surface percentage is needed for assessment.

Table 6.5 - ISAM on Transport.

Category Transport			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.12	Mobility	Energy consumption and related CO_2 emission due to traffic based on VPL-Kiss calculation	CI		✓		✓	✓		✓		
PD.13		Quality public transport based on average distance to stops or stations, capacity and frequency	CI		✓	✓	✓	✓	✓			✓
PD.14	Pedestrians & cyclists	Reduction of barriers based on ratio of travel distance compared to shortest connection			✓	✓	✓	✓	✓			✓
PD.15		Surface percentage of restricted motorized traffic areas without reducing accessibility			✓	✓	✓	✓	✓			✓
PD.16	Land use	Surface percentage of flexible used (road) infrastructure			✓	✓	✓	✓	✓			✓
PD.17		Surface percentage use of locations with minimal impact on ecological and natural value			✓	✓	✓	✓	✓			✓

6.2.6 Flora & Fauna

Flora and fauna is mutually related to the built environment. There are opportunities to increase both the quality of nature and the physical infrastructure facilities in an area development. The measures for infrastructure sustainability on the category flora and fauna are presented in Table 6.6.

(PD.18) Preceding to the development a study needs to be carried out to specify the valuable ecological elements of the area and to plan for preservation in construction and harmonization in operation stage. This study needs to be executed in cooperation with a local environmental organization to increase its effectiveness. Contracts and the results of the study are required for the assessment. (PD.19) In Dutch context, the preservation of a high biodiversity is a central aspect in national policies. ISAM therefore additionally measures the estimated efficiency of the initiated preservation and harmonization practices on biodiversity.

The integration of the regulative, ecological and recreational function of open and rain water in urban water management is a complex matter and highly dependent on local characteristics. ISAM assesses several of the central aspects. (PD.20) There are numerous techniques and best practices for uncoupling rain water from sewage systems. In ISAM the most qualifying parameter for the assessment of the performance of these practices included, the percentage of uncoupled surface. (PD.21) Surface of open water is a measure for storm water storage capacity. Specific public spaces in the area can be appointed to serve occasionally as overflow for water storage. (PD.22) Application of infrastructural techniques or systems to stimulate water quality is dependent on numerous local characteristics, therefore in ISAM it is assumed that a preceding study will provide in an optimal set of specific measures. (PD.23) The relevance of practices for local treatment and drainage of waste water is stressed several times in the interviews. Local treatment of waste water reduces stresses on central treatment facilities (see also PD.5 and PD.28) and can be used to increase open water quality (see also PD.22). Infiltration reduces the cost for transport and prevents dehydration of soil. In this category, ISAM measures the estimated efficiency of the systems in proportion to the total amount of waste water.

Table 6.6 - ISAM on Flora & Fauna.

Category Flora & Fauna			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.18	Ecological value	Study existing relevant ecological elements and formulate measures for preservation in construction and harmonization in operation stage		✓	✓	✓	✓	✓	✓			✓
PD.19		Calculated efficiency of initiated practices for biodiversity preservation		✓	✓	✓	✓	✓	✓			✓
PD.20	Water management	Percentage of not paved surface and paved surface uncoupled from central sewage system	CI		✓	✓	✓	✓	✓	✓		
PD.21		Total surface of (occasionally) open water to store extreme precipitation			✓	✓	✓	✓	✓			✓
PD.22		Study local characteristics water system and formulate optimal set of measures to ensure water quality			✓	✓	✓	✓	✓			✓
PD.23		Percentage of (waste) water treated and drained locally	CI		✓	✓	✓	✓	✓			✓

6.2.7 CLIMATE

An area development does have several negative impacts on climate. In this category these impacts on local climate are clustered. The indicators however are not focused on measuring the negative impacts (stresses) but on the efficiency of practices to neutralize the impacts. The measures for infrastructure sustainability on the category climate are presented in Table 6.7.

(PD.24) Indications for CO_2 emission due to infrastructure development are in ISAM incorporated in different categories. Emission might be the consequence of energy consumption of installations or facilities (see PD.1 and PD.2), use of materials and construction process (see PD.6) or of traffic (see PD.12). However, in this category the efficiency of applied techniques for collection and storage of greenhouse gasses and fine dust is measured. (PD.25, PD.26 and PD.27) A broad range of sustainable practices can be applied to reduce nuisance due to the development of infrastructure, such as application of baffle boards to reduce for noise control. Initiated practices for noise, smell and light nuisance reduction will be assessed on calculated efficiency. For assessment of all indications of this theme, users need insight in calculated or estimated efficiency of the techniques planned for the area. In most cases these data will be available in mandatory reports as a standard part of planning procedures.

(PD.28) Realization of infrastructural elements may cause contamination of (ground) water, mainly due to runoff from roads and leaching materials. Although the indicators PD.22 and PD.23 assess the practices for treatment of the contaminated water, ISAM includes an additional indicator to assess the implementation of an optimal set of practices for prevention. (PD.29) Wind does have an impact on emission and smell and noise nuisance in an area. Based on this relation, planting structures can be used as a technical solution to neutralize the negative effects on these aspects. A study to specify the potential for neutralization using planting structures in a specific area is regarded a critical indication.

Table 6.7 - ISAM on Climate.

Category Climate			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.24	Nuisance reduction	Percentage storage of greenhouse gasses and fine dust emissions		✓	✓	✓	✓	✓	✓			✓
PD.25		Calculated efficiency of initiated practices for noise nuisance reduction		✓	✓	✓	✓	✓	✓			✓
PD.26		Calculated efficiency of initiated practices for smell nuisance reduction		✓	✓	✓	✓	✓	✓			✓
PD.27		Calculated efficiency of initiated practices for light nuisance reduction		✓	✓	✓	✓	✓	✓			✓
PD.28	Water contamination	Study local characteristics water system and formulate optimal set of measures to prevent contamination of (ground) water due to runoff		✓	✓	✓	✓	✓	✓			✓
PD.29	Neutralization	Study possibilities to neutralize negative impacts on micro climate using planting structures	CI		✓	✓	✓	✓	✓			✓

6.3 Strategies to Increase Innovation Potential in ISAM

Several strategies to improve the potential for innovation in an assessment method are suggested by experts and evaluated by practitioners in this study. This section clarifies how these strategies are implemented in ISAM. Besides, in paragraph 7.3, several recommendations are formulated for implementation of aspects of these strategies that exceed the scope of this study (for example related to the weight system formulation).

Indicator Flexibility

The first strategy is to avoid rigid formulation of indicators and criteria. This can be achieved when prescription of specific techniques or processes is prevented, and indicators instead assess the performance of the system being measured. Since ISAM is to be applied in the planning stage, users need to predict the potential performance of a design based on models or calculations.

As far as possible this strategy is applied to the formulation of all indicators in ISAM as presented in previous sections. Exceptions on this matter are discussed as a limitation on ISAM in paragraph 6.4. Flexible formulation of indicators and criteria allow the assessment of incremental environmental innovations (see section 3.2.3), since such innovations tend to improve the performance of existing technologies which are likely to be incorporated in ISAM on the moment of assessment already.

Separate Innovation Category

The second suggested strategy is to include a separate category for assessment of innovations. Innovative processes or technical solutions that are not reflected in or exceeding standard criteria of the method can be appraised in this category. This makes it possible to appraise both incremental and radical environmental innovations. For application of this strategy in ISAM, a separate category and an additional indicator is proposed as presented in Table 6.8 - ISAM on Innovation. Additionally, several general recommendations are formulated for this strategy in section 7.3.

The indicator for innovation (PD.30) is a level three measure, since technical or process innovations are most likely to be examples of sustainable response practices. Whether or not the indicator can be seen as critical, and the applicability on different phases and area types depends on the nature of the innovation. For assessment users need insight in the characteristics of the innovation in proportion to characteristics of comparable products or processes, the environmental aspects that are influenced by the innovation and an estimate of the performance of this impact.

Table 6.8 - ISAM on Innovation.

Category Innovation			CI	Phase		Area Type				Level		
Nr.	Theme	Description		R	O	N	U	B	I	1	2	3
PD.30	Innovation	Specify the intend of the proposed innovation, the characteristics of the product or process, the related environmental aspects and the estimated performance.	-	-	-	-	-	-	-			✓

Incentives on critical aspects

The third strategy is to stimulate designers to innovate on the specific criteria that are regarded as critical for the method. Incentives on the criteria of these critical indicators increases the ability of designers to innovate. A first prerequisite for adequate implementation of this strategy is a flexible formulation of the critical indicators (see strategy 1), to make assessment of innovations on these aspects possible. Besides, incentives need to be allocated using the weight system the criteria and weight system of the method to stimulate designers to innovate on these specific aspects.

Regarding the first prerequisite, the critical indicators are formulated flexible in ISAM. The implementation of incentives in the criteria and weight systems are exceeding the scope of this study. Recommendations on this matter are however formulated in paragraph 7.3.

6.4 Discussion and limitations of the proposed design

In this section limitations on several indicators in ISAM are discussed. The discussion of aspects of ISAM either is based on remarks from the evaluation phase, or can be interpreted as a personal evaluation of the proposed design. The discussion is clustered following ISAM categories:

- Energy. Assessment of public lighting efficiency in PD.3 is overlapping with measurement of energy performance in PD.1. Although inclusion of a separate indicator is justified considering the big potential for energy reduction, it is necessary to be aware of the overlap when formulating criteria for these indicators. Furthermore, flexible formulation of indicator PD.1 is limited since it prescribes the use of EPL methodology for calculation of energy performance in ISAM.
- Water. It might be useful to further divide the indicator for water need reduction (PD.4) in spate criteria for water collection, water reuse and efficient water use. Further, local treatment of waste water (PD.5) is regarded relevant by several experts, yet efficiency is doubted by several experts as well. If efficiency can be proved for a specific location, it is relevant to apply this measure since the benefits are obvious (reduces transport cost and energy consumption, increases reuse of gray water and reduces water need).
- Materials. Several experts and practitioners stressed the relevance of an indication for a closed soil balance for this category. However, in light of flexible formulation of indicators, such an indicator is too specific. Besides, the issue is also reflected in the indication for local reuse of residuals (PD.11).

- RESIDUALS. The relevance of an indication for public waste collection (PD.9) is favored by an expert and a practitioner, but also critically remarked by one practitioner. The indicator is however still incorporated in ISAM, as a majority of the interviewees agreed with its relevance. Validity of the aspect being as relevant as suggested is however doubted.
- TRANSPORT. The flexibility in formulation of indicator PD.12 is limited since it prescribes the use of VPL methodology for calculation of energy consumption by traffic. Furthermore, possible assessment of this critical indicator is to an high extent dependent on the type of area development, since VPL methodology is only applicable to urban areas. Another aspect for discussion is related to the two basic indicators for pedestrian and cyclist traffic that are left in the proposed design (PD.14 and PD.15). A lot more indicators on this topic were included in the initial design, but evaluation showed some were too specific and overlapping standard regulations in Dutch context (in Dutch: Duurzaam Veilig Verkeer). The two remaining indications in ISAM are exceeding the standard regulations and therefore relevant to assess. They are however a particular result of this study, it can be imagined other studies (based on other sources or instruments) will find other, or more, indications with the same intent.
- FLORA AND FAUNA. The indication for water quality (PD.22) is on advice of an expert formulated as in ISAM, referring to a study for an optimal set of measures for the specific situation of the area development. This is suggested since the application of facilities to increase water quality is complex to assess and highly dependent on local characteristics. An inevitable downside of such indicators that prescribe to conduct a study, is that these are to some extent subjective and relatively easy to fulfill.
- CLIMATE. Several indications in this category measure the estimated efficiency of initiated practices for reducing environmental stress (PD.24-PD.27). It might be difficult to formulate criteria, or standards for reference, for these indications, since they are dependent on local characteristics. Besides, indicator PD.28 is overlapping with PD.22, as they are both related to open water quality. However, PD.28 measures the planning of facilities to prevent contamination, whereas PD.22 is concerned with facilities to neutralize possible contamination and preserve water quality.

7 CONCLUSION, DISCUSSION AND RECOMMENDATIONS

In this chapter a conclusion is formulated to answer the central research question. Further, several aspects related to the methodology and scope of this study, as well as regarding the evaluation phases, are discussed. Finally, recommendations are formulated for further research and for implementation of ISAM.

7.1 CONCLUSION

The research objective of this study is to design and evaluate a method for assessment of infrastructure sustainability as part of the DGBC Area certificate. Requirements for this design are formulated based on scientific literature and analysis of DGBC Area and several existing practical instruments. An initial and concept design are evaluated with, respectively, experts in sustainability and practitioners of the Eeserwold case. Revision of the design based on the evaluations resulted in the proposed design for an Infrastructure Sustainability Assessment Method (ISAM), which is presented in chapter 6. This method contributes to the transition towards a sustainable construction industry, since it provides in a methodology to appraise sustainability in the planning and design of infrastructure facilities, whereas current research has mainly focused on such methods for buildings.

The central research question of this study is: How can infrastructure sustainability be assessed in DGBC Area? The answer to this question is: by implementing ISAM for sustainability assessment of technical infrastructure elements of area development projects in the DGBC Area certificate. ISAM is a comprehensive Infrastructure Sustainability Assessment Method that includes indicators on distinctly diverse environmental aspects. The method is intended to be used in the planning stage of development projects, to assess estimated environmental performance of design proposals in realization and operation stages. ISAM differentiates on eight categories, and the total of thirty indicators are clustered in seventeen themes within these categories. During evaluation of the initial design in this study, experts appointed several critical indications that reflect the essence of the corresponding environmental aspects. These are for example the extent to which infrastructure facilities contribute to the energy performance of an area and the amount of waste water that is treated and drained locally.

Two basic principles in the applied methodology and scope of this research are related to the ambition of the DGBC to harmonize with existing instruments and to increase potential for innovation in the DGBC Area certificate (see section 2.2). In this study the initial design of ISAM is based on indicators selected from eight existing instruments. Some of these indicators are overlapping with other indicators, and ultimately reformulated in a merged indicator for ISAM. However, in ISAM explicit harmonization with three existing instruments is suggested. These are EPL, VPL-Kiss and DuboCalc (the latter as a possible instrument to calculate shadow prices of materials in civil engineering context). Further, regarding the ambition to increase innovation potential, three strategies to structure the method have been developed and implemented in ISAM. These strategies comprise the performance based formulation of indicators, the set up of a separate category for assessment of innovation and the use of incentives to stimulate innovation on critical indicators.

7.2 DISCUSSION

In this paragraph several aspects of this research are discussed related to methodology, scope and evaluation of the initial and concept design. Specific aspects relating to indicators in ISAM are discussed in section 6.3.

METHODOLOGY

A basic assumption of the applied methodology in this study is to design a comprehensive assessment method, a method that concerns a broad range of environmental aspects instead of focusing on just one. Although this assumption is well considered and motivated, it does yield consequences for this studies reliability. This is due to the small group of experts and practitioners interviewed for the evaluation of the initial and concept design. Each category of the initial design is discussed with one expert, and in addition all indicators are in this phase evaluated with general experts. The concept design is discussed in total with three practitioners. Consequently, evaluation of indicators is in some cases based on just one remark or suggestion. This makes the result of this study, ISAM (including the suggested strategies for increasing innovation potential), a method that is to some extent less reliable. However, this aspect of discussion was already known beforehand and it has been a deliberate choice to continue anyway. Moreover, reliability and construct validity is on the other hand improved, since this study applied two separate synthesis-evaluation iterations (initial and concept design).

Although the experts and practitioners are asked to evaluate the completeness of the method, validity on this aspect is questionable. This is due to the basic principle to found the initial design on measures proposed in scientific literature and existing practical instruments. It is possible relevant indicators are lacking in these sources, and thus in the initial design, and the experts and practitioners did not suggest them as well. The sensitivity of ISAM on this issue is for example illustrated in the lack of indicators on the category management, and for assessment of infrastructural communication facilities.

SCOPE

Of all domains of technical infrastructure (see paragraph 3.1.1), communication is not explicitly incorporated in ISAM at all (this might be related to methodological aspects as discussed above). In the case evaluation it became clear that the planned application of a glass fiber connection cable was not reflected in the concept method (whereas this cable, in the view of the project organization, is a direct result of their formulated sustainability ambition). However, general aspects and characteristics of communication infrastructure elements are assessed in general indications such as energy performance and material choice. Moreover, one might argue sustainability is considered to be reflected in the implementation of state of the art techniques, as is most likely to be the case for communication facilities. On the other hand, other aspects, related to for example social or economical benefits, are clearly lacking in ISAM.

Green areas, planting structures and application of greenery in (or on) infrastructural objects are aspects discussed several times in interviews and analysis of practical instruments in this study. In principle however, these aspects are just outside the scope of the assessment method, since greenery and planting are not considered as elements of physical, technical infrastructure. On the contrary the close relation and, to some extent, overlap are obvious. Thus, in ISAM several indicators are related to greenery and planting, although this exceeds the scope of the method. On the other hand, the choice has been made to remove several other indicators that were more explicitly focused on these aspects, and less on infrastructure.

Evaluation

In the initial design several indicators related to the category management were included. Since the initial design is based on measures from literature and practical instruments, these aspects are thus regarded relevant in the original sources. However, the expert evaluation showed these specific proposed indicators are not considered relevant, overlapping with others or exceeding the scope of the method. Based on these results of the expert evaluation, the decision is made to exclude the category management in the concept design. Although this decision is valid for this research, it remains questionable, since a comprehensive method should also assess management aspects.

Multiple experts gave reasons to remove the indicators for local composting of organic waste. In their view, local composting is not considered to be efficient when compared to central composting or burning for energy generation. Besides, related to the indicators for travel information facilities, experts gave reasons to remove them as well. This is remarkable since all these indicators are selected for the initial design from both the instruments BREEAM-NL Nieuwbouw and BREEAM Communities. In other words, in BREEAM philosophy composting and travel information are considered to be relevant aspects in light of sustainable development. However, the choice made in this research to remove the indicators from the initial design, is founded on the opinion of multiple experts and thus regarded valid for ISAM.

7.3 Recommendations

It is recommended to expand and validate ISAM in further research. Besides, several recommendations are formulated regarding necessary steps for successful implementation of ISAM.

Further research

ISAM is a relevant supplement to existing instruments for assessment of sustainability of the built environment, since little tools and instruments are developed specifically for infrastructure systems. However, other studies are necessary to further develop ISAM. First of all, another study is recommended to increase reliability and validate ISAM. This can be done in a research with an higher number of respondents, both experts and practitioners, to increase reliability. It is also possible to expand this research with an analysis of applicability of practical instruments used in other countries and context to increase the possibility to generalize the method for other regions. Secondly, in this study the scope is restricted to infrastructure in the context of area development, but the method has potential to be used for sustainability appraisal in general infrastructure projects as well. This will make it possible to not only use ISAM as part of DGBC Area, but as an independent method for application in any setting. It is therefore relevant to study the necessary adjustments on ISAM when the scope of the method will be expanded.

Implementation

To realize a proper implementation and use of ISAM, recommendations are formulated on further necessary steps and actions to counterbalance scope limitations. Specifically, the recommendations are related to the formulation of criteria, the expansion of the scope of ISAM, the completeness of the method and the strategies for increasing innovation potential.

In ISAM indicators are identified to make it possible to assess sustainability of an infrastructure system on a certain point in time. To gain insight in the state of the system, criteria are necessary that represent the standards or norms. The formulation of these criteria is outside the scope of this research (see paragraph 3.2.34), but apparently very relevant for use of ISAM. Formulation of the criteria is the next necessary step for ISAM and this is for example possible surveying and collecting data that represent the baseline of what is considered sustainable. Further, several experts and practitioners mentioned the high standards in Dutch regulatory context on distinct environmental aspects. If standards are high in common practices, the criteria need to exceed these in order to be useful and to keep stimulating the industry to improve their practices.

Finally, it is recommended to accent the critical indicators amplified in this study in the weighting system of DGBC Area, since these represent the essence of the corresponding environmental aspects.

In implementation or use of ISAM it is important to consider the scope, assumptions and design requirements formulated for this research. For example, scope of ISAM is limited to technical infrastructure in area development context, ISAM is designed to be used as part of DGBC Area and the indicators in ISAM are intended to be used in the planning stage. Unless expanded in further research, ISAM is not intended to be used outside this scope.

Further, ISAM assesses the performance of the transport, water and waste domains of technical infrastructure (in for example PD.5, PD.8 and PD.13), but indications for performance of energy and communication facilities are lacking. This is a consequence of the applied methodology, since the initial design is based on existing measures and the experts did not suggest indicators for these aspects in the evaluation. Such indicators can for example assess the potential of energy facilities to reckon with expansion of the area development (and consequently an increase in energy need) or the potential of facilities for communication to adapt to changing needs in bandwidth. This issue is related to the absence of indicators for the category management, since the ability of the method to reckon with future developments can be assessed in indicators for this category. It is therefore recommended to verify the completeness of the method on these aspects and to synchronize this with such indicators for other elements of the area development (i.e. social and market infrastructure elements).

Finally, recommendations can be formulated for implementation of the, in this study, suggested strategies to improve the potential for innovation in the assessment method. First of all, in ISAM almost all indicators are formulated flexible in order to adopt an open option approach. This approach is recommended to adopt in DGBC Area as well, both in indications for technical infrastructure as well as for indicators used for assessment of other aspects. Secondly, as is applied in ISAM, it is recommended to incorporate a separate category for assessment of innovations, especially to make it possible to reckon with radical innovations. Assessment of aspects in this category can be performed by a neutral commission of experts that assigns credits in the first applicable case. Subsequently, this commission can (re)formulate indicators and criteria to make future assessment of the new techniques standard. Third, it is recommended to increase flexibility in the formulation of critical indicators as much as possible, and to allocate more weight to these indicators, in order to stimulate innovations on these aspects exceedingly.

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Appendix I – INDICATORS FROM SCIENTIFIC LITERATURE

The indicators proposed in scientific literature are presented in Table A I.1. This table reflects the title of the indicators, the original source, the selected indicators for the initial design and shows references to indicators in the initial design in which overlapping indicators are merged.

