MASTER THESIS SUSTAINABLE ENERGY TECHNOLOGY

Evaluating urban quality and sustainability

Presentation of a framework for the development of indicator assessment methods, by which the existing urban environment may be evaluated on quality and sustainability performance on a neighborhood scale

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Evaluating urban quality and sustainability

Master thesis

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Summary

With rising urban populations it is becoming more important how we design and construct our urban environment. Focus of designers, urban planners, and developers is increasingly aimed at creating and maintaining high quality sustainable urban areas. However, defining precisely what consists as a high quality sustainable urban environment remains a challenge.

A literature study reveals that a high quality sustainable urban environment can be conceptualized by modelling the urban environment as an ecological system, and described using four characteristics.

- A sustainable urban environment must achieve bio-physical sustainability.
- A high quality urban environment must provide a high level of need satisfaction on the hierarchy of Maslow for the majority of its inhabitants.
- Urban quality in regards to sustainability is an urban environment that is flexible, resilient, and is therefore in a position to effectively implement and maintain increased sustainability measures.
- A high quality sustainable urban environment must maintain (and improve) upon the urban ecological space, its natural capital.

It was determined that the various aspects of a high quality sustainable urban environment can be qualitatively and quantitatively described by means of a system of indicators. The results of the literature study have been applied to construct a framework that can assist in the development of such indicator assessment methodologies on a neighborhood scale. Application of the constructed framework was demonstrated in relation to an existing Dutch neighborhood assessment methodology, "Duurzaamheids Profiel van een Locatie" (DPL) which translates to Sustainability Profile of a Location.

It was concluded that although the framework provides a structural approach to the development of assessment methods, the framework does not assist in the design of specific features of an assessment methodology. As such, both experience in urban development and a sound knowledge base, part of which is provided by the chapters 2, 3 and 4 of this report, remain essential to successfully develop indicator assessment tools.

Foreword

"Against the dark screen of night, Vimes had a vision of Ankh-Morpork. It wasn't a city; it was a process, a weight on the world that distorted the land for hundreds of miles around. People who'd never see it in their whole life nevertheless spent that life working for it. Thousands and thousands of green acres were part of it, forests were part of it. It drew in and consumed…

…and gave back the dung from its pens, and the soot from its chimneys, and steel, and saucepans, and all the tools by which its food was made. And also clothes, and fashions, and ideas, and interesting vices, songs, and knowledge, and something which, if looked at in the right light, was called civilization. That was what civilization meant. It meant the city."

— Terry Pratchett, *Night Watch*

Although I owe thanks too many people for their help and support during my studies and graduation research, there are a few who deserve special mention in this report.

Thanks go out to my supervisors, Maarten Arentsen and Thomas Hoppe. Due to our different scientific backgrounds, social sciences versus my engineering background, I often despaired if we would ever find common ground to work from. In the words of Maarten Arentsen: *"We will just have to view that as an extra challenge and learning experience in the process."* It seems that we have finally succeeded. Thank you for your help and incredible patience in the process.

Of my friends I would like to thank Allard Katstra for moral and technical support and Wouter Knoben for going through and commenting on my conclusions. Special thanks go out to Rik Arends, who took the time to go through my entire report and was not shy about criticizing my work. *"Robert, get to the point!"* Especially encouraging in this process where the discussions I could have with him about the subject.

To my parents I owe a special debt of gratitude. It is due to their patience and support that I was able not only to immerse myself *in* my studies, but had ample opportunity to develop myself *besides* my studies. It has made me the person that I am today.

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Abbreviations

The following abbreviations appear throughout the thesis.

BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
DGBC	Dutch Green Building Council
DPL	Duurzaamheids Profiel van een Locatie (Sustainability Profile of a Location)
LEED	Leadership in Energy and Environmental Design
NSA	Neighborhood Sustainability Assessment
QOL	Quality Of Life
UN	United Nations

1. Introduction

This chapter will provide an introduction to the problem in section 1.1, and formulate the research goals and questions in sections 1.2 and 1.3. Section 1.4 will present the methodology and report structure.

1.1 Background

The Dutch Green Building Council (DGBC) is a non-governmental organization in the Netherlands that exploits various assessment tools by which aspects of the urban environment may be evaluated on sustainability performance. Current evaluation tools are able to evaluate the sustainability of:

1. New construction of buildings
2. In-use sustainability of buildings
3. Neighborhood development projects
4. Demolition projects

The DGBC has no experience of its own in developing assessment tools from the ground up. Rather, the tools are translated from their British counterparts developed by the Building Research Establishment (BRE) in the UK, and have been adapted to the Dutch market.