STRUCTURE OF THE MATRIX

In Table A I.1 each indicator is marked with a number, IL stands for Indicator from Literature. The title or description of the indicators is formulated exactly as in the original sources. These sources are:

1. Dasgupta & Tam (2005)
2. Sahely et al. (2005)
3. Ugwu and Haupt (2007)
4. Bourdeau & Nibel (2004)

The next column to the right contains a number if the indicator unfits with one of the following design requirements (see section 3.2.2):

- IR.1: Applicable. Clear, unambiguous interpretation is possible.
- IR.2: Reliable. Based on reliable data, transparent method.
- IR.3: Inspiring. Inspires and motivates users.
- IR.4: Representative. Specifically for system being analyzed, broadly accepted.
- IR.5: Quantitative. As much as possible quantitative.

The last column gives insight in the process of merging overlapping indicators. If appropriate, the column shows a reference to an indicator in the Initial Design (ID). For example IL.2 and IL.3 show overlap with each other and are therefore joined in indicator ID.23 in the initial design.

Table A I.1 - Indicators proposed in scientific literature.

Nr.	Title	Source	Unfit	ID
IL.1	Material intensity	1		ID.16
IL.2	Material recycled intensity	1		ID.23
IL.3	Material recycled	1		ID.23
IL.4	Energy intensity	1		ID.1
IL.5	Solid waste generation	1		ID.28
IL.6	Emission intensity	1		ID.75
IL.7	Design life	1		ID.91
IL.8	Public health	1	2, 4	
IL.9	Risk due to exposure	1	4	
IL.10	Life expectancy	1	4	
IL.11	GDP growth	1	4	
IL.12	Total property value appreciation/depreciation	1		ID.85
IL.13	Tax revenue	1	4	
IL.14	Investors credit rank	1	2, 4	
IL.15	Threatened mammals	1		ID.60

Nr.	Title	Source	Unfit	ID
IL.16	Threatened higher plants	1		ID.60
IL.17	Threatened fishes	1		ID.60
IL.18	Number of mammal species per km2	1		ID.60
IL.19	Number of higher plant species per km2	1		ID.60
IL.20	Average number of fish species per km2	1		ID.60
IL.21	Annual deforestation per km2	1		ID.63
IL.22	Construction materials usage	2		ID.16
IL.23	Land use	2	1,2	
IL.24	Energy usage	2		ID.1
IL.25	Water usage	2		ID.5
IL.26	Chemical use	2		ID.12
IL.27	Construction waste	2		ID.28
IL.28	Local air pollution	2		ID.75
IL.29	GHG emissions	2		ID.75
IL.30	Contaminants	2		ID.12
IL.31	Nutrients	2		ID.12
IL.32	Sludge	2		ID.12
IL.33	Capital and operation and maintenance cost	2		ID.91
IL.34	User fees	2		ID.91
IL.35	Service fees	2		ID.91
IL.36	Expenditures R&D	2	2,4	
IL.37	Reserve funds	2	2,4	
IL.38	Capacity	2	1,2	
IL.39	Durability	2		
IL.40	Service interruptions	2		ID.91
IL.41	Storage	2	1,2	
IL.42	Leakage	2		ID.6
IL.43	Mode choice	2	1,2	
IL.44	Travel times	2	1,2	
IL.45	Access to potable water and sanitation services	2		ID.15
IL.46	Collision frequency and severity	2	1,2	
IL.47	Water quality	2		ID12-14
IL.48	Public participation	2		ID.87
IL.49	Initial cost	3		ID.91
IL.50	Life cycle cost	3		ID.91
IL.51	Resettling cost of people	3		ID.88
IL.52	Rehabilitating cost of ecosystem	3		ID.91
IL.53	Adverse impact on tourism values	3	2, 4	
IL.54	Employment of labor	3	4	
IL.55	Extent of land acquisition	3		ID.36-37
IL.56	Extent of tree felling	3		ID.63
IL.57	Extent of loss of habitat	3		ID.65
IL.58	Connectivity with hinterland	3	1	

Nr.	Title	Source	Unfit	ID
IL.59	Impact as to assessment under EIAR (water)	3	4	
IL.60	Water reuse	3		ID.9-11
IL.61	Impact as to assessment under EIAR (air)	3	4	
IL.62	Air outlet design	3	1,2	
IL.63	Ventilation design-during construction	3	1,2	
IL.64	Ventilation design-service stage	3	1,2	
IL.65	Impact as to assessment under EIAR (noise)	3	4	
IL.66	Design flexibility towards noise reduction measures	3		ID.78-79
IL.67	Impact as to assessment under EIAR (ecology)	3	4	
IL.68	Reprovision of habitat	3		ID.65
IL.69	Impact as to assessment under EIAR (visual impact)	3	4	
IL.70	View from assessor on visual impact	3	2,4	
IL.71	Harmony with surrounding	3	2,4	
IL.72	Waste management solid-construction material	3		ID.31-33
IL.73	Waste management-solid dredged/excavated material	3		ID.31-33
IL.74	Waste management toxic liquid waste	3		ID.31-33
IL.75	Waste management non-toxic liquid waste	3		ID.31-33
IL.76	Extent of encroachment upon concerned areas	3		ID.64
IL.77	Footprint of project in archaeological site	3		
IL.78	Complaints from local parties/villages	3	1,4	
IL.79	Extent of diversion	3	1	
IL.80	Extent of blockage	3		ID.41
IL.81	Extent of congestion	3	1	
IL.82	View from local authorities	3	1,4	
IL.83	Ubuntu	3	4	
IL.84	Route(s) for waste disposal	3		
IL.85	Route(s) for construction traffic	3		
IL.86	Site access: availability of construction material	3	1	
IL.87	Use of local materials	3		ID.19
IL.88	Those associated with the chosen materials	3	1	
IL.89	Prefabricated material	3		
IL.90	Innovative material	3		
IL.91	Early contractors' involvement	3		ID.90
IL.92	Early suppliers' involvement	3		ID.90
IL.93	Reusability of moulds, formwork etc.	3		ID.20
IL.94	Scrap value after decommissioning	3	1, 2	
IL.95	Ease of quality control	3	1	
IL.96	Short-term health	3	4	
IL.97	Long-term health	3	4	
IL.98	Accidents, injuries, fatalities	3	4	
IL.99	Management systems	3	4	
IL.100	Public health	3	4	
IL.101	Public safety	3	4	

Nr.	Title	Source	Unfit	ID
IL.102	Type of contract	3	1	
IL.103	Inclusion sustainability clauses in project specification	3		ID.89
IL.104	Project duration	3		ID.91
IL.105	Project complexity	3	1	
IL.106	Amount of paperwork	3	1	
IL.107	Approach/criterion towards contractors	3		ID.89
IL.108	Approach/criterion towards suppliers	3		ID.89
IL.109	Choice of delivery systems	3		ID.89-90
IL.110	Local mobility and passenger transportation-a	4		ID.37
IL.111	Local mobility and passenger transportation-b	4		ID.38
IL.112	Radioactive waste	4	4	
IL.113	Stratospheric ozone formation	4		ID.76
IL.114	Restricted traffic areas	4		ID.54
IL.115	Land use	4		ID.36-37
IL.116	Sewerage and purification degree	4		ID.15
IL.117	Contaminated sites	4		ID.36-37
IL.118	Reuse of phosphorous from waste water	4		ID.13
IL.119	Water consumption per capita	4		ID.5
IL.120	Public transport	4	1	
IL.121	Biodiversity: selection of flora	4		ID.66
IL.122	Alimentation soil	4		ID.21
IL.123	Link road network and structuring axis	4	1,5	
IL.124	Urban furniture providing	4	4	
IL.125	Quality of pedestrians pathways	4		ID.47-51
IL.126	Parking areas for residents	4		ID.56-57
IL.127	Public transport accessibility	4		ID.42
IL.128	Surface impermeability rate	4		ID.68
IL.129	Outdoor noise nuisance	4		ID.78-79
IL.130	Fuels	4	1,4	
IL.131	Free area dissection	4		ID.40
IL.132	Emission of green house gases	4		ID.39
IL.133	Influence on ground water	4		
IL.134	Exceeding of impact limits	4		ID.46
IL.135	Influence on lakes and rivers	4		
IL.136	Influence on landscape	4	1,5	
IL.137	Noise conditions	4		ID.78-79
IL.138	Emission of pollutants	4		ID.45
IL.139	Protected areas and areas for special use	4		ID.64
IL.140	Traffic safety	4		ID.52-55
IL.141	Barriers within built-up areas	4		ID.41
IL.142	Accessibility of industrial estates	4	1	
IL.143	Building compactness around railway junctions	4		ID.40
IL.144	Driving cars	4	4	

Nr.	Title	Source	Unfit	ID
IL.145	Bike paths	4		ID.47-51
IL.146	New urban land planning documents	4	4	

Appendix II – Analysis of practical instruments

In this appendix the results of the analysis of the practical instruments are reported. First the structure of the analysis is described and subsequently each of the instruments is presented in this way.

A.II.I Structure of the practical instruments analysis

In this appendix the eleven practical instruments that are selected for analysis are described in further detail. Each section attends a single instrument following a standard structure.

First a short description of the instrument including purpose and general characteristics is given. The used methodology, calculations or approach in the instrument are then further specified to give insight in the potential for applicability in this study. Third, this potential for applicability of the particular instrument is summarized. This gives answer to the question: Can (elements of) the instrument be used in an initial design for an assessment method for infrastructure sustainability, and if so, how?

Further characteristics of the instruments are listed in a textbox for each instrument. If appropriate, the reformulated measures are included as well. These textboxes provide the following information:

- Title. The full name, and if appropriate the abbreviation, of the instrument.
- Number. To structure the report the instruments are numbered as PI (Practical Instrument) followed with a number.
- Development. A reference to the organization(s) that developed the instrument originally and, if appropriate, important aspects of the development and current application.
- Scale. The instruments can be applicable to different scales of development. Related to the scope of infrastructure, the instruments can be applicable to physical infrastructure (all types) or specifically to market, social or technical infrastructure. Some are even more specific and relate to certain domains of technical infrastructure. It is also possible the instruments are applicable to a closed system, that might even exceed the scope of area development projects. The distinguished possibilities are therefore: closed system, area, physical infrastructure, technical (or social, market) infrastructure, domain, element.
- Stage. All instruments are to be used in the planning stage, but the development stage the results of the instruments apply to diversify. These can be design, realization, operation and demolition.
- II - ID. Here a reference is given to the specific indicators selected from the instrument (II) to be used in the initial design. The indicators are not described in detail, instead the original title of the indicators is used or a short description. The last column gives insight in the process of merging overlapping indicators. If appropriate, the column shows a reference to an indicator in the Initial Design (ID). For example II.26 and II.27 show overlap with each other and are therefore joined in indicator ID.12 in the initial design. (It is also possible there is overlap with indicators selected from scientific literature, see Appendix I)
- Sources. References to the used sources for the analysis. A full reference can be found in the reference list of this report.

A.II.II Nationaal Pakket Duurzaam Bouwen GWW

The instrument Nationaal Pakket Duurzaam Bouwen GWW (NPGWW) is a book of reference containing approved knowledge on sustainable construction in the civil engineering sector. The instrument is used as a foundation for government policies and offers assistance for stakeholders to make agreements on sustainable practices.

The instrument represents a package of measures (practices) that are broadly accepted in the sector. The practices are categorized in different themes: process, water, greenery, soil, road, rail, cables and constructions. These are all specified and described in detail in the instrument, which results in prescriptions such as: to strive for limited disturbing of traffic around construction site. Besides, a road map is given for effective implementation of sustainable initiatives in a construction project.

The instrument gives insight in practicable examples of sustainable construction of infrastructure. However, the instrument does not provide any measures or indicators with which one can assess the effective implementation of such practices. In the end, it should be possible to assess the practices proposed in NPGWW with the developed method in this study, since these practices are broadly accepted. Further information on the instrument is presented in Table A II.1 .

Table A II.1 - Characteristics Nationaal Pakket Duurzaam Bouwen.

Title	Nationaal Pakket Duurzaam Bouwen GWW (NPGWW)			PI.1
Development	NPGWW is developed by SBR, Nationaal DuBo Centrum, CUR and CROW, Dutch organizations for research and standardization in construction. Since the latest version (released in 2006) the instrument will not be updated anymore.			
Scale	Technical infrastructure		Element	
Stage	Planning	Realization	Operation	Demolition
Sources	CROW, CUR, Nationaal DuBo Centrum (2006)			
II - ID	-			

A.II.III ENERGIE PRESTATIE OP LOCATIE

Energie Prestatie op Locatie (EPL) is a measure for reduction on fossil fuels off a building project. A whole area can be analyzed: multiple buildings, including their energy networks and sources for energy supply. Goal of the instrument is to achieve an optimal energy facility by means of taking CO_2 reducing measures on the location and in the buildings.

A higher EPL score indicates lower use of fossil fuels in an area. The energy performance is reflected to a reference project and ranked in a 10 point scale. Changing the energy demand or changing the rate of fossil fuels of the energy supplier will result in higher scores. Based on the EPL score it is also possible to calculate the CO_2 reduction of the area reflected to the reference project.

Some elements of infrastructure (such as installations for drainage, installations in tunnels and public lighting) consume energy. It is possible to include the energy consumption of these elements in an EPL calculation. Besides, it is also possible elements of infrastructure generate energy (such as heat installations in for example asphalt). Renewable energy generated by infrastructure elements highly impact the energy performance of an area, and should therefore be included in the calculation. The EPL score as such can be used in the criterion of DGBC Area. The applicable measures are (re)formulated in Table A II.2.

Table A II.2 - Characteristics Energie Prestatie op Locatie.

Title	Energie Prestatie op Locatie (EPL)		PI.2
Development	EPL was introduced in 1998 by the Dutch department of Housing, Space and Environment and the Financial department as an extension of the existing energy performance norm (EPN). Since then, EPL is used frequently. EPL Monitor is an annual publication in which Dutch building sites are ranked using the EPL scores. EPL will be adjusted when norms or references change.		
Scale	Area	Physical infrastructure	
Stage	Operation		
Sources	Groot et al. (2008)	Nationaal DuBo Centrum (2009)	
II - ID	II.1	Technical infrastructure facilities as part of EPL calculation	ID.2
	II.2	Energy generated in infrastructure as part of EPL calculation	ID.3

A.II.IV VERVOERS PRESATIE OP LOCATIE

Vervoers Prestatie op Locatie (VPL) is an approach for integral spatial planning in which urban development and traffic planning are combined. Its purpose is to centralize traffic performance in the planning process of area developments. Part of the approach (VPL-Kiss) is a specific methodology to reduce energy use in traffic and transport by calculating the CO_2 reduction of alternative plan variants.

VPL-Kiss as part of the planning approach VPL gives insight in the score of a plan variant on sustainable mobility and quality of the built environment. Input for the methodology are a reference mobility and characteristics of population, houses, streets and zones. Based on these characteristics, the model calculates the estimated mobility (in number of daily movements and average daily traveled distance per citizen, separated in type of movement and mode), the related energy use of traffic (MJ per day, per citizen separated in car and public transport) and finally the related emissions CO_2 and NO_x (KTon per year, whole area, for cars). Further, the model gives a qualitative indication of traffic safety and the quality of the built environment by filtering the variables that are impacting urban diversity and spatial functional quality and relating this to available figures on means.

VPL approach as such is not applicable for use in the initial design, for it is a planning approach to structure the process. However, calculation method VPL-Kiss is relevant to assess the effects of traffic planning for an area in a cost effective and fast way. Disadvantages of using VPL-Kiss are the limited scope of the model, it can only be applied to housing zones. Besides, it can only be applied to relatively small area developments and the model can be characterized as a typical quick scan methodology. The qualitative output of the model will not be used in the initial design, for it is just a presentation of common available figures. The quantitative output will be used as indications for mobility, energy use and emission in the initial design. The applicable measures are (re)formulated in Table A II.3.

Table A II.3 - Characteristics Vervoers Prestatie op Locatie.

Title	Vervoers Prestatie op Locatie (VPL)		PI.3
Development	VPL has been developed by Novem en was introduced in 1998. Since, several traffic consultancy companies have specialized in the approach, and it has been applied much in the governmental program Spatial Planning and Traffic. The specific calculation model VPL-Kiss is, among others, adopted in Greencalc+ software.		
Scale	Area		
Stage	Operation		
Sources	Novem, CROW (2001)		
II - ID	II.3	Energy use in traffic	
	II.4	Emissions CO_2 en NO_x of traffic	ID.45
	II.5	Number of movements per day per household	ID.37
	II.6	Average length of movements per mode	ID.38

A.II.V DUBOCALC

DuboCalc is an instrument to calculate the environmental impact of material use and embedded energy consumption of infrastructure projects. Designers and principals can use the instrument to optimize a design and compare alternatives.

Specific characteristics of an infrastructural project are input for the software. The environmental impacts of both materials and processes are calculated based on the DuboCalc database. The calculation is based on life cycle analysis, environmental impacts of realization, operation, maintenance and demolition are included. The environmental impact is expressed in the environmental cost indicator (in Dutch: Milieu Kosten Indicator, MKI), a measure for the monetary units necessary to compensate the environmental impact of the project. The software makes it possible to compare the environmental cost of alternative designs per element, life cycle stage and environmental impact factor. The instrument can be applied in the planning stage.

DuboCalc provides a single indication, the environmental cost indicator. This indicator is relevant and based on a mature methodology for assessment of environmental impact of materials. In formulation of criteria for this indicator, minimum values can be set for material and energy use. The applicable measures are (re)formulated in Table A II.4.

Table A II.4 - Characteristics DuboCalc.

Title	DuboCalc			PI.4
Development	DuboCalc is still in development, in 2010 the instrument will be ready to be used in practice. Advin, NIBE and CENOSCO are organizations involved in the development, by order of Rijkswaterstaat.			
Scale	Technical infrastructure		Elements	
Stage	Realization	Operation	Demolition	
Sources	Van 't Wout (2009)	DuboCalc (2009)	Nationaal DuBo Centrum (2009)	
II - ID	II.33	Environmental Cost Indicator		ID.17

A.II.VI GREENCALC+

Greencalc+ is an instrument for calculation of the sustainability of a building or a whole area. The result is expressed in an environmental index. The environmental impact assessment of areas includes buildings, mobility, technical infrastructure, pavement and energy supply.

In Greencalc+ environmental impact is expressed in monetary units necessary to realize the project fully sustainable. The calculation methodology is based on several norms and methods that are broadly accepted. The instruments differentiates environmental impact on energy consumption, water use, material use and mobility. Energy consumption is calculated based on EPL methodology. Besides, based on average numbers, the energy consumption due to public lighting and drainage is calculated. With respect to material use, data on infrastructural installations and pavement are input for the calculation. Specifically, the method reckons the material used for networks of gas, electricity, heat, water and sewage and for pavement and foundation of roads and pedestrian and cyclists paths. With respect to the category water use, the instrument does not contain indicators related to infrastructure, since the water use is calculated per building. The score for mobility is based on the VPL-Kiss methodology, but is not a part of the final index score in Greencalc+.

Since Greencalc+ assesses the mobility of a complete area, elements of technical infrastructure are also part of the calculation methodology. The instrument is based on other existing methodologies: EPL for energy consumption, environmental cost indication for material use and VPL-Kiss for mobility. However, indicators for energy consumption and material use are formulated as input for the initial design. The applicable measures are (re)formulated in Table A II.5.

Table A II.5 - Characteristics Greencalc+.

Title	Greencalc+			PI.5
Development	The instrument is developed by order of Stichting Sureac, an establishment founded by several public and private partners and research institutes.			
Scale	Area	Technical infrastructure	Elements	
Stage	Realization		Operation	
Sources	Bijleveld et al. (2009)		Greencalc (2009)	
II - ID	II.7	Environmental cost material use area installations		ID.17
	II.8	Energy use lighting		ID.2/4
	II.9	Energy use drainage		ID.2
	II.10	Environmental cost material use surfacing		ID.17

A.II.VII MILIEUKWALITEIT IN DE LEEFOMGEVING

The purpose of the instrument Milieukwaliteit in de Leefomgeving (MILO) is to increase the contribution of environmental policies to the quality of the surroundings by means of an approach for integral area development. Ambitions are attuned to functions, characteristics and potential of an area. The instrument will give government organizations the possibility to specify environmental quality early in the process and to integrate it in the process.

MILO describes 7 steps for formulation of environmental quality ambitions for an area. These are: (i) analysis of existing functions and qualities, (ii) determination of area type, (iii) determination of indicators for environmental quality, (iv) references for area type, (v) analysis existing environmental quality, (vi) determination of ambitions in environmental policy of area and (vii) measures for realization and monitoring. Further the instrument clarifies how to handle environmental ambitions in all stages of the development. The instrument will stimulate the development to exceed standard environmental quality requirements.

The steps ii-iv are important for a theoretical background in this study. MILO shows how to formulate indicators for environmental quality and gives insight in minimum norms and values for each area type. However, the instrument does not provide any specific indicators for use in the initial design. Further information on the instrument is presented in Table A II.6.

Table A II.6 - Characteristics Milieukwaliteit in de LeefOmgeving.

Title	Milieukwaliteit in de LeefOmgeving (MILO)	PI.6
Development	MILO is the result of cooperation between several governmental agencies and departments: VNG, IPO, UvW and VROM. After publication, the instrument will have to prove itself in several projects.	
Scale	Area	
Stage	Operation	
Sources	VROM, IPO, VNG & UvW (2004)	
II - ID	-	

A.II.VIII ENERGIESCAN GWW

The instrument Energiescan GWW gives insight in the energy consumption of installations in infrastructure. It is developed to support choices in technical solutions based on energy performance, and thereby to increase CO_2 reduction.

Characteristics of infrastructure objects in a certain management area are input for the calculation. The energy consumption of these objects can either be estimated or filled in based on data of the supplier. The assessment of the infrastructural objects is based on index numbers provided for reference situations.

Energiescan GWW provides relevant information to support decision making in a specific situation of a specific project. The instrument does not value the energy performance, it only compares it to a reference and makes differences visible. The instrument does not provide specific measures, or indicators for the initial design, since the methodology is only based on average numbers. These numbers might be used when formulating criteria. Further information on the instrument is presented in Table A II.7.

Table A II.7 - Characteristics Energiescan GWW.

Title	Energiescan GWW		PI.7
Development	Energiescan GWW is developed by a governmental program for energy reduction in the civil engineering sector. The software is not updated since 2005. The program currently focuses on energy reduction of public lighting.		
Scale	Technical infrastructure	Element	
Stage	Operation		
Sources	Projectbureau Energiebesparing GWW (2005)		
II - ID	-		

A.II.IX MIMOSA

The full name of MIMOSA is (in Dutch) Milieu Indicatie Model voor Optimalisatie en Samenwerking in de wAterketen. MIMOSA is intended for support in decision making in water cycle issues and gives insight in improvements of environmental performance of specific intended measures.