It has been the ambition of the DGBC to develop a new assessment tool by which the existing urban environment can be evaluated on sustainability performance on a neighborhood scale. The decision was made by the DGBC to adapt their current tool for neighborhood development in such a way that the tool would also be applicable for assessment of the current state of affairs of the urban environment as well as assessment of urban development.

Although practical, development of an assessment tool in such a way lacks a systematic and scientific approach. It is therefore the purpose of the work described in this report to research how an assessment tool for the existing urban environment might be developed in a structured and scientifically sound way.

A initial review of scientific literature (Alberti, 1996; Gahin, Veleva, & Hart, 2003; Gasparatos & Scolobig, 2012; Gil & Duarte, 2010; Holman, 2009; Hoppe & Coenen, 2011; Nguyen & Altan, 2011; Reed, Fraser, & Dougill, 2006; Sharifi & Murayama, 2013; L. Shen, Kyllo, & Guo, 2013; L.-Y. Shen, Jorge Ochoa, Shah, & Zhang, 2011; UN Habitat, 2009; Williams & Dair, 2007) shows that there are a variety of frameworks being proposed for the development of indicator tools in general and the urban environment in particular. However, proposed frameworks often conflict in methodology. Furthermore, there seems to be no framework singularly suited for the development of an indicator assessment tool by which the quality and sustainability of the existing urban environment may be evaluated on a neighborhood scale level. These observations have been the starting point for the research presented in this report.

1.2 Research goals

It is the purpose of the work described in this report to research how a sustainability assessment method for the existing urban environment might be developed in a structured and scientifically sound way. The final goal of this study is to create a framework by which such tools might be developed.

In order to develop this framework, we will fist build up a knowledge base of the urban environment itself. In order to better understand the urban environment, the process of urbanization will be placed in historical perspective. It will then be determined what constitutes as a high quality sustainable urban environment.

There are currently a number of proposed methods for measuring and monitoring of various aspects of the urban environment. An evaluation of the currently proposed methods as well as knowledge of development of such methods will provide the information needed to develop a framework by which a sustainability assessment method for the existing urban environment may be developed.

The goals of this report are to:

- Provide a historical perspective of the phenomenon of urbanization;
- Define the concepts of urban quality and urban sustainability;
- Identify and map current and relevant knowledge regarding the measuring and monitoring of the quality and sustainability of the existing urban environment;
- Propose a conceptual framework by which a quality and sustainability assessment tool may be developed, specifically suited for the evaluation of the existing urban environment on a neighborhood scale.

1.3 Research questions

Based on the research goals, the following research questions have been formulated:

1. How is urban quality and urban sustainability conceptualized in the current scientific literature?
2. What methods are being discussed in current literature to systematically monitor the urban environment?
3. How can the answers to the previous two research questions be applied to develop an indicator assessment tool for the existing urban environment in a systematic and structured way?

1.4 Report structure

The basic structure of the work presented in this report has been depicted in Figure 1. In order to assist the reader in navigation of this report, a visual representation of the table of contents has been added in appendixes A and B. The charts in the appendixes demonstrate how the information in the various sections of this report is linked to each other. Appendix A shows how the work presented in chapters 2, 3, and 4 has led to the construction of a framework for the development of a neighborhood assessment tool as is the goal of this research. Appendix B represents how the functioning of the constructed framework has been demonstrated in chapter 5 of this report. The contents of each chapter are briefly described below.