Eleven environmental aspects are differentiated and further clustered in four categories: climate change, disruption, streams and water load. For each of these themes several environmental performance indicators are formulated. Data on water balance and these performance indicators are input for each stage of the water cycle. These stages are production and collection, distribution, users, sewage system, transport and treatment. The calculation will give insight in water balance and total energy consumption and chemical use and it is possible to determine on an optimal design variant.

MIMOSA is applicable for a complete water cycle, which comprises several production locations, transport areas, municipalities, sewage systems and/or treatment facilities. In other words, the scope of MIMOSA exceeds the scope of an area development by far. The instrument does however contain several relevant indicators concerning the water cycle, since these are formulated in detail. Thus, despite MIMOSA cannot be used as calculation software, these indicators will be used as input for the initial design. The applicable measures are (re)formulated in Table A II.8.

Table A II.8 - Characteristics MIMOSA.

Title	MIMOSA		PI.8
Development	MIMOSA is developed by Kiwa Management Consultants, Kiwa Water Research and Tauw. The development project was guided by a group stakeholders from water cycle practice.		
Scale	Closed system		
Stage	Operation		
Sources	Voorhoeve-Zeegers et al. (2003)		
II - ID	II.22	Energy	ID.1
	II.23	Production of greenhouse gas	ID.75
	II.24	Use of chemicals	ID.12
	II.25	Waste products	ID.28
	II.26	Emission czv	ID.12
	II.27	Emission water	ID.12
	II.28	Emission zinc	ID.12
	II.29	Emission copper	ID.12
	II.30	Water load	ID.5
	II.31	Use of space water system	ID.35
	II.32	Cost	ID.91

A.II.X DUURZAAMHEIDS PROFIEL OP LOCATIE

The instrument Duurzaamheids Profiel op Locatie (DPL) intends to increase realization of sustainable areas by calculation of the sustainability profile of a zone and give insight in the strengths and weaknesses. Municipalities use the instrument in the planning stage of new urban areas and in management of existing areas.

Eleven themes related to sustainable development of urban areas are reflected in indicators for sustainability, that are the basis for the calculation of the profile. The scores are reflected to a chosen reference project. The model concerns both objective, physical aspects as well as subjective aspects (such as inhabitants experience).

The instrument uses very specific indicators, of which several are related to assessment of infrastructure. Besides a description of a theme the instrument provides insight in a methodology for assessment of the indicator. This is used in the reformulation of the indicators as input for the initial design. It should be noticed that the calculation methods proposed in DPL are rather simple, or sometimes even qualitative. The applicable measures are (re)formulated in Table A II.9.

Table A II.9 - Characteristics Duurzaamheids Profiel op Locatie.

Title	Duurzaamheids Profiel op Locatie (DPL)	PI.9
Development	DPL is developed by IVAM-UvA and TNO and was tested on several projects. The application of the methodology has become a central element of the requirements for sustainable tendering as recently formulated by Senter Novem.	
Scale	Area	

Title	Duurzaamheids Profiel op Locatie (DPL)		PI.9
Stage	Realisation	Operation	
Sources	IVAM (2009a)	IVAM (2009b)	
II - ID	II.11	Material use roads	ID.16
	II.12	Intensity of used space (FSI)	ID.35
	II.13	Surface uncoupled from sewerage	ID.68
	II.14	Present soil pollution	ID.36
	II.15	Exposure fine dust and NO_x	ID.46
	II.16	Noise nuisance	ID.78-79
	II.17	Smell nuisance	
	II.18	Traffic safety	ID.52-55
	II.19	Accessibility public transport	ID.42
	II.20	Green in the area	ID.67
	II.21	Water in the area	

A.II.XI BREEAM-NL NIEUWBOUW

The instrument BREEAM-NL Nieuwbouw makes it possible to assess sustainability of new buildings and of extensive renovation projects. The method assesses on a broad range of environmental aspects, from energy to management.

Environmental performance is assessed on several criteria that are subdivided in nine categories: management, health and comfort, energy, transport, water consumption, materials, land use, site ecology and pollution. Assessment credits are awarded for the environmental performance leading to a single score on these categories, a weighting systems is then applied across the categories to determine the final score.

In BREEAM-NL Nieuwbouw several criteria are included for measurement of aspects that are closely related to infrastructure facilities. For example, the method differentiates indicators for assessment of aspects related to the site of the building, such as lighting and land use. Further, there is overlap between BREEAM-NL and infrastructure on general aspects such as material use and quality of public transport. In total 23 indicators are selected to be used in the initial design, these are presented in Table A II.10.

Table A II.10 - Characteristics BREEAM-NL Nieuwbouw.

Title	BREEAM-NL Nieuwbouw			PI.10
Development	BREEAM-NL Nieuwbouw is developed by the DGBC. It is an adjusted version of the original BREEAM methodology specifically for Dutch context. The first official version of the instrument is launched in October 2009.			
Scale	Market infrastructure		Social infrastructure	
Stage	Planning	Realization	Operation	
Sources	DGBC (2009c)			
II - ID	II.34	Energy saving exterior lighting		
	II.35	Supply of public transport		ID.42
	II.36	Bicycle shed		ID.51
	II.37	Pedestrian- and cyclist safety		ID.47-50
	II.38	Transport information		ID.58
	II.39	Leak detection water connection		ID.75
	II.40	Water recycling		ID.9-11
	II.41	Irrigation systems		ID.10
	II.42	Carwash service		ID.11
	II.43	Clear origin of materials		
	II.44	Waste management on building site		
	II.45	Use of secondary material		ID.22-23
	II.46	Reusable waste storage		
	II.47	Compost		ID.29
	II.48	Reuse of land		ID.36
	II.49	Polluted soil		ID.36
	II.50	Present plants and animals on building site		ID.61
	II.51	Plants and animals as joint user of the area - short-term		ID.62

Title	BREEAM-NL Nieuwbouw		PI.10
	II.52	Plants and animals as joint user of the area - long-term	ID.62
	II.53	Partnership with local environmental organization	ID.88
	II.54	Minimize contamination of runoff	ID.81
	II.55	Minimize light nuisance	
	II.56	Noise nuisance	ID.78-79

A.II.XII BREEEAM COMMUNITIES

BREEAM Communities is an assessment and certification standard based on BREEAM methodology for proposed development projects within the built environment. The purpose is to stimulate delivery of sustainable communities and to enable recognition of such to the local community.

Credits are awarded in eight categories according to their performance against defined sustainability objectives and planning policy requirements. The categories of assessment are climate change and energy, community, place making, buildings, transport and movement, ecology, resources and business. The credits on each of the categories are added together to produce a single overall score.

BREEAM Communities is a method for assessment of area developments, just as DGBC Area will become. The instrument provides several measures that assess sustainability of infrastructure facilities. These measures can be used in the initial design in this research. The applicable measures are (re)formulated in Table A II.11.

Table A II.11 - Characteristics BREEAM Communities.

Title	BREEAM Communities			PI.11
Development	The instrument is developed by the BRE Global Sustainability Board.			
Scale	Area			
Stage	Realization		Operation	
Sources	BRE (2009)		BREEAM (2009)	
II - ID	II.57	Runoff		ID.81
	II.58	Heat Island Effect		
	II.59	Flexibility facilities		ID.91
	II.60	Gradual approach land use		ID.36
	II.61	Reuse of land		ID.36
	II.62	Green areas		ID.67
	II.63	Local flora		ID.66
	II.64	Location and capacity public transport		ID.42
	II.65	Accessibility and frequency public transport		ID.42
	II.66	Facilities public transport		ID.44
	II.67	Cyclist network		ID.47-50
	II.68	Cyclist facilities		ID.51
	II.69	Flexible parking areas		ID.57
	II.70	Residential areas		ID.54
	II.71	Low impact materials		ID.18
	II.72	Local origin materials		ID.19
	II.73	Compost		ID.29
	II.74	Groundwater		ID.70

Appendix III – Indicator Matrices Initial Design

This appendix contains various indicator matrices representing design steps in the initial design phase. The first section presents the initial design. Remarks of experts on the indicators are summarized in the second paragraph. Finally, the suggestions of experts for new indications are considered.

A.III.I Initial Design

The initial design is a combination of the selected measures from scientific literature and practical instruments. In the initial design overlapping indicators are merged and the measures are described more extensively. The initial design is structured following DGBC Area categorization.

Structure of the matrix

Table A III.1 shows the initial design for an environmental assessment method for infrastructure sustainability. The first column contains a number for each indicator, ID stands for Initial Design. The categories of indicators are highlighted in bold text in the merged rows. A theme is formulated to further cluster the measures in each category. The description of the measures contains information about the objective and the proposed method of the indicators. This description is based on the clarification in original sources.

Table A III.1 - Initial Design (ID).

Nr.	Theme	Description
Energy		
ID.1	Energy consumption	Total amount of energy consumed per unit of time
ID.2	Energy performance	Technical infrastructure facilities using energy are part of calculation energy performance
ID.3	Renewable energy	Energy generated in infrastructure is part of calculation energy performance
ID.4	Energy efficient lighting	Application of efficient lighting, which does not burn unnecessary, without harming social safety
Water		
ID.5	Water usage	Number of liter per person per unit of time
ID.6		Number of liter leakage per unit of time
ID.7		Specification and installation of a leak detection system of the water connection
ID.8		Application of water saving irrigation system or strategy
ID.9	Water reuse	Systems for storage (and eventually treatment) of gray water or rain water
ID.10		Use of gray water or rain water for irrigation systems
ID.11		Car wash facilities have reusable water systems
ID.12	Water quality	Use of chemicals
ID.13		Percentage reuse of phosphor from waste water compared to input
ID.14		Emission contaminating substances and heavy metals
ID.15	Availability	Percentage households with access to potable water and sewerage systems
Materials		
ID.16	Material use	Intensity use of material based on total mass or surface
ID.17	Material choice	Environmental cost (shadow price) of material- and energy use in lifecycle
ID.18		Percentage of material with a low impact on environment and originated from responsible sources

Nr.	Theme	Description
ID.19	Use local materials	Percentage of material with a local origin
ID.20	Material reuse	Reusability of moulds
ID.21		Reusability of alimentation soil
ID.22		Amount of recycled or reused aggregate used in high-grade applications
ID.23		Percentage of materials reusable and of reused materials in construction
ID.24	Durability	Choice of materials based on long term view
ID.25	Prefabrication	Percentage prefabricated materials applied
ID.26	Innovative materials	Percentage innovative materials applied
ID.27	Origin	Origin of a certain percentage of the used materials is demonstrable
Waste		
ID.28	Waste production	Total mass of produced waste in lifecycle
ID.29	Organic waste	Facilities to compost organic waste locally
ID.30	Storage	Facilities for separated storage of reusable waste
ID.31	Management Constr.	Contractor is compelled to minimize waste
ID.32		Separation of waste
ID.33		Percentage of recyclable waste that will be recycled
ID.34	Transport	Planning of routes for waste transport
Spatial Development		
ID.35	Land use	Relative intensity use of space by infrastructure as part of Floor Space Index
ID.36	Reuse of land	(Percentage of) the development on locations with low ecological and natural value, which is contaminated or developed before
Transport		
ID.37	Mobility	Number of daily movements and travel time per citizen, separated in type of movement and mode
ID.38		Total average daily traveled distance per citizen, separated in type of movement and mode
ID.39	Density	Km of transport network per km2 area
ID.40		Building compactness around railway stations in number of dwellings, enterprises and jobs within a certain radius
ID.41	Barriers	Barriers for pedestrians and cyclists: ratio of length or travel time compared to length or travel time of shortest connection
ID.42	Quality	Based on average distance to public transport stop, capacity and frequency
ID.43		(Actual) travel information at stops, in public buildings and areas
ID.44		Facilities for waiting passengers are safe, lighted and comfortable
ID.45	Emission	Emission of greenhouse gases in CO_2 equivalents per unit of time or per km
ID.46		Surface of area where norms are exceeded compared to surface where not
ID.47	Pedestrian and Cyclist traffic	Safe network of pedestrian and cyclist way in km per citizen
ID.48		Safety through jonction network and connection to grounds
ID.49		Safety through separation with motorized traffic
ID.50		safety through good lighting
ID.51		Facilities for cyclists such as bicycle shed, shower and change room
ID.52	Traffic safety	Number of accidents per year with injury
ID.53		Number of km road per speed categories
ID.54		Surface or percentage of restricted traffic areas
ID.55		Route for construction traffic
ID.56	Facilities	Safety parking areas
ID.57		Percentage of parking areas that can be used flexible

Nr.	Theme	Description
ID.58		(Actual) travel information facilities
ID.59	Energy	Energy consumption in traffic
Flora and Fauna		
ID.60	Flora and fauna	Number of (threatened) plant and animals species in project area
ID.61		Measures to protect and preserve plant and animals during construction
ID.62		Measures to let plants and animals be joint user of buildings and public space during operation in a sustainable way
ID.63	Trees	Number of felled trees per unit of time or surface
ID.64	Protected areas	Total surface of protected areas (nature, water collection, habitat) impacted (polluted, crossed, adjoined)
ID.65		Extent of loss and recovery of habitat in surface
ID.66	Biodiversity	Selection of (local) flora
ID.67	Green area	Surface of and average distance to green area in an area
ID.68	Water management	Percentage of not paved surface or percentage paved surface uncoupled from sewage system
ID.69		Extent to which an area can store extreme precipitation
ID.70		Surface of impacted groundwater compared to surface infrastructure
ID.71		Surface of open water within a certain radius of infrastructure
ID.72		Surface of water in the area
ID.73		Application of ecological banks or ponds in the area
Cultural Heritage		
ID.74	Archaeological value	Total surface of encroachment on archaeological site
Climate		
ID.75	Emission	Total emission of greenhouse gasses in CO_2 equivalents (per individual/household/building/surface)
ID.76		Total emission of ozone affecting substances in C_2H_2 equivalents (per individual/household/building/surface)
ID.77		Total emission of fine dust (per individual/household/building/surface)
ID.78	Noise	Surface with certain noise levels due to traffic, business etc.
ID.79		Difference in noise level before and after development
ID.80	Soil	Surface of soil pollution before development
ID.81	Water	Measures to prevent pollution of (ground)water due to runoff
ID.82	Smell	Surface with certain smell nuisance categories due to traffic, business, etc.
ID.83	Light	Minimize light nuisance
ID.84	Heat	Measures to prevent heating of the area (heat island effect)
Management		
ID.85	Participants	Total property value depreciation/appreciation due to development
ID.86		Indirect cost due to resettlement of people
ID.87		Participation of stakeholders
ID.88		Partnership with local environmental organization to involve knowledge of local ecosystem in management
ID.89	Contract	Project specification contains clauses with respect to sustainability
ID.90		Early involvement of contractors and suppliers
ID.91	Lifecycle analysis	Design (and calculation) based on lifecycle analysis (project duration, maintenance interruptions and cost, flexibility for expansion)
ID.92	Systems	Policy and programs with respect to sustainability, quality and safety

A.III.II SUMMARY REMARKS ON INITIAL DESIGN

The remarks following from the evaluation of the initial design are summarized in table Table A III.2. This table also reflects the final consequences for the indicators and references to the concept design.

STRUCTURE OF THE MATRIX

In Table A III.2 the summary of the evaluation of the initial design is presented. The first column again contains the number of the initial design indicator. The summary of remarks is based on the comments of the experts on the indicators (which can be found in appendix IV). In some cases concluding considerations are added to this summary. The final consequences for the initial design indicators are reflected in the next column. The possible consequences (C) are:

- CI: This is a critical indicator.
- R: This indicator can be removed from the assessment method directly.
- O: This indicator is overlapping other (suggested) indicators and should be merged.

The last column of the table shows, if appropriate, a reference to the concept design. That is, if an indicator from this initial design is used again in the concept design (be it adjusted or merged) the number of the related concept design indicator is presented here.

Table A III.2 - Summary of remarks and final considerations on initial design.

Nr.	Summary of remarks	C	CD
Energy			
ID.1	Insight in actual energy consumption is less relevant compared to, and besides part of, energy reduction calculation.	O	1
ID.2	Assessing of energy reduction is seen as critical, coefficients for infrastructural objects are in development. Mention EPL methodology explicitly in the description.	CI	1
ID.3	Some sources of renewable energy also have local negative effects. But it contributes to CO_2 emission reduction, however keep it separate to stimulate initiatives on both fields.	CI	2
ID.4	Public lighting is confirmed to be not only the biggest energy consumer of all infrastructure elements, it also has the biggest potential for reduction. The terminology of the indicator needs to be more explicit.	A	3
Water			
ID.5	Infrastructure elements consume little water, but instead can be used to reduce the need for water. Besides water use quantity is less relevant in Dutch context. Adjust the indication to assessment of water usage efficiency, this will cover all indications ID.5-ID.11.	CI	4
ID.6	Leakage of water is impossible to measure in design stage and state of the art installations are assumed of sufficient quality. Besides, leakage is part of an efficient system (ID.5).	O	4
ID.7	Leak detection on scale of an area is responsibility of the water board. Besides, systems for leakage reduction are part of an efficient system (ID.5). It should however be prevented to include just installation of such systems, they should also be assessed on performance.	O	4
ID.8	In Dutch context water usage for irrigation is less relevant than for water level management, but for the latter no potable water will be used. Also, changing climate makes irrigation more relevant during droughts in summer times. Systems to save water for irrigation are therefore relevant but part of an efficient system (ID.5).	O	4
ID.9	Efficiency of such systems is still doubtful, but with regard to the scope very relevant. Storage of water for reuse is best done centrally. Join all indications for water reuse in one and see it as part of an efficient water system (ID.5).	O	4
ID.10	Joined in ID.5	O	4
ID.11	Indication outside scope of infrastructure, is more related to buildings.	R	-
ID.12	Needs to be made more specific. Is closely connected to treatment technique of sewerage systems. Change in an indication for use and quantity of chemicals for local treatment of (waste) water.	A	5
ID.13	In most cases reuse of phosphor will comparatively not be relevant.	R	-
ID.14	In civil engineering scope this is leach out of construction metals in surface water runoff. This is assessed in ID.81.	O	32
ID.15	Access to potable water and sewerage systems is standard in Dutch context, for it is regulated in construction law.	R	-

Nr.	Summary of remarks	C	CD
Materials			
ID.16	Weight and sustainability of materials are related. However, it is overlapping ID.17.	O	6
ID.17	Environmental cost indication is a mature and valuable method to measure material sustainability. It is possible to harmonize existing instruments like DuboCalc in BREEAM.	C	6
ID.18	Not relevant in Dutch construction, for it is based on relative classification.	R	-
ID.19	Transport of materials is incorporated in ID.17. Percentage should be weight percentage.	O	6
ID.20	Indication only qualitative and too specific. Besides less relevant in infrastructural scope.	R	-
ID.21	Reuse of soil is part of standard construction regulations. It is possible to indicate the percentage to which ground balance of a project is closed locally.	R	-
ID.22	Partly included in ID.17. Should be far more specific for different types of materials. Reuse of aggregates is common practice in civil engineering.	O	6
ID.23	Should made specific for different types of materials. Only use weight percentage for reuse or recycling that can are known for sure in design stage.	A	7
ID.24	Included in lifecycle analysis of environmental cost indicator.	O	6
ID.25	Included in lifecycle analysis of environmental cost indicator.	O	6
ID.26	Percentage will always be low. What materials are innovative, impossible to measure in this way.	R	-
ID.27	Relevant to ensure sustainable management of sources. Assessment can be based on certificates or distance (part of environmental cost indicator).	A	8
Waste			
ID.28	Different formulation required to make it relative. Life cycle analysis is to insecure and less relevant for infrastructure because of high extent of recycling. A weight percentage of produced waste during construction is however relevant, but overlapping ID.31.	O	11
ID.29	Collection of organic residuals is common practice in Dutch context. Central collection is preferred because this will ensure efficient use of the residual.	R	-
ID.30	Separation of waste is a central theme in waste management. Local centralization of collection points is preferred.	CI	9
ID.31	Waste production is low in civil engineering context. Partly it is common practice, but stimulation is relevant. Assess in proportion to numbers of average waste production.	A	11
ID.32	Partly it is common practice, but stimulation is relevant. Separation means automatically recycling or reuse.	A	12
ID.33	This indication can be joined with ID.32. Separated residuals will be recycled or reused consequently.	O	12
ID.34	Common practice, both in realization and operation stage. Besides, comparatively not relevant.	R	-
Spatial Development			
ID.35	Flexibility in road infrastructure capacity and intensity is better measure. Reposition in category transport, because is specific for road infrastructure.	A	19
ID.36	Instead of measuring use of land with low ecological value, it is possible to change to measuring added ecological value due to development.	O	20
Transport			
ID.37	Explicate VPL. Mobility is central theme, but can be improved unsustainable as well.	R	-
ID.38	Explicate VPL. Mobility is central theme, but can be improved unsustainable as well.	R	-
ID.39	This calculation does not measure sustainability and is not referable.	R	-
ID.40	The indication is a (buildings related) inverse of ID.42.	O	14
ID.41	Relevant theme to stimulate pedestrian and cyclist traffic. Explicate method of calculation.	A	16
ID.42	Stimulating clean transport modalities is a key to sustainable transport. In infrastructure scope, P+R locations might be a valuable addition.	CI	14
ID.43	In theory travel information is valuable, but in practice it does comparatively speaking not have an impact.	R	-
ID.44	These characteristics of travelers facilities are standard procedure in Dutch context, but to assess extra initiatives is stimulating progress.	A	15
ID.45	Emission is directly linked to mobility and energy consumption of traffic.	O	13
ID.46	Complex assessment, dependent on location choice, therefore hard to compare.	R	-
ID.47	Part of standard road planning procedure (sustainable safe) in Dutch context. Assessing extra initiatives stimulates sustainable practices progress.	A	17
ID.48	Part of standard road planning procedure (sustainable safe) in Dutch context.	R	-

Nr.	Summary of remarks	C	CD
ID.49	Part of standard road planning procedure (sustainable safe) in Dutch context.	R	-
ID.50	Enhance visibility of whole area in design. Part of standard road planning procedure (sustainable safe) in Dutch context.	R	-
ID.51	Related to the scope of building sustainability.	R	-
ID.52	Number of accidents not related to the design. Part of standard road planning procedure (sustainable safe) in Dutch context.	R	-
ID.53	Part of standard road planning procedure (sustainable safe) in Dutch context.	R	-
ID.54	Include preservation of accessibility.	A	18
ID.55	Common practice and standard procedure.	R	-
ID.56	The indication is not measurable. Traffic safety is important, social safety is beyond scope.	R	-
ID.57	Example of flexible use of infrastructure, related to ID.35.	O	19
ID.58	In theory travel information is valuable, but in practice it does comparatively speaking not have an impact.	R	-
ID.59	Closely related to emission and mobility. Stimulating cleaner transport will impact consumption of energy in transport. Explicate VPL.	CI	13
Flora and Fauna			
ID.60	Join indications ID.61,62,88 in one. A study on valuable ecological elements and proposed measures is necessary.	A	21
ID.61	Joined in ID.60	O	21
ID.62	Joined in ID.60	O	21
ID.63	Indication should be relative, cannot make a classification on just a number. Include new proposed planting and total planting.	A	22
ID.64	In Dutch context protected areas always are near. Besides, the indication overlaps ID.36.	O	20
ID.65	This indication is also overlapping ID.36. The three are joined in one new indication.	O	20
ID.66	Biodiversity can be calculated, selection of local flora improves it.	A	23
ID.67	No remarks of experts, remain in concept design.	A	24
ID.68	Decoupling as much as possible from the water treatment plant.	CI	25
ID.69	Self-sufficiency of the area is important, but should be explicit how. Relate storm water capacity to extent of open water (ID.72).	A	26
ID.70	Impact on ground water is complex to assess and in light of the scope of the method less relevant.	R	-
ID.71	The meaning of the indication is not clear. It can be a measure for storm water capacity. Besides it is overlapping ID.72.	O	26
ID.72	Is a measure for storm water capacity, in other lights less relevant.	O	26
ID.73	Make relation to water quality explicit, for esthetic reasons less relevant.	R	-
Cultural Heritage			
ID.74	Standard procedures of development projects, aspects above ground like urban structures are relevant too.	R	-
Climate			
ID.75	Indicate the absorption and balancing capacity of emissions.	A	29
ID.76	No clear relation with just infrastructure.	R	-
ID.77	Indicate the absorption and balancing capacity of emissions, unit should not be individuals.	A	30
ID.78	Relevant indication, but choose one approach of measurement.	R	-
ID.79	Relevant indication, but choose one approach of measurement.	A	31
ID.80	Joined in ID.36. Relevant indication, but choose one approach of measurement.	O	20
ID.81	Very relevant indication. But needs to be more specific, or assume a study will optimize solution. Relevant indication, but choose one approach of measurement.	A	32
ID.82	Relevant indication, but choose one approach of measurement.	A	33
ID.83	Relevant indication, but choose one approach of measurement.	A	34
ID.84	The effect is relevant and can be restrained if accounted for in the design phase using planting structures.	A	35
Management			

Nr.	Summary of remarks	C	CD
ID.85	Beyond scope of infrastructure. Include more economic measures, or leave the aspect.	R	-
ID.86	Standard procedures to guard social acceptable handling of these aspects.	R	-
ID.87	Relevant for sustainable development, but very dependent on type of development and hard to measure.	R	-
ID.88	Joined in ID.60	O	-
ID.89	Just clauses is not relevant, much more specified, minimum requirement above standard regulations.	R	-
ID.90	The indications is removed. Relevant aspect but beyond the scope of BREEAM.	R	-
ID.91	Life cycle approach closely related to material choice, thus overlapping.	O	-
ID.92	Just having the systems is not relevant, minimum requirement above standard regulations.	R	-

A.III.III SUMMARY SUGGESTIONS FOR INITIAL DESIGN

All suggestions for other ways to measure environmental aspects in the assessment method and for other elements of infrastructure lacking in the initial design are presented in this section.

STRUCTURE OF THE MATRIX

The suggestions for the initial design are listed in Table A III.3. The numbers of the suggestions refer to the number of the expert (for example SI1.1 is the first Suggestion of Interviewee 1). The description is a summary of the suggested indication. The next column reflects the considerations for including the suggestions in the concept design or not. If the suggestion will be included in the concept design, a reference to the related number is showed in the last column.

Table A III.3 - Suggestions for additional indications on initial design.

Nr.	Suggestion	Consideration	CD
SI1.1	Local treatment of runoff water for reuse.	Local treatment is suggested by multiple experts, water can be reused or drained.	28
SI1.2	Indication for relativity in intensity and capacity of roads.	Is relevant in high density areas and state of the art. Related to land use.	19
SI1.3	Indication for local drainage of filtered water.	Related to local treatment, merged in concept design.	28
SI2.1	Application for innovative materials: material is innovative if not in database and shadow price is significantly lower than substitute.	Can be part of central assessment of innovation in the certificate. Is not relevant to only assess innovation in materials.	-
SI4.1	Percentage of local treated waste water to reduce stress on central treatment plants.	Local treatment is suggested by multiple experts, water can be reused or drained.	28
SI4.2	Use surface of open water or other places that can be used occasionally as indication for storm water capacity.	Regarded as relevant indication, with simple method. Incorporated in concept design.	26
SI4.3	Assess water quality with indirect indication for study and implementation of measures.	Complex aspect, quantitative indications not possible on this scale and in line with BREEAM philosophy. Incorporated in concept design.	27
SI5.1	Two related indications for waste water: extent water cycle is closed and local treatment as part of this.	Indications are confirmed by the water expert and therefore incorporated in concept design.	4 28
SI6.1	Indication for local burning of waste (and related energy generation).	Overlaps energy performance indicators. Efficiency and social desirability is doubted by expert.	-
SI6.2	Facilities for collection of public waste.	Regarded relevant and lacking, incorporated in concept design.	10
SI6.3	Indication for the use of cleaner transport for waste collection (electro, robots, underground systems).	Relevant techniques but effects of practices are incorporated indicators for traffic emission and energy performance.	-
SI7.1	Indication for reduction of energy use of traffic with smart spatial planning.	Specific example of measure for reduction of energy use, incorporated in this indicator.	-
SI8.1	Local treatment of water with greenery (central in the area).	Local treatment is suggested by multiple experts, water can be reused or drained.	28

Nr.	Suggestion	Consideration	CD
SI8.2	Indication for neutralization of emission with planting structures.	Considered relevant and just in the scope of the method, incorporated in concept design.	35
SI8.3	Indication to apply planting structures as technical measure for neutralization of negative impacts on local climate.	Considered relevant and just in the scope of the method, incorporated in concept design.	35

Appendix IV – Expert Interviews

In this appendix first the interview protocol is presented, which is used to structure the course of the interviews with experts. Subsequently, the interview reports of all eight interviews with experts are included.

A.IV.I Interview protocol

Name:
Organization:
Date:

Introduction

Thank interviewee for cooperation.

1. Insight in the function and job description of the interviewee. Get clear what expertise is with respect to sustainable infrastructure.

2. Opportunity for interviewee to ask questions about the preparation document. Is context and method of research clear? Is (scope of) initial design clear?

3. Get clear what view of expert is on infrastructure sustainability, is it relevant?. Compare with sustainable buildings. What is opinion on development of DGBC Area certificate?

Evaluation initial design

4. Propose to discuss remarks on the indicators and subsequently suggestions for new ones per theme. Specific prepared questions are also asked per theme.

Nr.	Remark	C
Theme	**Suggestion**	

5. Ask to appoint or formulate a critical indicator for the category of the expert's specialism.

General remarks on initial design

6. Ask if the design contains sufficient indicators to cover the assessment of the theme the expert is specialized in.

7. Get clear if there are other themes that are lacking in the initial design.

Innovation strategies

Clarify the innovation paradox and the intention of the questions.

8. What can be done in general to solve this paradox? What is opinion on different strategies (formulation of indicators, structure method).

9. Discuss the critical indicator proposed by the expert on this subject. What would be the consequences for the indicator?

To conclude

Are there other remarks the expert wants to discuss? Thank again for cooperation and time.

A.IV.II INTERVIEW REPORT E.1

Expert number: E.1
Function: Advisor Environment and Ecology
Organization: Rijkswaterstaat Dienst Infrastructuur
Specialism: General
Date: 07-10-2009

JOB DESCRIPTION

As advisor on environment and ecology the expert has studied instruments and methods available to measure sustainability of construction in the civil engineering sector. Currently he is involved in the development of DuboCalc, an instrument to measure the impacts of materials and energy of a civil engineering project. As assistant leader of this project he is responsible for the content of the instrument. Another example of his tasks is the involvement in current negotiations on generating a new, harmonized database for construction materials.

VISION ON INFRASTRUCTURE SUSTAINABILITY

Based on the expert's study on assessment of sustainability of civil engineering projects it became clear that there are currently little instruments available, especially compared to the market for housing and building. In the latter market sustainable building is a bigger issue, this is because this market is much bigger and there is more diversity in clients (and a bigger proportion of them is commercial).

However, the lack on instruments and tools does not imply infrastructure sustainability does not exist. Sustainability is secured as a common aspect of civil engineering projects in the so called Milieu Effect Rapportage (MER), an environmental impact study. Other examples are LCA's and the NPGWW.

Initiatives like the development of DGBC Area can always positively influence sustainability practices. It would be preferred if this certificate would be a middle course between a checklist and a mainly quantitative model, and if existing instruments are harmonized in the method as much as possible.

EVALUATION INITIAL DESIGN

Nr.	Remark	C
ID.2	Can be further specified for different categories of infrastructural elements. Coefficients for energy performance of infrastructural objects are currently in development.	A
ID.2/3	Is best to keep them apart in the instrument: this stimulates both initiatives for reducing energy need as well as for sustainable energy generation.	CI
ID.4	Lighting is not the only infrastructural element that uses energy, installations (for example in tunnels), drainage etc. should also be considered.	A
ID.5	Indication is bound to buildings, not infrastructure. Relatively speaking infrastructure consumes little water.	R
ID.6	This indication is not appropriate to measure in development stage. It is however possible to value the measures to prevent leakage that are accounted for in the design.	R
ID.10	It is recommended to mind the possibility of double measurement with the indicators in the category flora and fauna.	A
ID.11	Indication is bound to buildings, not infrastructure.	R
ID.14	Specific civil engineering example of this is leach out of construction metals.	A
ID.15	Access to water is standard element of Dutch building law, this indicator is therefore not relevant in the Netherlands.	R
ID.17	Critical indicator. Environmental cost of materials is a mature method to measure sustainability. It is possible to harmonize with an existing instrument using DuboCalc.	CI
ID.18	Not relevant in the Netherlands because of use of shadow price is a more extensive method.	R
ID.19	Part of ID.17. Locality of materials does not imply more sustainability by definition.	O
ID.20-23	Make a choice between the quantitative or qualitative approach suggested in these indicators.	A
ID.22	Differences between the use of primary or secondary materials is accounted for in shadow price.	O

Nr.	Remark	C
ID.24	Durability, or robustness, is accounted for in the life cycle analysis of the shadow price of materials.	O
ID.25	The advantages of prefabricated materials are accounted for in the shadow price of materials.	O
ID.30	Is an aspect that will be organized by commercial parties. Moreover, in the Netherlands this is standard procedure.	A
ID.31	In civil engineering projects waste production is relatively low. This is because most residuals are used again as granulates.	A
ID.35	Flexibility in use of land by infrastructure is relevant, but it should not be calculated with FSI measure. See also suggestion.	A
ID.39	What does this indication imply? It is impossible to formulate values to make this measurable.	R
ID.40	Might be possible this indicator is bounded to buildings too much.	A
ID.42	With respect to infrastructure, P+R locations, might be a valuable addition to this indication.	A
ID.45	Emission of transport of materials (also during construction phase) is accounted for in shadow price of materials.	A
ID.50	Public spaces can be designed in such a way that visibility of the complete area is enhanced. This makes the use of lighting less necessary.	A
ID.55	It is not clear enough what is originally meant with this indication. It is also a standard procedure to manage construction transportation during a project.	R
ID.59	Choices in transport modes concerning energy use have sometimes other negative consequences (such as increasing fine dust of diesel engines).	A
ID.63	It is not always more sustainable if less trees are felled.	A
ID.75-77	Some negative impacts on climate are to the extent that they are related to materials also accounted for in the shadow price method.	A
ID.85	This indication goes beyond the scope of infrastructure and is not in line with the overall methods and themes. If this indication is part of the assessment, than a lot of other economic should be as well	R
ID.86	There are standard procedures to guard these aspects are handled in a social acceptable manner.	R
ID.89	Much more specified than just clauses in a contract is possible. See for instance the sustainable purchase ambition of the government.	A

Suggestions for measures

Nr.	Theme	Suggestion	CD
SI1.1	Water reuse	Precipitation runoff possibly is contaminated water. It is possible to purify this water locally and reuse it.	28
SI1.2	Use of space	Relativity in intensity and capacity of roads to measure if new solutions like dynamic traffic lanes are practiced.	19
SI1.3	Water management	Include an indication for the possibility to drain purified waste water locally.	28

Innovation

All methods and models have disadvantages and limitations as a consequence of modeling. Models always are a simplified way to represent reality. Making choices and assumptions for the model define the extent of the restrictions. It is however desirable to make an instrument as flexible as possible.

A possible solution for DGBC Area is to make it possible to appraise initiated practices in a design that exceed the standard requirements. That is, practices that are proposed in the area development design, but which are not covered with standard credit criteria in the certificate, need to be assessed isolated. To stimulate innovation it is possible to appreciate such initiatives more, using the weighting mechanism of the certificate. Further, such practices need to be assessed objectively. This can be secured using a neutral commission of experts that needs to jury the practices.

Further comments

Make for each indicator in the instrument more visible if it is applicable to: (i) a certain specific element of infrastructure, (ii) a certain type of area development, (iii) a specific stage of the development and (iv) to the physical objects of infrastructure or the functions of this infrastructure.

A.IV.III INTERVIEW REPORT E.2

Expert number: E.2
Function: Manager Sustainability
Organization: Bouwend Nederland
Specialism: General
Date: 09-10-2009

JOB DESCRIPTION

The expert is manager sustainability at Bouwend Nederland, the business association for construction and civil engineering companies. He is responsible for the policy of the organization regarding sustainable construction. He is also involved in the development of practical instruments such as DuboCalc.

EVALUATION INITIAL DESIGN

Nr.	Remark	C
ID.2	Make explicit that EPL is meant in this indication.	A
ID.3	Make more explicit what is meant by renewable energy when this is not done in the instrument itself. It might have negative effects as well, for example burning biomass to generate energy also generates a high local emission of CO_2.	A
ID.5	Why is the unit per person, what does it have to do with infrastructure? Besides this is aimed at the operations stage.	R
ID.6	This indicates the technical performance of a system, but how is it possible to formulate criteria? If it is also applicable on sustainability then it should not be in units per time, but in percentages.	R
ID.7	What does specification mean? This indication is a yes/no question, which is not desirable in an assessment method.	A
ID.8	Irrigation of planting is in Dutch context with respect to use of water relatively nothing compared to water level management. It might be relevant to indicate the sustainable management of water level therefore.	A
ID.9	Are systems like these sustainable? Some research does indicate it is not.	A
ID.11	Car wash facilities is too much aimed on buildings and should not be part of an infrastructure assessment method.	R
ID.12	Make more explicit what is meant. Water companies all offer the same quality of water, so the indication does not have any distinguishing capabilities.	A
ID.13	Expert was convinced it should not be phosphor, but phosphate that is mentioned in the indication. He then stated phosphate is not relevant, but nitrate is with respect to the water filter technique being used. Later turned out, the original indicator did mean phosphor for sure, therefore the experts remark is not included in the analysis.	-
ID.15	Not a relevant issue in Dutch context, is part of standard regulations.	R
ID.18	This indication suggests two different methods. Besides, it is less applicable for infrastructure systems, because soil and sand are the most used materials. Make anyway more specific what criteria there are to determine what certificates are used.	A
ID.19	When looking at travel distance for the materials, this is already part of the shadow price for materials. Besides it is less applicable to infrastructure systems.	O
ID.20	The indication is too specific. Besides it could also be possible to use moulds in an innovative way as part of the construction, this is in that case not rewarded.	R
ID.21	Soil is always being reused, part of construction regulations. Sometimes when it is contaminated, it will first be treated as waste, but later it will be reused. A relevant indication might be the percentage that indicates the extent to which the ground balance for the project development is closed.	R
ID.22 /23	Make it specific for each type of material, because the conditions will also vary between different types of materials.	O A
ID.24	This method is not correct, because it is not simple to determine what is more sustainable. It is a design choice, and life cycle analysis is standard procedure.	A
ID.28	Total mass is not the information needed, what does it say? What is the distinguishing capability of such an indicator? It might be possible to make it more relative in proportion to the used sources.	A
ID.31 /32	Partly this is common practice already. Obligating the contractor via contract clauses might be a good method. The indications are relevant, but make them more explicit.	A
ID.34	This is common practice and already done in the economic most efficient way by commercial companies.	R
ID.35	Make this more specific, what is meant? What does FSI mean and what is the advantage when infrastructure is part of the calculation? It should at least be referable.	A

Nr.	Remark	C
ID.36	Inverse indication of ID.64,65,80. Location choice is for infrastructure specifically for road infrastructure relevant.	O
ID.37	Make explicit that VPL is meant in this indication.	A
ID.39	The method of this indication calculates just a figure, it does not say anything about the systems sustainability.	R
ID.41	The proposed theme is relevant but the method needs to be more specific, whit the available information it is not possible to calculate and refer the indication.	A
ID.52	Number of accidents is in principle not related to the design. Besides the differences between projects will be thus small that comparing is not possible.	R
ID.55	Routes for construction transport might be also a part of the Considerate Contractors certificate. Moreover, this is to an high extent part of standard procedure, it will be difficult to distinguish on this subject.	A
ID.56	In this way the indicator is not measurable, it is then better to remove it. Of course safety is important, but it is very hard to measure, for sure in a referable way.	R
ID.63	Just the number of felled trees is not relevant, it should at least be relative. Also include new proposed planting.	A
ID.64	In Dutch context it is almost impossible not to adjoin with a protected area. The indication therefore needs to be made much more specific and otherwise removed. Moreover there is overlap with indication ID.36.	O
ID.65	This indication is overlapping with ID.36. Join the three indications and formulate a clear and extensive new one.	O
ID.66	Looking at biodiversity, just this indication is little. It is possible to calculate biodiversity in a simple manner, reflect it before and after the development.	A
ID.75 /77	Also indicate how much of the CO_2 and fine dust can be absorbed and balanced in the area. Also be aware that the emissions due to production processes already are part of the shadow price of materials.	A
ID.76	Delete this indication, it has not a clear relation with infrastructure (alone).	R
ID.80	This indication also is overlapping ID.36. Join into one indication for location choice.	O
ID.89	What will the content of these contract clauses be? When it is a yes/no indication it is to thin. It should at least be specifying minimum content of the clauses, and these minimums should be above standard regulations.	R
ID.92	The same argumentation as ID.89 holds for this indication. Make it more specific and worthy enough for developers to be able to distinguish their project with the indication or otherwise remove it.	R

Suggestions for measures

Nr.	Theme	Suggestion	CD
SI2.1	Innovative materials	Reward the use of materials that are not yet included in the new harmonized database and of which can be shown that their shadow price is significantly lower (more sustainable).	-

Innovation strategies

Using the certificates as a design tool does not have to be negative in the first place. Structuring the instrument in the right manner will help designers to always go to the edge of possibilities and stimulate them more to innovate. Make it possible for them to use the instrument flexible and to trifle with certain criteria, optimizing their design. These certain criteria should be the criteria with the most impact on the sustainability of the project development. Be aware the designer will focus on the categories of the assessment method that are rewarded the best, to which the highest weights are allocated.

Other strategies might be to split the three dimensions of sustainability explicitly, give designers room to work with each of these. Also try to avoid to formulate the indications to rigid, for example by prescribing the means to be sustainable. Several indicators in the initial design are example of too specific indicators. This is a well known paradox of normalization and innovation. It is also possible to give designers an exit-strategy: make it possible for them to design solutions that go beyond the formulated criteria, but that can be assessed by a panel of experts and in this way be rewarded in the total score of the assessment. It is further recommended to evaluate the designed assessment method on restriction for innovations after it is used for two years.

FURTHER COMMENTS

All indications for climate are measuring the extent of pollution or emission. But indications that challenge the designers and measure practices to neutralize the emissions are lacking. Also take another look at the categories for water treatment and management and discuss it in detail with an expert. Some indications are overlapping, others are lacking here.

A.IV.IV INTERVIEW REPORT E.3

Expert number: E.3
Function: Program Manager
Organization: Senter Novem – Program Energy Reduction GWW
Specialism: Energy
Date: 23-10-2009

NOTE

An interview was scheduled with this expert to evaluate the indications for the category energy. In the end the interview had to be cancelled, due to lack of available time of the expert. However, the department energy reduction in civil engineering industry, of which the expert is a manager, is considered the best organization to evaluate the energy category indicators of the initial design. Therefore, instead of an extensive interview, the proposed indications are evaluated with the expert by e-mail.

EVALUATION INITIAL DESIGN

Nr.	Remark	C
ID.1	Consumption of energy by infrastructural facilities are calculated, but the data might be outdated (2005). It is however better to assess the achieved energy reduction than actual consumption (which is also hard to measure).	O
ID.2	Assessing energy reduction is seen as critical. Possible units of measurement are %, kWh or CO_2 reduction. The latter is the unit used by the proposed EPL methodology.	CI
ID.3	There is no data available on the contribution of renewable energy for infrastructure installations in current practice situation. Renewable energy initiatives of course contribute to CO_2 reduction and are therefore relevant.	CI
ID.4	Public lighting being the biggest consumer of energy in infrastructure is confirmed. It is for this reason that the program for energy reduction of Senter Novem now concentrates on this aspect. The potential for energy reduction on public lighting in municipalities is calculated to be about 18%. It is therefore very relevant to assess public lighting separately, to stimulate initiatives on this field. However, the terminology of the indicator (energy saving, burn unnecessary, social safety) is very subjective, this should be made more explicit.	A

A.IV.V INTERVIEW REPORT E.4

Expert number: E.4
Function: Expert Urban Water Management
Organization: Tauw
Specialism: Water
Date: 06-10-2009

JOB DESCRIPTION

Tauw Water is a department where different disciplines concerning water management are clustered. The department consists of experts in urban water management, groundwater, ecology, spatial planning, waste water etc. Primarily they advise municipalities with regard to their policy on (waste) water management and study the (waste) water cycle, decoupling possibilities, energy use in the water cycle and finally storm water storage solutions. The expert is specialized in urban water management and sewerage systems. He obtained his doctorate with a thesis on water flow in storage basins. Besides his job at Tauw, he also is lector urban water management at the Hogeschool van Amsterdam. He was involved in the development of the practical instrument MIMOSA, a model to assess sustainability of a water cycle. However, the model is currently not being used anymore.