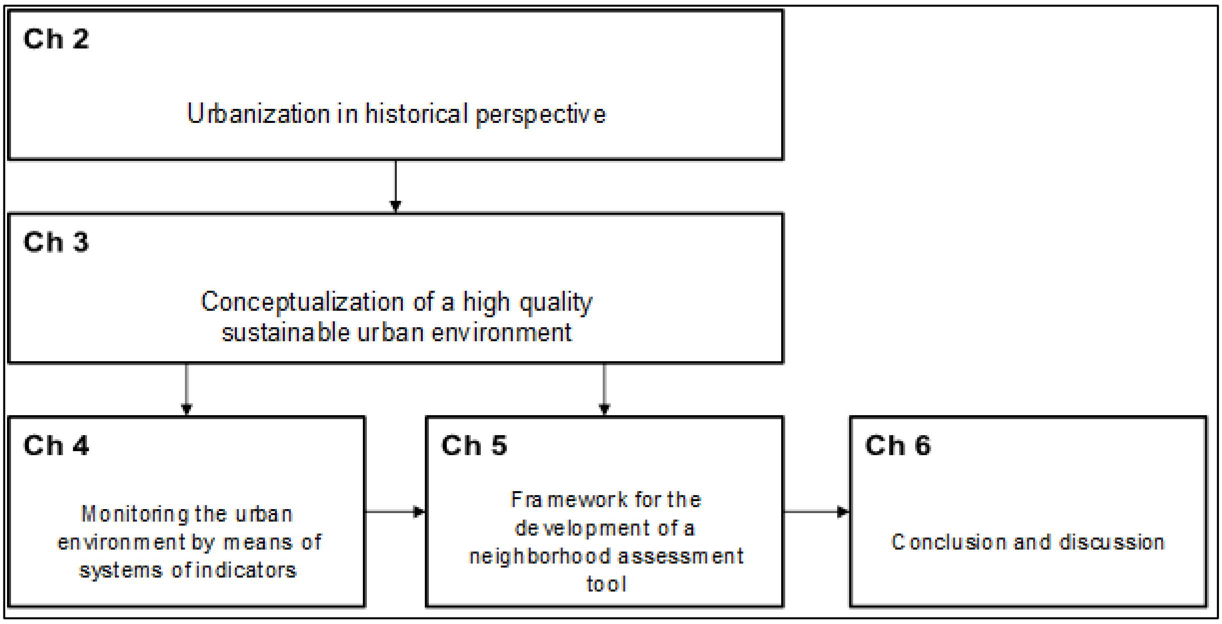

Figure 1 - Chapter structure of report

Chapter 2 – Urbanization in historical perspective

In chapter two the process of urbanization in general will be substantiated by placing it in historical context and exploring a number of influential forces on the process of urbanization. Placing the process of urbanization in perspective will provide a sound knowledge base on which the definition of a high quality sustainable urban environment can then be formulated.

Chapter 3 - Conceptualization of a high quality sustainable urban environment

In chapter three the first research question of this report will be answered.

> **How is urban quality and urban sustainability conceptualized in the current scientific literature?**

Urban planning as a concept has been around for at least 26 centuries (Stanislawski, 1946), tracked back as far as ancient Greece. City planning has come a long way since then, although the ancient ideas of grid planning can still been seen in cities around the world. Urban quality currently encompasses far more aspects then general layout of the city, although city layout still is an important aspect (Kamp, Leidelmeijer, Marsman, & Hollander, 2003). In contrast, the concept of sustainability is a rather recent development.

The first research question will focus on conceptualizing the concepts of urban quality and sustainability. Doing so will provide an all-encompassing scientific formulation of what is regarded as a high quality, sustainable urban environment.

Chapter 4 - Monitoring the urban environment by means of systems of indicators

Chapter four will explore the second research question of this report.

> **What methods are being discussed in current literature to systematically monitor the urban environment?**

Operationalizing the concept of a high quality sustainable environment constitutes the first step towards realizing such areas. The data that becomes available by measuring and monitoring the urban environment can assist decision makers in selecting policies that will drive the urban environment towards increased quality and sustainability (Alberti, 1996).

The second question of the research will focus on what methods are currently being proposed in literature to monitor the urban environment on issues concerning quality and sustainability, as has been identified by answering the first research question in this report.

Reviews of a number of measuring and monitoring systems have concluded that some assessment schemes are more successful than others. The key aspects that make indicator systems a success will be identified.

The most important result of this chapter is to identify the basic building blocks of indicator tools. An understanding of these basics will facilitate in the construction of a framework for the development of such tools.

Chapter 5 - Framework for the development of a neighborhood assessment tool

Chapter five will answer the final research question of this report.

> **How can the answers to the previous two research questions be applied to develop an indicator assessment tool for the existing urban environment in a systematic and structured way?**

Understanding of the urban environment, as researched in chapter 2 and chapter 3, combined with knowledge of indicator systems as researched in chapter 4, facilitates the construction of a framework for the development of an indicator assessment method for the existing urban environment on a neighborhood scale. Presentation of the proposed framework will be the contents of chapter 5 of this report.