EVALUATION INITIAL DESIGN

Nr.	Remark	C
ID.5	In Dutch context water use quantity is less relevant, cause there is sufficient potable water that can be purified inexpensive. Efficient water use might be a better goal of the assessment. Possible is to assess the self-sufficiency of the area in water use, the extent to which the water cycle is closed for the area. Water collection is often not (efficient) possible locally, but reduction of water need and reuse are aspect that can be incorporated. An indication might be the net quantity of imported water in the area referable to standard values. Formulate it in a way that extent of reduction, reuse and removal are implicitly incorporated.	CI
ID.6	Installation of new systems always are of sufficient quality regarding leakage. Leakage on average is about 1 to 2% of the systems input. Reducing leakage is part of an efficient water system.	R
ID.7	The water board will also have such systems, and control on these aspects. It is less relevant for an area development. Moreover, if efficient water system is the goal, this indication is overlapping.	R
ID.8	A relevant indication for sure. With changing climate, drought during summer times is less an exception and irrigation then always is an issue.	O
ID.9	This indication is critical, very relevant, but there might be overlap with indication ID.10. Reuse is reflected sufficient in this indication, but it is necessary to make it referable. A possibility might be a percentage in proportion to total water consumption.	O
ID.10	Overlap with indication ID.9.	O
ID.11	The indication is too specific, it prescribes a solution but it is not possible to generalize. Moreover it is also overlapping ID.9.	R
ID.12	Use of chemicals is too general, at least separate it in type of chemicals. But it is closely connected to the chosen treatment technique. It is however relevant and possible to assess: ask about the used chemicals and quantity in the treatment system for potable and sewerage water within the boundaries of the area.	A
ID.13	Reuse of phosphor is getting more relevant in water cycle practices. However, it is just significant if there is an industry in the area that uses a lot of it. Therefore in most cases it will not be a relevant issue.	R
ID.14	It is impossible to measure this in design stage. Besides, it is very dependent on the chosen systems and techniques. Moreover, much of this is already regulated in norms and legislation. It is however relevant to assess if there are any preserving measures in the area to prevent contamination of water caused by runoff (leaching materials, spread salt), but that is overlapping ID.84.	O
ID.15	Potable water and sewerage systems are standard in Dutch context. If sufficient space is available it might be relevant to purify used water locally, but it remains the question if this cannot be done more efficient in a large scale central plant.	R
ID.68	Relevant indication, to assess on percentage that is decoupled. Most relevant point is to decouple as much as possible from the treatment plant.	CI
ID.69	Regarding storm water self-sufficiency is very relevant. It is important to prevent that problems are passed to another area. Open water is a relevant indication for storm water capacity (ID.72).	A
ID.70	It is very complex to assess the impact on ground water. Deep ground water will not be impacted in anyway. The extent of the impact will be limited in the high streams as well. Drought might be a consequence, but is a very local problem. In the light of the scope of this method the whole issue is comparatively speaking of less importance.	R
ID.71	This indication is overlapping with ID.72. But is also not clear what is the meaning of the indication, is it better to have more open water in the surroundings? How is this done in urban areas?	O
ID.72	Surface of open water can be very relevant as an indication for storm water capacity, but is in other lights less important (but for esthetic reasons only).	O
ID.73	Only relevant if the ecological banks are to be used for water treatment, to preserve water quality. Otherwise it is comparatively of less importance.	R
ID.81	This indication needs of course to be made more specific, how will this be measured? But is very relevant.	A

SUGGESTIONS FOR MEASURES

Nr.	Theme	Suggestion	CD
SI4.1	Water treatment	Water treatment is lacking in the assessment method (except for the chemical use indication). It is possible to measure the percentage of sewage water that is not reused but treated within the boundaries of the area (i.e. does not have to be treated in a water sewage plant)	28

Nr.	Theme	Suggestion	CD
SI4.2	Storm water capacity	Surface of open water can be regarded as an indication for storage but available space (which can be paved or build-on) that can be used as overflow in case of extreme precipitation can be seen as open water too. Might be divided in two percentages in assessment method.	26
SI4.3	Water quality	Water quality of open water is very complex to assess. Calculations are complex and in every case very different. It suffices to assess the extent to which water quality has been an issue during design stage. If studies are conducted, a sustainable solution can be assumed. ID.73 is related to water quality as ecological banks are an example of sustainable practices.	27

INNOVATION STRATEGIES

It is desirable that each project will be designed with open eyes and thinking out of the box, but this will never be practice. Make sure that the instrument contains enough possibilities for designers to reach for the edges of what is known. Make it comfortable for them to use the method as an innovation tool. For example, by assessing the percentage of decoupling from sewage system, you leave room for designers to implement whatever solution they come up with. The same holds for the indicator for water use quantity, assessing the self sufficiency of the area stimulates to try new practices on such aspects.

FURTHER COMMENTS

Energy consumed to heat water is a relevant part of the all energy consumption. Many models just incorporate energy consumed to transport and purify water, whereas by far most of the energy consumed in the water cycle is used for heating (for use in household and industry). It is therefore also possible to make progress in this field.

A well functioning, sustainable water system should be evaluated on three main elements: retain, store and removal. Retain is for example possible in green roofs and planting (both outside scope). Surface of (space for) open water can be regarded as an indication for storage. Net removal of water is related to the extent of water that will be used to clean and prevent from contamination and pollution.

A.IV.VI INTERVIEW REPORT E.5

Expert number: E.5
Function: Professor Materials and Sustainability and Managing director
Organization: TU Delft and Nederlands Instituut voor Bouwbiologie en Ecologie (NIBE)
Specialism: Materials
Date: 24-09-2009

JOB DESCRIPTION

The expert is active in two different organizations. He recently accepted the appointment as professor of Materials and Sustainability at Delft University of Technology. As professor he is active in both research and education. Besides he also is managing director of NIBE, an institute for research and advise on environment and health in the built environment. The goal of the organization is to make it possible to communicate about sustainable building. NIBE developed the environmental cost method for classification of sustainability of materials. Currently NIBE is involved in the development of DuboCalc and the national database for materials.

VISION ON INFRASTRUCTURE SUSTAINABILITY

The expert confirms assessment of infrastructure sustainability has been appointed less effort to in proportion to buildings. He states Greencalc+ does have a module that includes infrastructure of an urban area, but admits its application is limited. There is however a trend that energy systems are being examined with a bigger scope than just buildings. When looking at infrastructure sustainability, its relation with the ecological surroundings is very important because they are closely connected. It is valuable to found design and practices of an area development on the existing ecological elements of the area.

Evaluation initial design

Nr.	Remark	C
ID.1	Energy use should be energy consumption. Besides another unit should be added to make this an indication for energy thrift that is measurable and relative. This might be per m2 gross area surface.	A
ID.2/3	EPL is not yet a regulatory reference, but it is a valuable method.	A
ID.4	Lighting is indeed an element of infrastructure that uses the most energy. It deserves extra interest.	A
ID.15	This is not relevant in Dutch context, it is part of standard procedures and construction regulation.	R
ID.16	Same argumentation as ID.1, add an extra unit like m2 gross surface. Mass is relevant for sure: weight and sustainability of materials appear to be related. Light materials always are of less environmental impact, and this is not only related to the consumed energy in the production process.	O
ID.17	Environmental cost indication is the most valuable method available and should be critical. It is possible to split the environment cost of energy and materials, make this clear in the formulation. Energy is in this context the embedded energy: energy used in the materials production processes. It is very well possible to use the indication in a method like BREEAM, as has been done in BREEAM-NL.	CI
ID.18	This indication can in principle not be used in Dutch context. It is based on the system of relative classification used in Great Britain. Relative classification is closely connected with absolute assessment: the latter is based on the first and gives more information. Absolute assessment (such as with the shadow price ID.17) should be preferred.	R
ID.19	This indication is only valuable when it concerns a weight percentage.	A
ID.20	Not relevant, especially not with respect to infrastructure because moulds are relatively not used much. Moreover, the indication is means directed and relatively much less relevant as the other proposed indicators.	R
ID.21	The theme of this indicator is relevant. However is should better be formulated as the percentage in which the ground balance is closed for the project development.	A
ID.22 /23	This indication is only valuable when it concerns a weight percentage. High-grade applications should be defined in more detail. Use just percentages for recycling and reuse that are known for sure in the design phase, do not involve percentages that are estimated for intended recycling or reuse in the future, for this is too insecure.	A
ID.24 -26	The proposed method of the indication can be used and they are for sure relevant. But it should be made more specific how to measure it.	A
ID.27	Origin of materials is relevant for two reasons: distance costs energy and for some material certificates are available that guarantee sustainable management. The method might be as follows: materials provided with a certificate can be assessed positive by default and other materials can be classified according to distance and this can be related to the shadow price of environmental cost.	A
ID.28	This indication is only valuable when it concerns a weight percentage. Lifecycle is too insecure: there is always a percentage of recycling, reuse and waste, but it is impossible to ascertain how these will be divided. This is why it is better to just involve the weight percentage of waste in the construction stage.	A
ID.29	What advantage does local composting have with respect to the green waste collection as known in Dutch society. In the latter situation the product (compost) can be used in a useful and efficient manner: as dung or biomass. The value of the product decreases when this is done in backyards.	R
ID.31	Do not only secure this in contact clauses. Make it quantitative. It is possible to reward the relative performance of the constructor in proportion to mean values.	A
ID.34	The relevance of this indication is dependent of its intention. When it is intended to assess the routes of the waste collection vehicles, it is relatively not important. However, When it is related to the mode chosen for this waste collection, it is relevant. Modern vehicles might be more environmentally friendly and maybe other innovative solutions might be too.	R
ID.60 -62	One step should precede these indications: a study on valuable ecological elements of the area to determine which measures should be taken (see ID.88). All elements should be classified in order to be able to preserve the most valuable elements. The indications can be formulated in one.	CI O
ID.63	For the indication as proposed it is not possible to make a judgment or classification. The number of felled trees should be made relative in proportion to the total amount of trees in the area for example.	A
ID.69	This indication remains to vague. Define it more extensive and assess the specific measures that are available for this purpose.	A
ID.87	It is in social context a relevant aspect of sustainable development. But it is very hard to practice it, let alone to measure it. Moreover it is very dependent on the type of development if it is even desirable.	R
ID.88	This indication is related to ID.60-62, the preceding step might be measured as is proposed in this indication. Involvement of (local) sustainability experts in the development stage of the project should be rewarded in the assessment method.	O

Nr.	Remark	C
ID.91	Life cycle approach in design is closely related to the choice of materials. Not all the elements of this indication are included in the shadow price, but some are. Be careful for overlapping measurements.	O

SUGGESTIONS FOR MEASURES

Nr.	Theme	Suggestion	CD
SI5.1	Water	Some of the indications can be replaced by a single indication for the extent to which the water (or material, or energy) cycle is closed. Part of this might be the extent to which households or industries filter their own waste or rain water.	4 28

INNOVATION STRATEGIES

The expert suggests two different strategies. The first is to give users of the certificate the possibility to abandon standard procedure and criteria when they do not match with the innovative practices initiated in their project. Of course this can only be done when there is a founded argumentation. Another strategy is to include innovation as a standard criterion in the structure of the certificate. Developers will be rewarded when they add innovative solutions to the design. Formulating the criteria of the assessment method in a performance oriented manner should be a standard approach. But it is also possible to give more weight to the criteria that assess innovation in the certificate.

FURTHER COMMENTS

The potential of an area to generate renewable energy should be part of the assessment to make it a fair judgment. Only then it is possible to make comparisons between developments. When a high renewable energy potential of an area is not included in the development design, it should lead to negative appraisal.

Be aware that now in all indications for the category flora and fauna lesion (or the extent to which this is prevented) is the central theme. But it might be valuable to also assess the initiatives that add something to ecology. Thus, an inverse approach for the indications is proposed.

A.IV.VII INTERVIEW REPORT E.6

Expert number: E.6
Function: Key Account Manager Benelux
Organization: Van Gansewinkel Groep
Specialism: Waste
Date: 06-10-2009

JOB DESCRIPTION

The expert function is not directly linked to sustainability issues. But as key account manager Benelux, the expert is involved in the vision of the Van Gansewinkel Groep. In the vision of this company sustainability and cradle to cradle has a central place. Waste is seen as residual that can be used as resources for other products. The company is a DGBC participant and the expert is in his function responsible for the contacts with the foundation.

EVALUATION INITIAL DESIGN

Nr.	Remark	C
ID.20	This indication is to specific. Striving for reuse is good, but not just for moulds.	R
ID.22	In principle this could be 100%. Reused and recycled aggregate application is a common practice in civil engineering industry. Besides, in the vision of the expert waste does not exist, thus reuse and recycling will always fully be possible (be it in different products).	A
ID.28	Mass of waste does certainly add something, it is usually a relevant indicator. In scope of infrastructure, it is however less relevant. In a products lifecycle most of the residuals come apart during demolition and the second during realization. For infrastructure almost all the residual of demolition can be reused or	O

Nr.	Remark	C
	recycled. Waste during construction is therefore comparatively speaking the only relevant aspect (see ID.31).	
ID.29	Local composting of organic waste is of course possible, but it is questionable if this is also efficient. Probably, the product will not be used. If organic waste is collected centrally it can be efficiently used as compost or biomass (to generate energy).	R
ID.30	Separation of waste is becoming a central issue in waste management. It is relevant if waste is considered residual and will be used again. There are norms and regulations for the maximum distance between households and waste collection points, centralization within the boundaries of this regulation is more energy efficient than house to house collection.	CI
ID.31	It is possible to compel this in contract clauses, but it should be made comparatively. Refer it to average waste numbers per a unit like surface.	A
ID.32 /33	These indications can be merged, because if waste is separated, it is consequently also recycled or reused (if possible). Separation therefore is the leading indication, what counts is the amount (for example volume percentage) of waste that leaves site in mono streams.	A O
ID.34	There are different norms and legislation that regulate waste transport. Planning of routes is the least waste collectors (have to) do in order to work efficient. This is comparatively speaking not relevant in light of the rest of the assessment method.	R

Suggestions for measures

Nr.	Theme	Suggestion	CD
SI6.1	Energy	It is possible to generate energy by burning waste. In principle an urban area will be a too small scale to install an incinerator, but it might be considered. Of course it should also be desirable in light of other (social) sustainability items.	-
SI6.2	Waste facilities	Facilities for public collection of waste are lacking in the assessment method. These are the facilities that are not bounded to households or industry.	CD. 10
SI6.3	Waste transport	Cleaner transport of waste is also a sustainability aspect. Instead of using diesel engine trucks it might be possible to use electronic cars. In some cities robots clean the streets and collect waste. Another example is the underground construction of canals under high pressure that extract waste of a whole area.	-

Innovation strategies

Create the assessment method in such a manner that it leaves as much possibilities for designers as possible. Adopt an open option approach, give the designer space, instead of restricting him. Specifically for innovation it is also possible to include an extra category in the structure.

A.IV.VIII Interview report E.7

Expert number: E.7
Function: Consultant Mobility & Logistics
Organization: TNO Mobiliteit
Specialism: Transport
Date: 12-10-2009

Job description

The department Mobility & Logistics of TNO acts as advisor for business and governmental organizations. The department is broadly oriented and has experts in the same wide range: emissions, vehicles, planning, asphalt etc. The expert interviewed is currently involved in projects with themes such as robustness of road networks, intelligent transport systems and checking of mobility design on CO_2 reduction measures. He also is involved in the development of Urban Strategy, a model for integrated urban planning which makes it possible to illustrate the consequences of design choices instantly.

Evaluation initial design

Nr.	Remark	C
ID.37	Mobility in fact is the central theme to which everything is connected. It is better to remove it from the assessment method, because it is also possible to improve mobility without sustainable development. To be sustainable in transport it is either possible to decrease mobility (socially not desirable) or to choose for better modalities. Transport mode is thus the key in sustainable development of urban areas.	R
ID.38	Same argumentation as ID.37	R
ID.39	This information can be used as input for mobility calculations. It is relevant information, but does not say anything about sustainability.	R
ID.40	The more facilities in surrounding of railway station the better is the underlying thought of this indication. But is an inverse of ID.42, which is used in sustainability context more often.	O
ID.41	Good indication to assess the stimulation measures for pedestrian and cyclist traffic.	A
ID.42	Stimulation of public transport is stimulating clean transport modalities and therefore a key to sustainable transport. The proposed indication is often used in this context.	CI
ID.43	Traffic or travel information is relatively not impacting mode choice. This transport mode choice has already been made before this information reaches the traveler (e.g. at home, outside the area). The traveler has to return with the same mode and thus this information does not contribute. Theoretically it might be helpful, but in practice this is relatively not interesting	R
ID.44	These characteristics of travel facilities are in Dutch context part of a standard procedure. It might be useful to ask what will be done extra in this light.	A
ID.45	This indication is directly linked to ID.37, but it is very relevant in sustainability context. It can directly be impacted by choosing for cleaner modalities. Measures to stimulate this are also part of it (e.g. electronic public transport, battery charges for cars, free electronic bikes etc.)	O
ID.46	In many cases the background concentration is already high. Besides, in some cases norms are already exceeded when people start complaining. This indication is thus very dependent on the location of the area development. It is therefore hard to assess and the chosen method might be sensitive.	R
ID.47-50	Planning of network is in Dutch context done using the so called sustainable safe regulatory guideline. The proposed measures are all part of this standard procedure.	A R
ID.51	This can be seen as a facility to stimulate cleaner transport modes. It is however, closely related to the scope of building sustainability.	R
ID.52-53	Same argumentation as ID.47.	R
ID.54	A good indication for spatial planning for safety with lower emissions when 'without adverse consequences for accessibility' is added.	A
ID.55	Part of standard procedure.	R
ID.56	This indication is not assessable. Moreover safety of parking areas is part of a higher level safety, beyond the scope of this assessment method.	R
ID.57	Example of doing something extra with facilities. This relates to use of space.	O
ID.58	Not relevant. Same argumentation as ID.43.	R
ID.59	High correlation with indication for emission. Stimulating cleaner transport modes will also impact this energy use.	CI

Suggestions for measures

Nr.	Theme	Suggestion	CD
SI7.1	Emission	The relation between emission and energy use of traffic and the spatial planning of an area can be influenced (e.g. choice between roundabouts or traffic lights). This relation needs to be investigated.	-

Innovation strategies

It is indeed a well known paradox. It might be possible to formulate indicators with a certain room or freedom. The assessment can then be controlled with qualitative criteria and norms. Try to reach for as much flexibility as possible, and always formulate in sense of performance. For example assessing energy consumption of traffic, leaves space for numerous possible strategies to decrease this consumption. For transport category examples of too specific indications are the indications that are not applicable because they are standard procedure in The Netherlands. It should for all aspects be possible to exceed standard procedures. However, it might be very well possible to keep them in the assessment method and to assess the practices that are initiated that go beyond the standard procedures.

Further comments

See mobility as the performance of the category transport. Mobility can thus be influenced in a sustainable manner in three ways: quality of public transport (as main stimulation of cleaner transport modes), reducing energy and emission (by stimulating (other) cleaner transport modes) and facilities (safety, comfort, barriers, pedestrian and cyclist).

A.IV.IX Interview report E.8

Expert number: E.8
Function: Managing Director
Organization: ES Consulting
Specialism: Climate
Date: 06-10-2009

Job description

The expert is educated as architect and urban developer and has been occupied with sustainable building from the beginning. He has studied the differences between energy consumption in the housing industry and found that this had all to do with wind. His company ES consulting is originated based on this theory: ES stands for Energetische Stedenbouw. The advisory and research company focuses on the application of planting as a technical measure instead of just for visual purposes. The expert consists of architectural as well as climatic knowledge with respect to air, energy and noise.

Vision on infrastructure sustainability

Sustainable construction practices are mainly focused on buildings. Design approaches in urban development and public spaces are still mainly traditional and far behind many other industries.

Evaluation initial design

Nr.	Remark	C
ID.1	Make it possible to account for big energy consumers (such as datacenters) that are not common in all projects. For infrastructure the method is good.	A
ID.6	How can this be measured in the design stage of a project? It is only applicable if known exact. Moreover, relatively this indication is less relevant.	R
ID.10	A common trend is to try to close the water cycle locally. It is possible to collect and reuse gray water, but it would be best to do this central in an area.	A
ID.15	This indication is in Dutch context not relevant anymore. It might be possible to adjust it in percentage of households or area that purifies its own water.	R
ID.20	Not relevant, in infrastructure projects moulds are relatively not much used. Moreover the indication is too specific.	R
ID.21	Better to adjust in percentage in which ground balance is closed.	A
ID.22	Most recycled materials are instead used in less high-grade applications.	A
ID.24	Long term view should at least be a life cycle analysis.	A
ID.26	A percentage is certainly not a good measure, this will always be low. And how should be decided which materials are innovative?	R
ID.29	Planting in an area produces trimmings that can be used locally as biomass.	A
ID.33	Relevant topic, but how and by whom can it be controlled?	A
ID.34	This is only necessary for heavy chemical waste, and in those cases it is already accounted for.	R
ID.36	It is best to change this indication the other way around: all area and grounds that are in development should add new ecological value.	A
ID.39	In this way the indication is useless. Might be possible to couple it with certain road categories.	A
ID.63	Make number of felled trees more relative. Moreover the indication implies negativity, might be better to ask for number of trees or planting structures.	A
ID.66	Local flora accommodate much more animals than foreign species. For biodiversity this is therefore a relevant indication.	A
ID.69	The storage capacity of green roofs can contribute to this.	A

Nr.	Remark	C
ID.70	If groundwater will be impacted by infrastructure developments is measurable, but what is sustainable?	R
ID.74	Standard procedure of development projects. Besides what is under the ground, other issues like urban structures are also relevant.	R
ID.77	The sources of the emissions are roads and industrial activities, but they are now accounted for per individuals or household.	A
ID.78-83	These indications for emissions are now measured in totally different approaches. Choose one approach for all the emissions.	R
ID.84	Relevant aspect. The effect can be restrained if accounted for in the design phase.	A

SUGGESTIONS FOR MEASURES

Nr.	Theme	Suggestion	CD
SI8.1	Water	It is possible to filter water with greenery. This has been applied on buildings but can most certainly also be done centrally in an area. Another advantage is the delaying effect with respect to storm water capacity.	28
SI8.2	Transport	A good planting structure can neutralize all emissions. An indication might be if the planting structure has been optimized for the specific contaminations with respect to the plantings place and appearance.	35
SI8.3	Climate	Critical indicator. Emission, smell, noise, energy are all connected to the microclimate of wind in an area. This is why it is possible to affect this with planting structures. For example, optimizing the planting structure makes it possible to store CO_2. The indicator would be: is planting structure used as a technique to neutralize negative impacts on climate in the area?	35

INNOVATION STRATEGIES

Everything is a choice, specifically in modeling, and this determines the extent to which flexibility is possible. However, it is possible to formulate criteria in such a way that the patterns or mechanisms that exist are covered, but that the way in which these mechanisms are used is free. The patterns then still exist and define the minimum of the valuation. This is for example the case for the critical indicator for climate. If such an indicator is included, the patterns of wind connected to emission, noise etc are covered, but you can leave the way in which the patterns are influenced (and thus the extent to which it has a positive effect) to the developer. Validation is then possible, since there are general numbers available that describe the common effects of the patterns.