Chapter 6 – Limitations of the presented research

This chapter will provide a brief discussion of the limitations of the research presented in this report.

Chapter 7 - Conclusion

The results of the presented research will be summarized in light of the research goals and questions.

2. Urbanization in historical perspective

It is the purpose of this chapter to provide perspective to the process of urbanization. This will be done by placing urbanization in a historical context. The first paragraph will discuss the origin of urbanization. The second paragraph will explore the growth of urban centers, and the driving forces behind urbanization increase. In the third paragraph of this chapter we will discuss the challenge of the ‘urban order’, the problems associated with the increasing urban environment, as well as the opportunities that the urban environment presents. The work presented in chapter two of this report will provide the platform on which to introduce the concepts of urban quality and sustainability in chapter three.

2.1 The origin of urbanization

The seeds of urbanization

The true origin of cities seems hard to pin down. The conventional wisdom states that the origin of early settlements may be found in the invention of agriculture, about 8000-10000 years ago. The surplus of food freed up labor, allowing for people to become specialists. Concentration of specialists allowed for increased efficiency and trade, providing benefits for all involved (Antrop, 2004).

On the other hand, archeological evidence seems to suggest that human settlements existed before the domestication of crops, at around 9.000 B.C. (Byrd, 2005). These settlements employed a hunter gatherer strategy that yielded sufficient sustenance to support a sedentary life style. Domestication of crops was discovered by these sedentary tribes as a means to increase the productivity and sustain the settlement indefinitely.

In the area referred to as the “Fertile Crescent”, expansion of the rural toolkit came with the domestication of animals for food production at around that same period, between 9000-8000 B.C. With the help of both archeological and genetic research, Malinda Zeder (Zeder, 2008) tracks the origin and spread of domesticated animals across the area now covered by the countries of Iraq, Kuwait, Syria, Lebanon, Jordan, Egypt, Israel and the southwest of Turkey. Although settlements where now more or less permanent, almost all inhabitants where still involved in the process of food gathering, either through agriculture, animal husbandry, or hunting and gathering, all of which required a significant amount of land per person.

The question concerning the first true form of urbanization seems to be one of definition. In his article on “The origin and growth of urbanization in the world”, Kingsley Davis (Davis, 1955) writes:

> “*Between 6000 and 4000 B.C. certain inventions such as the ox drawn plow and wheeled cart, the sailboat, metallurgy, irrigation, and the domestication of new plants facilitated, when taken together, a more intensive and more productive use of the Neolithic elements themselves. When this enriched technology was utilized in certain unusual regions where climate, soil, water, and topography were most favorable (broad river valleys with alluvial soil not exhausted by successive cropping, with a dry climate that minimized soil leaching, with plenty of sunshine, and with sediment-containing water for irrigation from the river itself), the result was a sufficiently productive economy to make possible the,* ***the concentration in one place of people who do not grow their own food.”***

The need for a social system to facilitate urbanization

The rise of urbanization does not appear to be just a matter of excess food production leading to specialization. Again from Kingsley Davis:

> *"The rise of towns and cities therefore required, in addition to highly favorable agricultural conditions, a form of social organization in which certain strata could appropriate for themselves part of the produce grown by the cultivator."*

Davis argues that it was possible for rural communities to limit food production to only that which was needed to sustain themselves. Some form of incentive or control was needed to ensure that surplus food was produced for those who did not produce their own. Examples of such social mechanisms to obtain food are the creation of governing social classes and taxation (chieftains governing and protecting the population), religion (priests protecting people from the gods in return for favors), and economics (craftsmen trading artifacts for produce). This blend of social organization and the newly discovered agricultural practices led to what can be called the first true cities.

2.2 Urbanization increase

Early limitations to city size

Early city population size was limited by the productivity of the surrounding countryside and the effectiveness of the city to control and organize this productivity. Estimations suggest it would take 50 to 90 farmers to support a single city dweller (Davis, 1955). Transportation, also a slow and labor intensive process, was another limiting factor to the amount of food that could be brought into the city from the surrounding countryside. Estimations of early city sizes limit population at approximately 60.000 inhabitants with the city of Babylon reaching 150.000 inhabitants at around 500 BCE (Morris, 2010).

The full potential of the ancient world to support truly large cities was first achieved through the organizational talents of the Roman Empire and culminated in the city of Rome (Davis, 1955). At the height of its power the city was estimated to contain a population of one million inhabitants (Morris, 2010). After the overthrow and decline of the empire, this city population size would not be achieved in Europe again until the growth of London in the 19th century.