FURTHER COMMENTS

By situating buildings in the shelter of planting it is possible to save a significant 10% on energy for heating. An indication might be if a planting structure is deployed effectively for energy saving purposes. (However, this is outside the scope of the assessment method because buildings and greenery are.)

Appendix V – CASE DESCRIPTION

For the evaluation of the concept design the area development project Eeserwold is selected. In this appendix more information on this case in general and regarding initiated sustainable infrastructure elements is given. The website of the project developers has been used as source for this description (Eeserwold, 2009).

A.V.I GENERAL INFORMATION

A complete new area will be realized just north of the Dutch municipality Steenwijk. The area development project comprises the development of an housing zone and an industrial zone. These two parts of the area are separated by Eeser lake, which covers almost 60 hectare. The lake is used for sand extraction during realization and for recreation afterwards. The design and planning of the area development project are almost finished and the zoning scheme is ratified.

The practical evaluation in this study focused on the industrial zone of the area development, since the planning of this part is leading the development process and the realization has already started. Figure A V.1 shows the spatial planning structure of the industrial zone. The zone is divided in two separate parts, Eeser Campus for offices and Eeser Gaard for (industrial) businesses.

Figure A V.1 – Spatial planning structure of the industrial estate zone of case Eeserwold and an artist impression of the situation after realization.

A.V.II SUSTAINABILITY AMBITION

In general the developers have declared sustainability and quality as two keywords that are central in the development. In their view this sustainability ambition is computed in several characteristics of the project. The website of the project mentions several general characteristics such as an open spatial structure and application of multiple green structures. These ambitions are guarded in a architectural and spatial structure plan. Besides, several of the characteristics are directly related to the domains of technical infrastructure. One of the objectives of the practical evaluation is therefore to check the reflection of these aspects in the concept design. The (in the project organizations view) sustainable characteristics of Eeserwold are:

- LAKE SOURCE COOLING SYSTEM. This systems uses natural cold from the Eeser Meer to cool the buildings of the industrial zone. To pump the water from the lake through the area and back, a station has been realized besides Eeser Boulevard. In Figure A V.2 an artist impression of the station is visible, it is the white building situated in the lake. The estimated CO_2 reduction due to application of this system is significant (according to the website 88%).

- LED PUBLIC LIGHTING. Recently the project organization started a feasibility study on the application of LED technology for public lighting. The technology is new and a test installation for comparative analysis is part of the feasibility study.
- ACCESSIBILITY. The industrial zone is connected to several networks which increases accessibility. The A32 highway (and access routes) are right beside the project. In Figure A V.2 this is visible in the middle of the photo. The intercity railway station of Steenwijk is situated on an 15 minutes walk from the centre of Eeserwold. Besides, the area development will be connected with two buss stops. Finally, the industrial zone is connected to Steenwijkerdiep, a canal for boats till 800 tons.
- GLASS FIBRE CONNECTION. For communication purposes, a state of the art glass fibre connection cable will be realized. This communication facility will guard the reliability, flexibility and availability of the service.
- PARKMANAGEMENT. A management organization is established, consisting of several public and private parties that jointly will maintain the area during operation. The services this organization will offer vary from maintenance of public space, security till road signs.

Figure A V.2 – Artist impression of an helicopter view on the industrial zone of project Eeserwold.

Appendix VI – INDICATOR MATRICES CONCEPT DESIGN

This appendix contains various indicator matrices representing design steps in the concept design phase. The concept design is presented in the first paragraph, the remarks of the practitioners on this design in the second and the considerations of their suggestions in the third.

A.VI.I CONCEPT DESIGN

In the concept design the remarks and suggestions of the initial design phase have been processed. The concept design is presented in Table A VI.1.

STRUCTURE OF THE MATRIX

Table A VI.1 shows the concept design of an environmental assessment method for infrastructure sustainability. The first column contains a number for each indicator, CD stands for Concept Design. The categories of indicators are highlighted in bold text in the merged rows. A theme is formulated to further cluster the measures in each category.

Table A VI.1 - Concept Design (CD).

Nr.	Theme	Description
Energy		
CD.1	Energy performance	Technical infrastructure facilities using energy are part of calculation energy performance (EPL)
CD.2	Renewable energy	Energy generated in infrastructure is part of calculation energy performance (EPL)
CD.3	Energy efficient lighting	Application of efficient lighting
Water		
CD.4	Water need	Percentage of potable water imported in the area in proportion to total water need
CD.5	Water quality	Extent use of chemicals for treatment of potable and waste water within the area
Materials		
CD.6	Material choice	Percentage improvement of environmental cost (shadow price) due to material use in lifecycle in proportion to a reference situation
CD.7	Material reuse	Ascertained weight percentage of reused materials in proportion to total used materials
CD.8	Origin	The origin of a certain weight percentage of used materials is demonstrable
Waste		
CD.9	Management operation stage	Central facilities for separate collection of (recyclable) waste
CD.10		Facilities for not household or industry bounded waste
CD.11	Management realization stage	Percentage of achieved waste minimization by constructor in proportion to a reference situation
CD.12		Volume percentages of waste that leaves construction site separated
Transport		
CD.13	Energy	Energy consumption and related CO_2 emission due to traffic based on VPL-Kiss calculation
CD.14	Public transport	Quality public transport based on average distance to stops or stations, capacity and frequency
CD.15		Realization of more than standard facilities for travelers

Nr.	Theme	Description
CD.16	Pedestrian and cyclist traffic	Barriers for pedestrians and cyclists: ratio of travel distance compared to shortest connection
CD.17		More than standard measures for a safe pedestrian and cyclist network of ways
CD.18	Traffic safety	Surface percentage of restricted motorized traffic areas without reducing accessibility
CD.19	Land use	Surface percentage of flexible used road infrastructure
CD.20		Surface percentage use of locations with low ecological and natural value, which has been contaminated or has been developed before
Flora and Fauna		
CD.21	Flora and fauna	Study of existing relevant ecological elements in the area with local environmental expert organization and formulation of preserving measures for construction and operation stage
CD.22		Nett percentage of trees to fell due to infrastructure development
CD.23		Difference in biodiversity before and after development
CD.24	Green area	Surface of and average distance to green area in area development
CD.25	Water management	Percentage of not paved surface and uncoupled paved surface to uncouple rainwater from sewage system
CD.26		Total surface of (occasionally) open water to store extreme precipitation
CD.27		Perform study on optimal set of measures to ensure local water quality
CD.28		Percentage of waste water treated and drained locally
Climate		
CD.29	Emission	Percentage storage of greenhouse gasses in CO_2 equivalents
CD.30		Percentage storage of fine dust
CD.31	Noise	Difference in surface percentage of certain noise levels before and after development
CD.32	Water	Perform study for optimal set of measures to prevent contamination of (ground)water (due to runoff)
CD.33	Smell	Difference in surface percentage with certain smell nuisance category levels before and after development
CD.34	Light	Difference in surface percentage with certain light nuisance categories before and after development
CD.35	Neutralization	Perform study on possibilities to neutralize negative impacts on climate using planting structures

A.VI.II SUMMARY REMARKS ON CONCEPT DESIGN

The remarks following from the practical evaluation of the concept design are summarized in Table A VI.2. This table also reflects the final consequences for the indicators and references to the proposed design.

STRUCTURE OF THE MATRIX

In Table A VI.2 the summary of the evaluation of the concept design is presented. The first column again contains the number of the concept design indicator. The summary of remarks is based on the comments of the practitioners on the indicators (see Appendix VII). In some cases concluding considerations are added to this summary. The final consequences for the initial design indicators are reflected in the next column. The possible consequences (C) are:

- CI: This is a critical indicator.
- R: This indicator can be removed from the assessment method directly.
- O: This indicator is overlapping other (suggested) indicators and should be merged.

The last column of the table shows, if appropriate, a reference to the proposed design. That is, if an indicator from this concept design is used again in the proposed design (be it adjusted or merged) the number of the related proposed design indicator is presented here.

Table A VI.2 - Summary of remarks and final considerations on concept design.

Nr.	Summary of remarks	C	PD
Energy			
CD.1	Make the indication explicit related to energy performance of infrastructure.	A	1
CD.2	Make the indication explicit related to generated energy in infrastructure.	A	2
CD.3	Not just application, related to energy reduction extent.	A	3
Water			
CD.4	Little insight in water need in development stage. Make explicit measure assesses effectiveness of infrastructure systems.	A	4
CD.5	-	-	5
Materials			
CD.6	-	-	6
CD.7	Ascertained added to formulation.	A	7
CD.8	Origin of materials is always for all used materials demonstrable.	R	-
Waste			
CD.9	Downside of central facilities is a complex pay for use strategy.	-	8
CD.10	Relevance is doubted, part of standard procedure. To stimulate new practices on this field it is relevant to mention it separately.	-	9
CD.11	Improvement on waste management during realization has an high potential.	-	10
CD.12	Specifically for infrastructure reuse and recycling is common practice, therefore add the extend to which this is achieved locally.	A	11
Transport			
CD.13	-	-	12
CD.14	Clear method, indication is regarded as a common known indication. However, not always possible to manage the aspects.	-	13
CD.15	Make indication more explicit, it is vague. Removed, indications like these are possible for all aspects.	R	-
CD.16	-	-	14
CD.17	Removed, indications like this are possible for all aspects.	R	-
CD.18	-	-	15
CD.19	-	-	16
CD.20	-	-	17
Flora and Fauna			
CD.21	Study for flora and fauna is standard in planning procedures.	A	18
CD.22	Planting study is part of standard planning procedures and common practice. Is overlapping CD.21.	R	-
CD.23	Reformulate indication to create flexibility for assessment of practices efficiency.	A	19
CD.24	To an high extent dependent on type of area development, besides beyond the scope of infrastructure.	R	-
CD.25	Decoupling is to some extent part of standard procedures.	A	20
CD.26	To some extent measures for water storage are part of standard procedures.	A	21
CD.27	Extend study for more than just water quality.	A	22
CD.28	-	-	23
Climate			
CD.29	Emission of greenhouse gasses and fine dust merged.	A	24
CD.30	Emission of greenhouse gasses and fine dust merged.	A	24
CD.31	Reformulate indication to create flexibility for assessment of practices efficiency.	A	25
CD.32	-	-	26

Nr.	Summary of remarks	C	PD
CD.33	Reformulate indication to create flexibility for assessment of practices efficiency.	A	27
CD.34	Reformulate indication to create flexibility for assessment of practices efficiency.	A	28
CD.35	-	-	29

A.VI.III SUMMARY SUGGESTIONS FOR CONCEPT DESIGN

All suggestions for other ways to measure environmental aspects in the assessment method and for other elements of infrastructure lacking in the concept design are listed in Table A VI.3.

STRUCTURE OF THE MATRIX

The suggestions for the concept design are listed in Table A VI.3. The numbers of the suggestions refer to the number of the practitioner (for example SP2.1 is the first Suggestion of Practitioner 2). The description is a summary of the suggested indication. The next column reflects the considerations for including the suggestions in the proposed design or not. If the suggestion will be included in the proposed design, a reference to the related number is showed in the last column.

Table A VI.3 - Suggestions for additional indications on concept design.

Nr.	Theme	Suggestion	PD
SP2.1	Infrastructure facilities related to safety and violence protection.	These facilities exceed the scope of infrastructure, they are more related to buildings. Besides, if not standard procedure, relation to sustainability is doubted.	-
SP3.1	Indication for effort in design stage to organize maintenance management.	It is a relevant indication, but related to management. Suggestion is not included since category management is abandoned in concept design.	-
SP3.2	Indication for multifunctional (land) use in the area.	Related to infrastructure it is incorporated in indication for flexible infrastructure.	-
SP3.3	Indication for communication infrastructure such as data cables.	Is relevant aspect, no separate indication for communication. But too specific, moreover part of planning for maintenance using life cycle analysis.	-

Appendix VII – Practitioner Interviews

In this appendix first the interview protocol is presented, which is used to structure the course of the interviews with practitioners. Subsequently, the interview reports of all three interviews with practitioners are included.

A.VII.I Practical evaluation protocol

Name:
Organization:
Date:

Introduction

Thank interviewee for cooperation.

1. Opportunity for interviewee to ask questions about the preparation document. Is context and method of research clear? Is (scope of) initial design clear? Is objective of this evaluation clear?

2. Sustainability ambition of Eeserwold: Specific examples of this ambition related to infrastructure system.

Evaluation concept design

3. Propose to discuss remarks on the indicators (clearness, proposed method, other) per theme. Specific prepared questions are also asked per theme.

Nr.	Remark	CO

4. Discussion of the completeness of the design. Are all sustainability items reflected? Are all infrastructure elements reflected? Ask specific prepared questions per theme.

Theme	Suggestion	CO

Innovation strategies

Clarify the innovation paradox and the intention of the questions.

5. Do the developers recognize this paradox?

6. Innovation at Eeserwold. Examples of sustainability innovations and description of the processes of these innovations? Ask Interviewee to imagine the possible effect of an assessment method on these processes.

Clarify strategies to solve paradox.

7. Opinion on applicability of strategies. Discuss indicator formulation requirements.

To conclude

Are there other remarks that the expert wants to discuss? Thank again for cooperation and time.

A.VII.II INTERVIEW REPORT P.1

Practitioner number: P.1
Function: Project Manager Spatial and Economical Development
Organization: Gemeente Steenwijkerland
Date: 29-10-2009

JOB DESCRIPTION

As project manager the respondent's job is to guide spatial development projects like Eeserwold on legal aspects. Specifically in the case of Eeserwold his job is to manage arrangements between the two involved commercial parties and the local municipality.

GENERAL INFORMATION ON THE CASE

The two commercial project development firms involved in the development of Eeserwold both own parts of the ground of the development, the local community does not own anything. The commercial parties agreed to develop and realize the infrastructure, buildings and houses in constant consultation with the municipality. After realization and selling of the buildings and houses the public space will be sold to the municipality for the symbolic fee of one Euro. The local community beforehand gave the developers a list of wishes and demands with respect to this public space.

SUSTAINABILITY AMBITION

The practitioners were asked to explain the formulated ambition that 'sustainability and quality are central aspects in the development of Eeserwold'. Practitioner 1 answered that these aspects were certainly not there from the beginning. The project already has a long history and sustainability aspects were not specifically involved in the original Structuurvisie dating from 2002. The fact that these aspects are now mentioned as central is a consequence of recent developments. He mentions the lake cooling system and the 'sustainable safe' certificate as specific examples of the ambition.

EVALUATION INITIAL DESIGN

Respondent A did not note any comments before the interview. Because of his function he concentrated on the legal aspects of the development and therefore does not know much about specific aspects of infrastructure. He recommends to interview the head of public works on this subject as well (Practitioner 3). Despite this remark the following aspects are discussed.

Nr.	Remark	C
CD.14	This indicator and the proposed method is clear, the practitioner agrees it is a common way to examine the quality of public transport. Provincial policy was starting point in planning of public transport facilities for Eeserwold, new office buildings should be developed close to railway stations. Furthermore the existing bus connection has been expanded with two stops for the development of Eeserwold.	-
CD.20	The land used on the location of project Eeserwold was not used before, but was not of high ecological value (which is investigated).	-
CD.21	Investigation of flora and fauna is a standard procedure in area development processes, so the indication should be slightly reformulated in order to be able to contrast between projects.	A
CD.22	To reckon for trees is partially a standard procedure of making an urban development plan. Furthermore it does not add anything special to indication 21.	R
CD.26	In the development process of Eeserwold water management really was a difficult aspect. The site was locally seen as the drain of the whole area. This has been solved by raising the site using sand from the lake. The lake can now be used as extra water storage facility in case of heavy rainfall.	-

SUGGESTIONS FOR MEASURES

The interviewee was asked about an indication for the relation between infrastructure and spatial planning. In his vision this relation is reflected implicitly but sufficient in other indications of the concept design.

Innovation

The practitioner recognizes and confirms the existence of the dilemma as it was explained. As an example in Eeserwold he mentions the certificate for 'sustainable safe' (for violence safety) that is achieved for the area. In this process the developers also just looked what had to be done to get the certificate. He also recognizes the different strategies that were suggested by the experts but cannot mention specific examples of innovations in Eeserwold and what the consequences of the different strategies would have been.

A.VII.III Interview report P.2

Practitioner number: P.2
Function: Project Manager Public Works
Organization: Gemeente Steenwijkerland
Date: 11-11-2009

Job description

The practitioner is involved in development of Eeserwold as project manager of the public works department of the municipality. In this function he has insight in the designs of the specific infrastructure practices proposed for the area development.

Sustainability ambition

To some extent sustainability is generally included in al spatial development projects. This is since there are standard protocols and procedures that incorporate such aspects. However, in the case, the ambition has indeed been formulated explicitly.

Evaluation initial design

Nr.	Remark	C
CD.1 /2	Make more explicit what this indication is meant for. Is the goal to just assess if infrastructure is part of the calculation or is the actual goal related to energy performance?	A
CD.3	Public lighting is indeed a relevant aspect of energy use for infrastructure and deserves an extra indication. In Eeserwold LED lighting will be applied as try out case.	-
CD.4	There is not much insight in the need for water in the design stage, especially not for development of business or industry parks. This is because in the design stage is not yet clear what kind of industries will settle. An example of water reuse is when it is stored for use by firefighters.	A
CD.5	Treatment and drainage of water from car wash facilities and runoff is locally possible. This is reflected in detail in CD.28.	-
CD.8	Origin of materials is demonstrable for all used materials. There are standard procedures and regulations that require this. Materials should be delivered with certificates that indicate origin, production date, production norms etc.	R
CD.9	Central facilities have as downside that it is more complex to let the disposer pay for the amount of waste, but it is not impossible.	-
CD.10	It might be relevant to mention this separately to stimulate practices on this field.	-
CD.11 /12	Waste management during construction is a relevant aspect with an high potential for improvement.	-
CD.15	This indication is vague. Is it not part of CD.14? Examples of extra facilities for travelers are accessibility for disabled persons and bus stops planning.	-
CD.22	Felling of trees is inevitable in Eeserwold case, but in the design there is enough room for replant of trees. Moreover, a planting study is part of standard legal development planning procedure and trees are a standard element of such studies.	R
CD.23	In municipality Steenwijkerland it is decided to turn in mow method from intensive to extensive: this leaves more space for plants and animals. It is not mentioned specifically in the assessment method, but it might be an example of a practice to increase biodiversity. Current indication leaves no room for initiated practices.	A
CD.25	To some extent decoupling of rainwater from sewerage system is obligation, part of building permit. Therefore, make invisible what basis effort should be to be differentiating.	A
CD.26	For Eeserwold the lake is used for storage purposes. However, in some extent this is also part of a standard	A

Nr.	Remark	C
	development planning procedure.	
CD.27	This indication might be extended for other aspects as just water quality? For example, practices to release ground water tension (such as seepage drainage) are also very case specific and can be subject for study.	A
CD.29 -35	Of course these are al relevant aspects. It is however necessary to make very clear how it will be possible for a development project to be differentiable on these aspects. There are already norms and regulations for these aspects, so assessment of sustainability should exceed these norms.	-

Suggestions for measures

Nr.	Theme	Suggestion	FD
PS2.1	Violence safety	The theme safety is lacking in the assessment methodology. It is possible to include an indication for infrastructure facilities related to safety and violence protection. Example are centralized video surveillance, barriers and fences.	-

Innovation

Compare the solution strategies to initiatives for integrated contracts in construction practice. Principals formulate functional demands for the design of construction projects in a way designers and constructors can approach these innovatively. (In this way) it is possible to create liberties in the formulation of the criteria for the assessment method. It requires however a more complex formulation of the norms and values to guard a certain requested (sustainable) quality. The practitioner does not have insights in the processes preceding the innovative techniques that are implemented in Eeserwold.

A.VII.IV Interview report P.3

Practitioner number: P.3
Function: Project Manager Planning Development
Organization: Roelofs Planontwikkeling
Date: 30-10-2009

Job description

As project manager practitioner 3 has been involved in the development process of Eeserwold. Roelofs Planontwikkeling is responsible for the design and realization of infrastructure in the development of Eeserwold. The company has been involved in the development from the beginning, as they own part of the land the project will be realized on.

General information on the case

Within the company consist different views on sustainability, the division Planontwikkeling is mainly concerned with social aspects of sustainability. For example they are focused on creating commitment between involved stakeholders and on good communication.

Sustainability ambition

Has been clearly formulated for project Eeserwold. In the view of the practitioner it now also is a central aspect in the actual planning. For example for infrastructure he mentions the lake cooling system and the extensive sewage system.