Urban growth in the following centuries in Europe and the United States

In her book "The economy of cities" Jane Jacobs (Jacobs, 1969) writes: *"Rural economies, including agricultural work, are directly built upon city economies and city work".* She argues for example that most farming innovations (or in fact al innovations) like improved tools and crop rotation find their origin in or near cities and from there slowly diffuse to outlying agricultural areas. The invention of such tools and methods led to increased food production, which in turn allowed for a larger city population to be sustained.

Along similar lines Marc Antrop (Antrop, 2004) argues that transportation innovations had a huge influence on an increasing urban population. During the middle ages, when travel between places would take days or weeks, villages would spring up along the trade and pilgrim routes, providing distinct services to traders and travelers. Larger cities and their connections thus had a huge influence on the shape of the outlying landscape.

Explosive growth of urbanization began at the beginning of the 19th century. Britain entered the period known as the industrial revolution. Production capacity significantly increased and new economic opportunities arose in the cities. London, by then already a city of around 800.000 increased to a population of over six million in the next century (Davis, 1955; Morris, 2010). Along with the industrial revolution came the agricultural revolution. New technologies increased agricultural efficiency, thus decreasing the number of people needed to feed an urban population. Peter Hall (Hall, 1998)(p410) writes: *"In 1863 one farmer could feed five city people, after world war II, thirty."* National agricultural production was supplemented with food import, made possible by increasing transportation efficiency and supported by industrial productivity. By 1950 more than 50% of the population of West-Europe was living in urban environments (Antrop, 2004).

In his book "Cities in Civilization", Sir Peter Hall (Hall, 1998)describes the golden ages of some of the most influential cities in Western civilization. In regards to the question why people flock to the city he paraphrases Aristotle by writing: *"People move to the city to have a life, they stay in the city to live the good life"*. He expands this simple statement by describing the appeal of the excitement, the culture and the stimulus that comes with living in urbanized environments, not to mention the economic potential that may be found in the city.

Many other researchers have attempted to capture this phenomenon in a more scientific way using a push-pull model for population migration (Mabogunje, 1970). Pull factors that inspire people to mover to an urban environment include higher income jobs, better healthcare and education, and overall higher standards of living. Corresponding push-factors include rural overpopulation, low income, and decreasing farmland quality. Most of these models find their origins in Ravenstein's law of migration (Lee, 1966) which notes that migration distances, transportation technology and above all economic motive tend to drive migration processes.

Underlying mechanics notwithstanding, it seems that the size of cities has ever only been limited by the capacity of the city to house, feed and maintain its inhabitants. Ian Morrison (Morris, 2010) evaluates this capacity in terms of social development, by which he means, in his own words: "*A group's ability to master its physical and intellectual environment to get things done".* One variable he considers when measuring this social development is the energy capture per capita, expressed in kJ/person. When estimating this energy capture index, Morrison considers not only food production, but includes fuel resources and the gathering of raw production materials. He reasons that this combined index should give a reflection of how well organized a population is at a certain point in time (how efficient they get things done) and correlates this index to the size achieved by the biggest cities of that time.

Although the correlation is clearly shown in his research, this theory does not seem to cover the entire story. While referring to Malthus' *Essay on the principles of population* (Malthus, 1798), Morrison himself admits that limits to food production and distribution have always been the brake on rising living standards and population. Throughout history, first small villages, and later cities, have been pushing against this Malthusian ceiling, only to again decline in inhabitants under the pressure of their own population. It was only in the industrial revolution that excess energy capture per capita could be translated into increased food production, thus making dramatic population increase in the cities possible.

Urbanization of the world

By 1950 over 50% of the western population was living in cities. With new innovations and whole new branches of industry springing up in urban areas, this percentage has been increasing ever since. Breakthroughs in healthcare and sanitation ensured that populations did not die off through illnesses and plagues that occur when populations become too dense. Technology such as pesticides, seed-breeding, and genetic engineering of crops have further increased food production, making even larger cities possible (Brand, 2009).

In todays interconnected world, innovations allowing for increased city populations have spread across the world. Although the western countries have had a slight head start, the world as a whole is starting to catch up. This is illustrated in Figure 2 in which the urban population percentages of a number of parts of the world have been graphed. The data has been obtained from the World Urbanization Prospects, compiled by the Department of Economic and Social Affairs of the United Nations. It has been projected that by the year 2050 close to 70% of the world population will be living in urban environments, while the urban population of the United States will consist of close to 90% of the total population.

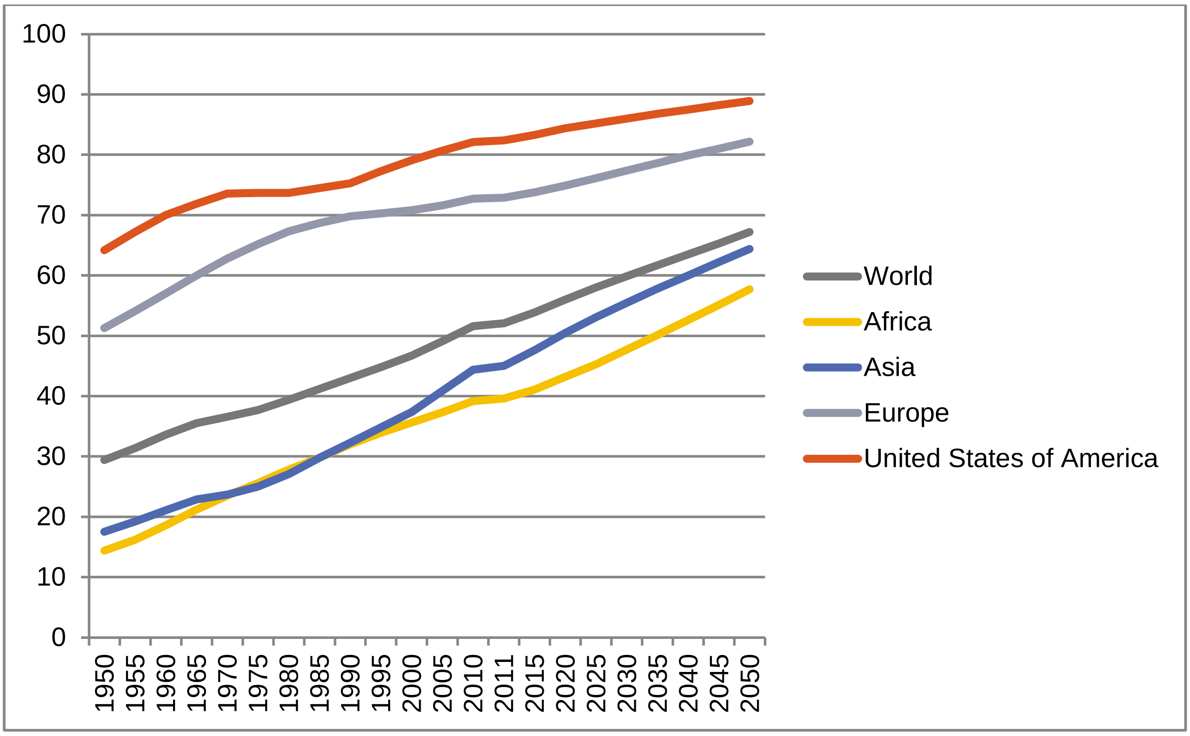

Figure 2 - Projected percentage of population living in an urban environment. (http://esa.un.org/unup/)

2.3 The costs and benefits of urbanization

On the topic of urban planning

A point made in the previous section is that throughout history, city size has always been limited by the capacity of the city to feed, house and maintain its citizens. On the topic of the urban order Peter Hall (Hall, 1998)(p611) writes:

> *"Cities are quintessentially disordered places, infinitely harder to manage than small towns or villages. Bringing order to them – cleaning the streets, collecting the rubbish, policing crime – consumes a large part of the energies of their citizens, a larger part than any of them would care to deploy. This chore is the price that these people pay for the advantages that come from living and working in cities."*

It is the purpose of urban planning to solve these issues as effectively as possible. Throughout history, a large range of solutions has been brought to bear on the challenges that come with city size and density. Perhaps one of the earliest examples of urban planning can be found in the design of cities in grid pattern. Early application of street patterns in grid formation can be found in cities as far back as 2000 BC (Stanislawski, 1946). Application of such patterns offers immediate advantages to the city with regards to transportation and thus to trade. This in turn enables the acquisition and distribution of appropriate amounts of food to feed city population. Other examples of historical approaches to urban planning include the placement of markets and the erection of public buildings such as courts and theatres, deepening of harbors, the raising of city walls and the placement of aqueducts to provide the growing city with fresh water.