Evaluation initial design

Nr.	Remark	C
CD.2	The application of the URCool Lake Cooling System, which was invented for Eeserwold, is represented sufficient in this indicator.	-
CD.8	In principle the origin of all materials are demonstrable. It is therefore questionable to what extent this indicator will be of comparable value.	R

Nr.	Remark	C
CD.10	The relevance of this indication is doubted. In principle public waste facilities should be part of a standard procedure.	R
CD.12	The objective of this indication is to be able to recycle or reuse waste. This is however specifically for infrastructure materials common practice. Therefore add to the indication that it should be stimulated to reuse residual on the same location.	A
CD.14	In some types of area developments it is not possible to control these aspects, the developers are then dependent on existing public transport facilities.	-
CD.22	This also is standard procedure in area development processes. Planning for more green and trees is common practice. However, making this indication part of the methodology stimulates designers and practitioners to think about it.	-
CD.24	This indication is to an high extent dependent on the type of area development that is assessed. For example in some urban areas it is not possible to incorporate green areas.	A
CD.28	In Eeserwold there are three different sewage water systems: for rainwater from the roofs, rainwater from pavements and used drink water (gray water). This possibility is in the current formulation not reflected.	A

Suggestions for measures

Nr.	Theme	Suggestion	FD
SP3.1	Management	In the assessment method an indication concerning maintenance management is lacking. In the case of Eeserwold a lot of effort has been put in the establishment of a park management organization.	-
SP3.2	Land use flexibility	The possibility for multifunctional use of (elements of) the area. For example the lake in the area is used as a sand extraction depot, as essential part of the lake cooling system and is furthermore also part of the main ecological structure in the area.	-
SP3.3	Communication infrastructure	In Eeserwold a glass fiber connection is realized. To date this might not be very stunning but ten years ago, when there was first talked about the development, these plans were already there. It is therefore good to add an indication for communication facilities.	-

Innovation

The respondent mentions a lot of innovations or new concepts that were applied in the development of Eeserwold: Lake Cooling System URCool, threeway sewage system, open characteristic by reducing building density, multidisciplinary functions of the area and using the lake as water storage facility.

At Roelofs Planontwikkeling they recognize that developers use checklists and other tools in the design of new projects. But their ambition is to go further. They therefore listed criteria from multiple instruments in their own checklist and formulated demands for each of their projects to go beyond these criteria. Using a checklist thus is not a limitation for innovation but a guarantee for minimal sustainability. The consequence is however that at Roelofs they would not let a certain certificate reduce their ambition for sustainability.

The dilemma is however impossible to solve. New concepts or innovations are not easy to assess. It might be possible to use functional demands (as in design and construct tenders). Another strategy might be to bring the innovation back to percentages of existing themes, thus making the performance of the innovation relative to existing criteria. Try to express it in existing terminology.

ISAM: Een methode voor het beoordelen van

Duurzaamheid van Infrastructuur

ISAM: Een methode voor het beoordelen van

Duurzaamheid van Infrastructuur

J.F. van de Pol
Enschede
Januari 2010

INLEIDING

In de bouwsector neemt de aandacht voor transitie naar een duurzaam bebouwde omgeving toe, waardoor het noodzakelijk is om duurzaamheid meetbaar te maken. In 2009 is de Dutch Green Building Council gestart met de ontwikkeling van DGBC Gebied, een certificaat voor de beoordeling van duurzaamheid van gebiedsontwikkelingen. In deze context is het van belang om de relatie tussen de verschillende elementen van een gebied (zoals gebouwen, publieke ruimte en infrastructuur) bij beoordeling op duurzaamheid integraal te beschouwen. De meeste bestaande instrumenten, methoden en databases voor het waarderen van duurzaamheid zijn echter gefocust op de beoordeling van gebouwen en in mindere mate op technische infrastructuur voorzieningen.

ISAM

In het licht van deze ontwikkelingen is een methodiek ontwikkeld die specifiek gericht is op het beoordelen van duurzaamheid van infrastructuur in de context van gebiedsontwikkeling. De methode heeft als titel ISAM, wat staat voor Infrastructure Sustainability Assessment Method.

LEESWIJZER

Deze publicatie is gericht op gebruikers die de methode verder willen ontwikkelen, of willen integreren in methodieken op andere schaal, zoals DGBC Gebied. Daarom worden in dit document de grondslagen en de kenmerken van ISAM nader toegelicht. Allereerst worden de structurele uitgangs-punten en de methode van onderzoek verantwoord. Vervolgens worden algemene kenmerken van ISAM besproken, die bepalend zijn voor de scope van de methodiek. Hierna wordt de methode per categorie in detail gepresenteerd, waarbij voorbeelden[i] van duurzame maatregelen in infrastructuur worden gegeven. Ook worden de stappen beschreven die nog gezet moeten worden voor een succesvolle implementatie van ISAM.

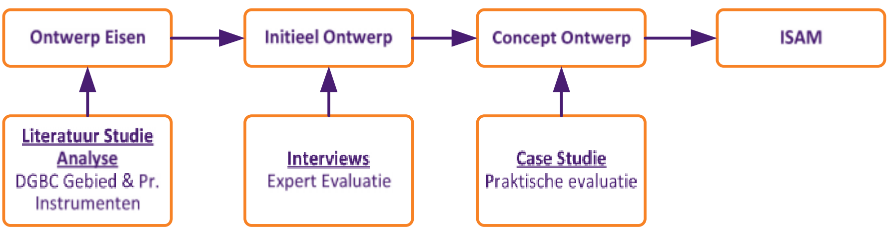
INHOUD

HET ONDERZOEK

Een aantal aspecten zijn leidend geweest in de opzet en uitvoering van het onderzoek waarvan ISAM het resultaat is. Dit heeft consequenties voor de methode en de wijze waarop deze gebruikt kan worden. In dit hoofdstuk worden het onderzoeksmodel en een aantal uitgangspunten toegelicht.

ONDERZOEKSMODEL

ISAM is het resultaat van een ontwerpgericht onderzoek[ii] dat is uitgevoerd in vier stappen (zie figuur 1). In de eerste fase zijn, op basis van literatuur en een analyse van de kenmerken van DGBC Gebied, eisen voor het ontwerp opgesteld met betrekking tot de scope en de structuur van de methode. Een initieel ontwerp is gebaseerd op indicatoren die worden onderscheiden in wetenschappelijke literatuur en in bestaande praktische instrumenten. Het ontwerp is in twee opeenvolgende iteratiestappen geëvalueerd met experts en mensen uit de praktijk van gebiedsontwikkeling. In de laatste stap zijn de resultaten van de evaluaties verwerkt in het uiteindelijke ontwerp van de methode: ISAM.



Figuur 1 - Stappenschema ontwerponderzoek ISAM

Grenzen onderzoek

Het doel van het onderzoek is om een methode te ontwerpen waarmee duurzaamheid van infrastructuur is te beoordelen. Het onderzoek heeft zich beperkt tot het vaststellen van de scope van de methode en het identificeren van indicatoren. Theoretisch volgt hierop een laatste stap waarin standaarden en limieten worden geformuleerd in criteria voor deze indicatoren. Deze stap is nog niet uitgevoerd.

Harmonisatie

Het initiële ontwerp van de methode is gebaseerd op indicatoren die worden genoemd in wetenschappelijke literatuur of die worden gebruikt in bestaande praktische instrumenten. Voor de selectie van indicatoren behorend tot de laatste groep zijn een aantal instrumenten op bruikbaarheid geanalyseerd. Dit zijn onder andere DuboCalc, DPL, het nieuwe BREEAM-NL Nieuwbouw certificaat en het originele BREEAM Communities systeem. Doel van deze aanpak is om direct duidelijkheid te krijgen in de mogelijkheden om ISAM met bestaande instrumenten te harmoniseren.

Innovatie

Het gebruik van beoordelingsmethoden kan een belemmering vormen voor het initiëren van innovatieve technieken, systemen of processen bij de ontwikkeling van infrastructuur. Omdat een beoordelingsmethode per definitie in een bepaalde mate star is, lopen ontwerpers het risico dat hun duurzame initiatieven niet of beperkt tot uitdrukking komen in de score na beoordeling. In het onderzoek zijn strategieën ontwikkeld en geïmplementeerd in ISAM om de potentie van de methode voor beoordeling van innovaties te vergroten.

DGBC Gebied

De methode is afgestemd op de kenmerken en context van DGBC Gebied. Het is mogelijk om ISAM in DGBC Gebied te integreren, of verder te ontwikkelen in een methode specifiek voor infrastructuur.

ISAM is het resultaat van een onderzoek dat is uitgevoerd in het kader van een afstudeerproject, in opdracht van de Dutch Green Building Council, Advin B.V. en de Universiteit Twente.

De methode

ISAM beoordeelt de potentiële prestatie van ontwerpen voor technische infrastructuur voorzieningen op een aantal uiteenlopende milieuaspecten. In dit hoofdstuk worden eerst de algemene kenmerken van ISAM besproken. In de hierop volgende secties wordt de methode per categorie in detail toegelicht.

ISAM in het kort

ISAM is een methode waarmee duurzaamheid van elementen van technische infrastructuur beoordeeld kan worden op uiteenlopende milieuaspecten. Deze aspecten zijn verdeeld in zeven categorieën: Energie, Water, Materialen, Reststoffen, Transport, Flora en Fauna en Klimaat. Aanvullend is een categorie Innovatie opgesteld voor de beoordeling van innovaties in technieken, systemen of processen. In totaal bestaat ISAM uit 30 indicatoren.

Scope

ISAM heeft als doel om de duurzaamheid van fysieke, technische infrastructuur te beoordelen. Onder technische infrastructuur worden de voorzieningen verstaan die indirect de economische productie ondersteunen, zoals wegen, elektriciteitsnetwerken en de systemen voor behandeling van afvalwater. Naar functie kunnen deze voorzieningen worden verdeeld in vijf domeinen: transport, energie, water, communicatie en afval.

Bepalend voor de scope is verder de context van gebiedsontwikkeling. De technische infrastructuur voorzieningen moeten worden gezien in deze context en vertonen soms overlap of raakvlakken met de andere fysieke elementen van een gebied. In deze context wordt ook wel gesproken van stedelijke infrastructuur.

Kenmerken van indicatoren

ISAM is ontworpen om te worden toegepast in de planningfase van een gebiedsontwikkeling. Hiermee zijn de plannen en het ontwerp voor de infrastructuur voorzieningen in een gebied het onderwerp van de beoordeling. De indicatoren in ISAM meten echter de berekende potentiële prestaties die het ontwerp zal hebben in de realisatie- en gebruiksfase van de ontwikkeling.

Niet alle indicatoren in ISAM zijn van toepassing op alle soorten gebieds-ontwikkeling projecten. Er wordt onderscheidt gemaakt tussen vier verschillende gebiedstypes: buiten-stedelijk gebied, stadsranden, stedelijk gebied en bedrijven-terreinen. Het is mogelijk om de methode verder uit te breiden voor andere gebiedstypes.

De indicatoren in de methode kunnen op basis van hun doel worden onderscheiden in drie niveaus. De indicatoren beoordelen namelijk ofwel de mate van invloed die wordt veroorzaakt door de ontwikkeling, ofwel de staat van de natuurlijke omgeving of de efficiëntie van duurzame oplossingen die worden toegepast.

TOELICHTING PRESENTATIE

ISAM wordt hierna voor elke categorie in detail toegelicht. De indicatoren zijn geclusterd per thema in een tekstvak gepresenteerd. De tekst geeft een toelichting op de indicatoren en de onderlinge relaties. Ook worden voorbeelden gegeven uit de praktijk van duurzaam bouwen. Voor elke categorie zijn vervolgens aanbevelingen geformuleerd voor de noodzakelijke vervolgstappen bij de implementatie van de methode. Hier worden tevens eventuele beperkingen van de methode besproken. Voor alle indicatoren is tenslotte in een tekstvak (zoals hiernaast) aangegeven of deze als kritisch kunnen worden beschouwd en op welke ontwikkelingsfase en gebiedstype ze van toepassing zijn. Hierin is:

- K - Kritische indicator
- R - Realisatie
- G - Gebruik
- B - Buitenstedelijk gebied
- S - Stedelijk gebied
- R - Stadsrand
- I - Bedrijventerrein

Nr.	K	R	G	B	S	R	I
10		✓		✓	✓	✓	✓
11		✓		✓	✓	✓	✓
12	✓		✓		✓	✓	

Energie

Het toepassen van efficiënte infrastructuursystemen draagt bij aan de energieprestatie van een gebied. In ISAM wordt de mate van reductie in energiebehoefte en de bijdrage aan duurzame energie van infrastructuur voorzieningen beoordeeld. Aanvullend is voor openbare verlichting een beoordeling van de efficiëntie opgesteld.

Nr.	Omschrijving
1	Mate van reductie in energiebehoefte van infrastructuurvoorzieningen in verhouding tot een referentie, gebaseerd op een EPL berekening.
2	Mate van duurzame energie opgewekt door infrastructuursystemen ten opzichte van het totaal.

Energieprestatie

In ISAM wordt aanbevolen gebruik te maken van de methodiek van het instrument Energie Prestatie op Locatie (EPL), om het aandeel van infrastructuur in de energieprestatie te berekenen. De energieprestatie kan verbeterd worden door de energiebehoefte te reduceren (1) of door meer gebruik te maken van duurzame energie (2). Installaties (zoals pompen en ventilatoren) voor beweegbare bruggen, sluizen, gemalen, tunnels en waterzuivering zijn voorbeelden van infrastructuurvoorzieningen die energie verbruiken. De efficiëntie van de toegepaste systemen komt tot uitdrukking in de reductie van de energiebehoefte.

Voor het opwekken van duurzame energie zijn per definitie infrastructuur systemen nodig, zoals de leidingen naar de installaties. In ISAM richt de beoordeling zich echter specifiek op de energie die wordt opgewekt in standaard infrastructuur voorzieningen die in het gebied gerealiseerd worden. Dit kan bijvoorbeeld door PV-cellen te integreren met geluidsbarrières of door temperatuurverschillen in verhardingsconstructies om te zetten in energie.

Nr.	Omschrijving
3	Mate van berekende energiereductie in openbare verlichting.

OPENBARE VERLICHTING

Van alle infrastructuursystemen heeft openbare verlichting het grootste potentieel voor energiebesparing (3). In feite komt de efficiëntie van het toegepaste verlichtingsysteem ook tot uitdrukking in de energieprestatie, maar een aparte beoordeling is in ISAM opgenomen om initiatieven op dit gebied te stimuleren. Voorbeelden van maatregelen voor besparing zijn de toepassing van zuinige lampen, actieve wegmarkering, aanpassing van de mastafstanden en managementsystemen om verlichting op afstand te regelen.

IMPLEMENTATIE

Criteria voor de beoordeling kunnen worden gebaseerd op de referentie situaties die zijn vastgesteld voor de EPL methodiek. Voor openbare verlichting zijn specifieke kengetallen te verkrijgen[iii]. Bij het opstellen van de criteria dient rekening gehouden te worden met de overlap tussen de energieprestatie en de aanvullende indicator voor openbare verlichting.

Gebruikers hebben voor de beoordeling inzicht nodig in het energieverbruik van alle geplande systemen en de verhouding tussen de verschillende (duurzame en fossiele) energiedragers die toegepast worden in het gebied. Met betrekking tot openbare verlichting is aanvullende informatie over de technische kenmerken van het geplande systeem vereist.

Nr.	K	R	G	B	S	R	I
1	✓		✓	✓	✓	✓	✓
2	✓		✓	✓	✓	✓	✓
3			✓	✓	✓	✓	✓

WATER

In deze categorie gaat het om water als bron voor het gebied. De indicatoren beoordelen de prestatie van de toegepaste infrastructuursystemen om hier efficiënt en duurzaam aan bij te dragen. Specifiek gaat het om de reductie van de behoefte aan water en het lokaal zuiveren van grijs en regenwater.

Nr.	Omschrijving
4	Mate waarin de totale waterbehoefte wordt gereduceerd door toepassing van specifieke technieken of systemen.

WATERBEHOEFTE

Deze indicator beoordeelt de reductie in de totale waterbehoefte van het gebied, die wordt bereikt door toepassing van infrastructurele systemen of technieken (4). Met waterbehoefte wordt bedoeld de mate waarin het gebied niet in staat is om zelfvoorzienend te zijn. Het gaat dus om de hoeveelheid (gezuiverd) water die van buiten de grenzen moet worden geïmporteerd. ISAM beoordeelt alleen de bijdrage die infrastructurele voorzieningen hebben in het reduceren van deze behoefte. Er zijn drie manieren om dit te doen: het toepassen van efficiëntere systemen, het lokaal winnen van water of het her-gebruiken van water. Een specifiek voorbeeld voor het verbeteren van de efficiëntie, is een systeem voor lekdetectie in het leidingnetwerk. Een ander voorbeeld is het zuiveren van grijs- of regenwater om het te (her)gebruiken voor bijvoorbeeld irrigatie. De invloed die de laatstgenoemde systemen hebben op de reductie van de waterbehoefte komt in deze indicator tot uit-drukking, de duurzaamheid van de toegepaste techniek is afhankelijk van het gebruik van chemicaliën (zie verder indicator 5).

Nr.	Omschrijving
5	Mate en gebruik van chemicaliën voor lokale zuivering van (afval) water.

Lokale zuivering

Het is mogelijk om licht vervuild afvalwater op lokale schaal te zuiveren en te infiltreren of hergebruiken. Dit zorgt voor een reductie in benodigde energie en kosten voor transport van afvalwater naar centrale zuiveringsinstallaties. Daarnaast kan gezuiverd water worden gebruikt voor bijvoorbeeld irrigatie. Op deze manier dragen de zuiveringstechnieken bij aan het reduceren van de waterbehoefte (4). De zuiveringstechniek wordt beoordeeld op het gebruik van chemicaliën (5) omdat dit de onderscheidende factor in zuiveringstechnieken is. Hiermee wordt het gebruik van duurzame technieken gestimuleerd.

Er is sprake van overlap met de indicatoren 22 en 23 in de categorie Flora en Fauna. Die indicatoren hebben specifiek betrekking op het zuiveren van oppervlakte- en regenwater dat vervolgens niet als bron voor het gebied gebruikt wordt.

Implementatie

De beoordeling van de reductie in waterbehoefte kan worden gebaseerd op de relatieve prestatie die in een project wordt bereikt. In de criteria moeten standaarden voor deze prestatie worden geformuleerd, bijvoorbeeld in percentages. Voor het opstellen van criteria voor het beoordelen van zuiveringstechnieken is een uitgebreide analyse van de bestaande technieken nodig.

Bij toepassing van ISAM hebben gebruikers inzicht nodig in de totale waterbehoefte van het gebied en in de efficiëntie of capaciteit van de geplande systemen. Verder moet bekend zijn welke zuiveringstechniek wordt toegepast.

Nr.	K	R	G	B	S	R	I
4	✓	✓	✓	✓	✓	✓	✓
5			✓	✓	✓	✓	✓

MATERIALEN

Duurzaam materiaalgebruik heeft betrekking op de keuze tussen materialen met verschillende milieueffecten en op hergebruik van materialen of componenten. In ISAM zijn de schaduwprijs en de mate van hergebruik indicaties voor de beoordeling.

Nr.	Omschrijving
6	Percentage verbetering in milieukosten (schaduwprijs) van materiaalgebruik ten opzichte van een referentie.

MATERIAALKEUZE

De beoordeling van duurzaamheid van materialen is in ISAM gebaseerd op een schaduwprijs voor milieukosten (6). Het monetariseren van milieueffecten van materiaalgebruik is een volwassen en breed toegepaste methode. In de schaduwprijs zijn de milieueffecten op het gebied van emissies, energie, hinder, etc. voor de gehele levenscyclus bepaald en in economische waarden uitgedrukt. De berekening kan worden uitgevoerd met behulp van verschillende instrumenten die zijn gebaseerd op uitgebreide databases met kenmerken van verschillende soorten materialen (zoals DuboCalc). Door het percentage van verbetering ten opzichte van een referentie te beoordelen worden gebruikers gestimuleerd om duurzamere materialen toe te passen. Een bekende toepassing in de sector is het verwerken van secundaire grondstoffen, met name in wegfunderingen. Maar ook in andere materiaalgroepen zijn keuzes te maken die de duurzaamheid bevorderen. Voorbeelden zijn biologisch afbreekbare geotextielen voor tijdelijke constructies, riet als zinkstuk en keramisch materiaal voor rioleringsbuizen.

Nr.	Omschrijving
7	Vastgesteld gewichtspercentage van hergebruikte en gerecyclede materialen ten opzichte van het totale materiaalgebruik.

MATERIAAL HERGEBRUIK

In het percentage van hergebruikte materialen (7) worden alleen de materialen bedoeld die toegepast worden in de realisatiefase van de gebiedsontwikkeling. Het gaat dus om het percentage van hergebruik dat in de planningsfase vastgesteld kan worden. Met andere woorden, de potentie van het ontwerp om na de gebruiksfase materialen te hergebruiken of recyclen valt hierbuiten, omdat deze potentie met te weinig zekerheid te berekenen is. In de GWW-sector wordt hergebruik van materialen veelvuldig toegepast. Er wordt volop gebruik gemaakt van secundaire grondstoffen in wegfunderingen en in toenemende mate als grindvervanger in betonproducten. Elementen van constructies worden op verschillende schaal hergebruikt, van de straatklinker tot het brugdeel.

IMPLEMENTATIE

De uitdaging bij het opstellen van de criteria voor materiaalkeuze is gelegen in het vaststellen van de referentie schaduwprijs. Hiervoor is aanvullend onderzoek noodzakelijk. Verder is de waardering gebaseerd op percentages waarin de prestatie van een specifiek project uitgedrukt kan worden.

De gebruikers hebben voor de berekening van zowel de schaduwprijs, als voor het gewichtspercentage van hergebruik, inzicht nodig in het type en de hoeveelheid van de materialen die gebruikt gaan worden in de realisatie.

Nr.	K	R	G	B	S	R	I
6	✓	✓	✓	✓	✓	✓	✓
7		✓		✓	✓	✓	✓

RESTSTOFFEN

Afval wordt in toenemende mate gezien als reststof, als basis voor grondstoffen en energie. Minimaliseren van afvalproductie is echter niet minder van belang. Indicatoren in deze categorie hebben betrekking op de fysieke voorzieningen voor afvalverzameling en op de maatregelen om afval te minimaliseren.

Nr.	Omschrijving
8	Realisatie van centrale voorzieningen voor gescheiden inzameling van (recyclebaar) afval.
9	Realisatie van voorzieningen voor inzameling van openbaar afval.

INZAMELING

Afval scheiden bij de bron is een voorwaarde om te komen tot een efficiënte verwerking en een nuttige toepassing van het afval als bron voor hergebruik of energie (8). Transportkosten worden gereduceerd door de voorzieningen centraal in het gebied te situeren, binnen de eisen voor maximale afstand vanaf woningen die daarvoor gelden. De plannen voor de ontwikkeling dienen verder te voorzien in voldoende voorzieningen voor het verzamelen van publiek afval (9). Met publiek afval wordt het afval bedoeld dat niet huishouden of industrie gebonden is. In de Nederlandse praktijk zijn de zaken rondom afvalinzameling over het algemeen al goed geregeld. ISAM stimuleert ontwerpers om verder te gaan dan standaard praktijken. Het kan bijvoorbeeld nuttig zijn om extra afvalstromen te scheiden op industrieterreinen. Een recent ontwikkeld concept voor een ondergronds afvaltransportsysteem is een voorbeeld van zeer centraal inzamelen.

Nr.	Omschrijving
10	Berekende minimalisering van afval in percentage ten opzichte van gemiddelde afvalproductie cijfers.
11	Mate van lokaal toegepaste hergebruikte of gerecyclede reststoffen.

MINIMALISEREN BOUWAFVAL

Met name in de bouwsector, welke een substantieel aandeel heeft in de totale afvalberg van de samenleving, is preventie van afvalproductie een belangrijk aspect. In ISAM worden uitvoerende partijen gestimuleerd om de hoeveelheid afval die geproduceerd wordt te minimaliseren (10). Daarnaast wordt ook tijdens de uitvoering het scheiden van afval gestimuleerd (11). Omdat hergebruik een veelvuldig toegepaste praktijk is in de GWW-sector wordt hier (in het verlengde van indicator 7) de toepassing van reststoffen in hetzelfde project als waar ze vrijgekomen zijn beoordeeld. Het is bijvoorbeeld mogelijk om puin, dat binnen het gebied is vrijgekomen bij sloop, te gebruiken als granulaat in de fundering van wegen. Project-ontwikkelaars spreken daarnaast vaak van een ambitie om voor het gebied de grondbalans zo veel mogelijk te sluiten.

IMPLEMENTATIE

Vanwege de hoge standaarden in de Nederlandse praktijk, vereist het opstellen van criteria voor deze categorie creativiteit. De bereikte prestatie in minimalisering kan worden gemeten door de geschatte afvalproductie af te zetten tegen gemiddelde cijfers in de criteria.

De gebruikers van de methode hebben bij de beoordeling inzicht nodig in het type en de ruimtelijke planning van de fysieke voorzieningen die gerealiseerd worden. Voor de indicatoren met betrekking tot minimalisering moeten ontwikkelaars met berekeningen de potentie van hun ontwerpen aantonen.

Nr.	K	R	G	B	S	R	I
8	✓		✓	✓	✓	✓	✓
9			✓	✓	✓	✓	✓
10		✓		✓	✓	✓	✓
11		✓		✓	✓	✓	✓

TRANSPORT

Een doordachte planning kan bijdragen aan het gebruik van schonere vervoerswijzen. In ISAM worden de voorzieningen voor openbaar vervoer en langzaam verkeer getoetst. Het ruimtelijke aspect is van belang vanwege de grote invloed van transport infrastructuur op het landgebruik.

Nr.	Omschrijving
12	Energieverbruik en gerelateerde CO_2-emissie als gevolg van verkeer, gebaseerd op een VPL-Kiss berekening.
13	Kwaliteit openbaar vervoer op basis van gemiddelde afstand tot haltes en stations, capaciteit en frequentie.

MOBILITEIT

Een algemene indicatie om de prestatie van transport infrastructuur te beoordelen is mobiliteit. Deze indicator is niet direct in ISAM opgenomen, omdat het ook mogelijk is mobiliteit te bevorderen met maatregelen die niet als duurzaam beschouwd kunnen worden. De keuze voor schone en efficiënte vervoerswijzen is de sleutel in duurzame ontwikkeling van transport infrastructuur.

Een breed scala aan duurzame maatregelen kan bijdragen aan de reductie van energieverbruik en emissie van verkeer (12). Een voorbeeld is de keuze tussen rotondes of verkeerslichten. De VPL-Kiss methodiek voorziet in een relatief simpele berekening om dit te kwantificeren. Deze berekening gaat uit van gegevens over de ruimtelijke inrichting, bevolkingskenmerken en sociale voorzieningen in het gebied.

Openbaar vervoer wordt gezien als de modaliteit met het grootste potentieel om het energieverbruik te reduceren zonder dat dit de mobiliteit laat afnemen. Om mensen te stimuleren van het openbaar vervoer gebruik te maken is hoogwaardige kwaliteit een vereiste (13). Beoordeling van deze kwaliteit op basis van dienstroosters, ruimtelijke situering en de routes van buslijnen is een veel gebruikte methode.

Nr.	Omschrijving
14	Reductie van barrières op basis van de verhouding tussen de werkelijke reisafstand en de kortst mogelijke route.
15	Oppervlakte percentage van verkeersluwe gebieden zonder de bereikbaarheid te verminderen.

Voetgangers en fietsers

Het stimuleren van voetganger- en fietsverkeer is bevorderlijk voor energiereductie en bovendien goed voor de gezondheid. De richtlijn Duurzaam Veilig Verkeer zet op dit gebied voor de Nederlandse context een hoge standaard. In ISAM zijn uiteindelijk twee indicatoren opgenomen die hierop een aanvulling vormen. De reductie van barrières (14) moet het voetgangers- en fietsverkeer in het gebied stimuleren. De morfologie van een duurzame wijk (het ontwerp van de situatie van straten, gebouwen en verbindingen) vormt de basis voor een prettige omgeving voor deze verkeersgroepen. Verkeersluwe gebieden (15) dragen bij aan de veiligheid voor de voetgangers en fietsers, en hebben bovendien een positieve invloed op het energiegebruik in verkeer en het lokale klimaat.

Nr.	Omschrijving
16	Oppervlakte percentage van flexibel gebruikte (weg) infrastructuur.
17	Oppervlakte percentage gebruik van locaties met minimale invloed op eclogische en natuurlijke waarden.

Landgebruik

Transport netwerken hebben, van alle domeinen van technische infrastructuur, de grootste invloed op het landgebruik. In ISAM wordt daarom het flexibel gebruik van infrastructuur beoordeeld (16), een maat voor efficiëntie van landgebruik. Flexibiliteit draagt bij aan de compactheid van de gebiedsontwikkeling. Voorbeelden van toepassingen zijn spitsstroken en multifunctioneel gebruik van parkeerplaatsen. De oppervlakte van flexibel te gebruiken infrastructuur kan afgezet worden tegen de totale oppervlakte van infrastructuur, of tegen de totale oppervlakte van het gebied. Daarnaast verdient het de voorkeur om de infrastructuur te ontwikkelen op locaties waar sprake is van minimale invloed op ecologische of natuurlijke waarden (17). Deze methode van beoordeling wordt (in verschillende vormen) veelvuldig toegepast en heeft bijvoorbeeld ook betrekking op gebouwen. Het is mogelijk de indicator te splitsen in meerdere beoordelingsaspecten. Zo kan de grootte van de ecologische of natuurlijke waarde een uitgangspunt vormen, kan meespelen of op de locatie eerder sprake is geweest van vervuiling of dat de locatie reeds eerder ontwikkeld is geweest. Het oppervlakte percentage maakt de beoordeling kwantitatief.

IMPLEMENTATIE

Voor de beoordeling op basis van VPL-Kiss berekeningen moeten referenties opgesteld worden. De methodiek kan verschillende varianten voor een wijk doorrekenen, maar voorziet niet in gemiddelde cijfers voor energiegebruik. De andere indicatoren beoordelen op basis van relatieve prestaties, in criteria moeten hier grenzen voor vastgesteld worden.

Om de beoordeling uit te kunnen voeren moeten de ruimtelijke plannen voor de wijk vastgesteld zijn. Er moet inzicht zijn in welke transport infrastructuur waar zal worden gerealiseerd, in wegcategorieën, in voorzieningen voor openbaar vervoer, etc. Aanvullend zijn voor de VPL-Kiss berekening gegevens nodig over de sociale voorzieningen in het gebied en de bevolkingskenmerken.

Een beperking van de VPL-Kiss methode is dat deze alleen voor (kleinere) gebiedsontwikkelingen met wonen als voornaamste functie gebruikt kan worden. Daarnaast zijn de indicatoren voor voetgangers- en fietsverkeer relatief specifiek, er zijn waarschijnlijk nog aanvullende indicatoren van hetzelfde kaliber te formuleren.

Nr.	K	R	G	B	S	R	I
12	✓		✓		✓	✓	
13	✓		✓	✓	✓	✓	✓
14			✓	✓	✓	✓	✓
15			✓	✓	✓	✓	✓
16			✓	✓	✓	✓	✓
17			✓	✓	✓	✓	✓

Flora en Fauna

Tussen flora en fauna en de ontwikkeling van bebouwde omgeving treedt een wisselwerking op. Er is sprake van kansen voor zowel de natuur als voor de kwaliteit van de ontwikkeling. In ISAM stimuleren de indicatoren het benutten van deze kansen.

Nr.	Omschrijving
18	Studie naar bestaande relevante ecologische elementen en het opstellen van maatregelen voor bescherming gedurende realisatie en harmonisatie gedurende gebruik.
19	Berekende efficiëntie van geïnitieerde maatregelen voor behoud van biodiversiteit.

Ecologische waarde

Voorafgaand aan de ontwikkeling wordt in samenwerking met een lokale ecologische organisatie een studie uitgevoerd om de waardevolle ecologische elementen in het gebied te identificeren (18). Er wordt een plan opgesteld om deze elementen tijdens de uitvoering te beschermen en tijdens de gebruiksfase te harmoniseren. Overeenkomsten met lokale partijen en de plannen zelf dienen als bewijsvoering voor de beoordeling. Maatregelen tijdens de uitvoering zijn bijvoorbeeld het afschermen van groen en een doordachte bronbemaling. Harmonisatie tijdens gebruik is een ruim begrip, hieronder vallen maatregelen als ecologisch beheer, voorkomen van onnodige verharding en realiseren van faunapassages.

In landelijk beleid is het handhaven van een grote soortenrijkdom een kernpunt. ISAM beoordeelt daarom ook specifiek de efficiëntie van de maatregelen om de biodiversiteit te behouden (19). Het is mogelijk de verwachte biodiversiteit te berekenen op basis van de voorgestelde maatregelen (in 18). Voorbeelden van maatregelen om de biodiversiteit te bevorderen zijn het aanbrengen van een ecologisch netwerk (zo mogelijk aangesloten op hoofdstructuur) en toepassen van een geleidelijke ruimtelijke overgang.

Nr.	Omschrijving
20	Percentage van niet verhard oppervlak en verhard oppervlak dat is ontkoppeld van het centrale zuiveringssysteem.
21	Oppervlakte percentage van (ruimte voor) open water als opslagcapaciteit voor extreme neerslag.
22	Bestudeer lokale karakteristieken van het water systeem en formuleer een optimaal pakket van maatregelen om water kwaliteit te garanderen.
23	Percentage van (afval) water dat lokaal gezuiverd en geïnfiltreerd wordt.

Waterbeheer

Oppervlaktewater in de bebouwde omgeving heeft een regulerende functie in de waterhuishouding en kan daarnaast een ecologische en recreatieve functie hebben. In integraal waterbeheer worden deze functies gecombineerd, maar dit is een complexe zaak en in hoge mate afhankelijk van lokale omstandigheden. ISAM beoordeelt een aantal van de kernaspecten.

Er zijn uiteenlopende voorbeelden van technieken, systemen en maatregelen die ingezet kunnen worden om regenwater te scheiden van het rioleringssysteem. ISAM beoordeelt de factor die uiteindelijk bepalend is voor de prestatie van deze maatregelen, het percentage van het oppervlak dat afgekoppeld is (20).

Het oppervlak van open water dient als maat voor de opslagcapaciteit van het gebied voor regenwater ten tijde van extreme neerslag (21). Specifieke plekken in het gebied kunnen worden aangewezen om als noodoverloop te dienen (bv een parkeerplaats of een park).

Het toepassen van infrastructurele systemen of technieken om waterkwaliteit van open water te garanderen of verbeteren is sterk afhankelijk van lokale karakteristieken van het watersysteem. Zo is het realiseren van een gesloten watersysteem of van een natuurvriendelijke oever niet in iedere situatie mogelijk. Er wordt daarom in ISAM vanuit gegaan dat het uitvoeren van een studie naar deze karakteristieken en het afstemmen van een maatregelenpakket hierop zal leiden tot de meest optimale aanpak om waterkwaliteit duurzaam te bevorderen (22).

Een specifieke indicator is in ISAM opgenomen voor lokaal zuiveren en infiltreren van afvalwater of oppervlaktewater. Het belang van dit aspect is tijdens het onderzoek veelvuldig benadrukt. Voorbeelden van zuiveringstechnieken zijn helofytenfilters en riet- of biezenvelden. Lokale zuivering kan worden toegepast om decentrale zuiveringen voor afvalwater te ontlasten, om water te kunnen hergebruiken (zie voor deze aspecten ook indicator 5) of om de kwaliteit van oppervlaktewater te bevorderen (zie 22). Daarnaast zorgt infiltratie er voor dat er minder water afgevoerd hoeft te worden en voorkomt het verdroging van de bodem. De indicator in ISAM (23) beoordeelt hier de prestatie van de systemen ten opzichte van de totale hoeveelheid afvalwater.

IMPLEMENTATIE

Twee van de indicatoren in deze categorie schrijven het uitvoeren van een studie voor. Waardering van deze indicatoren in criteria kan door het uitvoeren te controleren en eisen te stellen aan de implementatie. Deze indicatoren voorzien niet in een kwantitatieve beoordeling en zijn bovendien niet prestatiegericht. De complexiteit van de problematiek en de sterke afhankelijkheid van mogelijke oplossingen van lokale karakteristieken maakt de keuze voor deze indicatoren echter noodzakelijk.

De indicatoren met betrekking tot de ecologische waarden zijn niet alleen van toepassing op de technische infrastructuur. Deze gelden ook voor andere elementen van de gebiedsontwikkeling en moeten hiermee geïntegreerd worden.

Nr.	K	R	G	B	S	R	I
18		✓	✓	✓	✓	✓	✓
19		✓	✓	✓	✓	✓	✓
20	✓		✓	✓	✓	✓	✓
21			✓	✓	✓	✓	✓
22			✓	✓	✓	✓	✓
23	✓		✓	✓	✓	✓	✓

KLIMAAT

De ontwikkeling van een gebied heeft verschillende negatieve invloeden op het (lokale micro) klimaat. In ISAM beoordelen de indicatoren niet de mate van invloed maar de efficiëntie van maatregelen om de negatieve effecten te neutraliseren.

Nr.	Omschrijving
24	Percentage opslag van broeikasgas en fijnstof emissie.
25	Berekende efficiëntie van maatregelen om geluidshinder te reduceren.
26	Berekende efficiëntie van maatregelen om geurhinder te reduceren.
27	Berekende efficiëntie van maatregelen om lichthinder te reduceren.

HINDER REDUCTIE

In ISAM zijn meerdere indicatoren opgenomen die gerelateerd zijn aan CO_2-emissie. Emissie kan het gevolg zijn van energieverbruik (zie 1 en 2), van het gebruik van materialen en de daarbij horende processen (zie 6) of van verkeer (zie 12). In deze categorie wordt niet de mate van emissie beoordeeld, maar de mate waarin voorzieningen in het gebied in staat zijn broeikasgassen en fijnstof op te slaan (24). Een voorbeeld is het integreren van geluidsschermen met technieken om fijnstof af te vangen.

Veelal zijn de hindercategorieën als gevolg van infrastructuur verdeeld in geluid, geur en licht. Er is een scala aan mogelijkheden om hinder van bijvoorbeeld verkeer te reduceren. De maatregelen variëren van toepassing van stille wegdekken tot dimbare verlichting. Daarnaast kunnen er maatregelen getroffen worden om hinder in de uitvoerings-fase te minimaliseren. Bij de beoordeling van deze aspecten wordt in ISAM gevraagd om de efficiëntie van de maatregelen aan te tonen (25-27).

Nr.	Omschrijving
28	Bestudeer karakteristieken van het lokale watersysteem en formuleer maatregelen om vervuiling van (grond) water als gevolg van afstroming te voorkomen.
29	Bestudeer de mogelijkheden om negatieve invloeden op het microklimaat te neutraliseren door het toepassen van beplantingstructuren.

Watervervuiling

Infrastructuur kan een vervuiling van water, en indirect grondwater, in het gebied veroorzaken. Dit komt met name doordat afstromend regenwater alle vervuilende deeltjes op wegen, maar ook stoffen uit uitlogende materialen, meevoert in het watersysteem. Hoewel de maatregelen om de vervuiling op te heffen worden beoordeeld in het thema waterbeheer (zie 22 en 23) is hier aanvullend een specifieke indicator opgesteld. Het gaat hier om een directe invloed op de natuurlijke omgeving als gevolg van de ontwikkeling van infrastructuur en het doel van deze indicator (28) is om de vervuiling te voorkomen.

Neutraliseren

Emissie en geur- en geluidshinder zijn door de windverplaatsing gerelateerd aan het microklimaat in een gebied. Door beplantingstructuren in te zetten als technische maatregel kan de mate waarin de effecten worden geneutraliseerd beïnvloed worden (29).

Implementatie

Gebruikers van ISAM moeten voor deze categorie inzicht hebben in de efficiëntie van de maatregelen die in de plannen zijn opgenomen. Meestal zijn deze al onderbouwd in rapporten van onderzoek als onderdeel van de planningprocedures. Het uitvoeren van de studie om watervervuiling te voorkomen kan een integraal onderdeel zijn van de studie bedoeld in indicator 22.

Nr.	K	R	G	B	S	R	I
24		✓	✓	✓	✓	✓	✓
25		✓	✓	✓	✓	✓	✓
26		✓	✓	✓	✓	✓	✓
27		✓	✓	✓	✓	✓	✓
28		✓	✓	✓	✓	✓	✓
29	✓		✓	✓	✓	✓	✓

INNOVATIE

In het onderzoek waarop ISAM is gebaseerd zijn een aantal strategieën geformuleerd om de potentie van de methode om innovaties te beoordelen te vergroten. Voor zover de strategieën binnen de scope van de methode vallen, zijn deze in ISAM verwerkt.

1. FLEXIBILITEIT INDICATOREN

De eerste strategie heeft als doel om te voorkomen dat indicatoren (en criteria) op een starre wijze worden geformuleerd. Er is bijvoorbeeld sprake van een starre formulering wanneer het toepassen van bepaalde technieken, systemen of processen wordt voorgeschreven. Aan de andere kant wordt in een flexibele formulering alleen de prestatie van de maatregelen op bepaalde milieuaspecten beoordeeld.

Een toenemende flexibiliteit maakt het mogelijk om incrementele innovaties in de methode te beoordelen. Incrementele innovaties zijn vaak een verbetering van prestaties van bestaande technieken, waarvan het voor de hand ligt dat deze al in ISAM gereflecteerd worden. Beoordeling is dan mogelijk omdat in een flexibele formulering nu juist de prestatie gemeten wordt. Het kan dan wel nodig zijn om de standaarden in criteria op de nieuwe technieken af te stemmen.

Deze strategie is op alle indicatoren van ISAM toegepast. Deels een uitzondering hierop vormt het voorschrijven van de EPL methodiek in indicator 1, en van de VPL-Kiss methodiek in indicator 12. Daarnaast wordt in de indicatoren 18, 22, 28 en 29 het uitvoeren van een studie voorgeschreven. In deze indicatoren is dus geen sprake van het beoordelen van een prestatie. Er blijft echter ruimte voor de toepassing van innovaties, omdat de mogelijkheden om invulling te geven aan het beoogde doel van de indicatoren open staan.

Nr.	Omschrijving
30	Specificeer het doel van de innovatie, de karakteristieken van het product of proces, de milieuaspecten waarop de innovatie invloed heeft en de berekende prestatie.

2. Innovatie categorie

De tweede strategie is om een aparte categorie voor het beoordelen van innovatieve maatregelen of praktijken in de beoordelingsmethode op te nemen. Als aanvulling op de eerst genoemde strategie vergroot dit de potentie van de methode om innovatie te stimuleren, omdat het mogelijk wordt om ook radicale innovaties te beoordelen. Radicale innovaties worden gekenmerkt door het creëren van totaal nieuwe producten of processen, waarvan het niet waarschijnlijk is dat deze op het moment van innovatie al in ISAM zijn gereflecteerd.

In ISAM is deze strategie verwerkt door een indicator op te stellen waarin gevraagd wordt de benodigde informatie te specificeren die nodig is om een innovatie te kunnen beoordelen (30). Bij integratie van ISAM in een methode op een andere schaal (zoals DGBC Gebied), wordt aanbevolen om de strategie over te nemen in de overkoepelende methode.

3. Kritische innovaties

De derde strategie is om ontwerpers extra te stimuleren om te innoveren op de indicatoren die als kritisch worden beschouwd in ISAM. Een eerste voorwaarde voor succesvol gebruik van deze strategie is dat de kritische indicatoren flexibel zijn geformuleerd (zie strategie 1). Daarnaast moeten de gebruikers van de methode uitgedaagd worden om juist op deze aspecten creatief te zijn en grenzen te verleggen.

Dit stimuleren is mogelijk door de relevantie van de indicatoren te benadrukken in de structuur van het scoresysteem van de methode. Dit kan indirect door meer gewicht toe te kennen aan de betreffende indicatoren, met behulp van het wegingsysteem. Daarnaast is het mogelijk om voor de kritieke indicatoren aanvullende criteria op te stellen, op basis waarvan direct extra punten toegekend worden wanneer de standaardeisen worden overschreden.

NOTEN

[i] Voorbeelden deels gebaseerd op het rapport: Basisdoc: XS2 Duurzaam Bouwen. (Senter Novem, 2008).

[ii] Zie verder het onderzoeksrapport: Van de Pol, J.F. (2009). Design of an Infrastructure Sustainability Assessment Method for application in DGBC Area.

[iii] Kengetallen verkrijgbaar bij het Programmabureau Openbare Verlichting van Senter Novem. Zie http://www.senternovem.nl/openbareverlichting/

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