Rather ironically, solving a lot of the problems related to urban growth and densification has until recent years always led to an ever increasing urban population and a whole new set of problems and challenges related to the urban environment. Based on the research done by Ian Morrison (Morris, 2010), city size is a reflection of the effectiveness of urban planning, social organization and available technology. Increasingly capable social organization and urban planning capacity may lead to an ever increasing urban population. Failure to rise to the new challenges presented by rising population numbers may however be the downfall of great cities.

The toll of urban development

Building cities and maintaining the urban order consumes vast amounts of resources and energy. In previous centuries the rate of resource consumption was checked by our ability to capture and utilize energy to gather and convert required resources (Morris, 2010). This check was removed with the coming of the industrial revolution, when burning of fossil fuels provided humanity with an abundant, but ultimately finite, source of energy. To put it crudely: Any challenge of the urban order could be solved by throwing large amounts of energy and resources at it. In the last two centuries this has led to increasingly energy intensive solutions to creating and maintaining livable and appealing urban environments.

Cities were and still are forced to make choices concerning their development. The ancient Greek city of Athens chose to erect temples and impressive public buildings while the population lived in squalor. Ancient Rome built aqueducts, roads and sewers. In more contemporary times, the city of Los Angeles opted to invest heavily in a network of freeways, while across the country the city of New York chose to invest in an underground rail network

(Hall, 1998). Policies and development choices made by cities ultimately influence and dictate the form and structure of the urban landscape.

Throughout centuries the resources and energy required to develop and sustain the urban order have always been brought in from the urban hinterland, either through trade, war or other form of social construct. Rome was able to finance its great public works with the spoils of its conquests, part of which came in the form of slaves (Hall, 1998). The renaissance city of Florence grew on the profits of European trade. Industrial Britain and indeed all west European great cities could only expand due to the trade and resources that could be brought in from around the world. This trend has culminated in the classical "economical" point of view, in which natural resources, combined with human ingenuity and technology are assessed as an open cycle with inputs and outputs (Newman, 1999).

This approach has held up well in a huge world with unexplored frontiers and a seemingly limitless supply of undiscovered natural resources (Boulding, 1966). Furthermore, this worldview encourages throughput and consumption, as these parameters translate into a growing GDP. In our current world, this view does not hold up as the planet we live on is in fact a closed system with only sunlight as an external input to this system. One phrase associated with this worldview is termed "space ship earth". This shift in worldview has caused a shift in thinking, away from an open loop approach and towards a closed loop system approach.

This has consequences for the way in which urban challenges are to be solved. Pollution may no longer be mitigated to areas away from the city or dumped in oceans. Urban challenges can no longer be solved by 'throwing natural resources and energy at it'. Instead, the urban environment itself must be viewed as a closed system, in which both inputs and outputs must be minimized by means of increased (energy) efficiency and capturing and reusing of waste streams. As an added challenge, we wish to do so without giving up on the quality of life that the developed world has come to expect.

The benefits of urbanization

The list of urban problems is a long one. Increasing population densities around concentrated areas has had a significant effect on the way people live and interact, not to mention the local and even global environment. Studies have shown the negative effects of urbanization on local water quality (Booth & Reinelt, 1993), air quality (Akimoto, 2003), soil quality, and the flora and fauna of the area (Diamond, 2005). Studies also show the effect of bad environmental conditions on population health. Combining these problems with the enormous resource sink that cities represent, in part through changing consumption patterns of a population, has often led to the thought that urbanization itself is a bad thing: "The problem of urbanization"

One may argue that referring to the process of urbanization as a problem may do the phenomenon itself some injustice. It is therefore useful to provide some nuance to this viewpoint. In historical perspective urbanization can be viewed as a valid and highly successful survival method. Settlements provided efficient means to organize agricultural activity. Walled towns could provide protection from outsiders. Furthermore, dense settlements provide exactly the kind of environment in which creativity, invention and innovation is born. Borrowing from Gunnar Tornqvist's theory of the "creative milieu", Peter Hall (Hall, 1998), p18) writes:

"*They* (creativity and innovation, auth.) n*eed communication between individuals and between different areas of competence; so there must be a certain density of communication, which seems to require a rich, old-fashioned, dense, even overcrowded traditional kind of city."*

Along these lines Jane Jacobs (Jacobs, 1969) argues that most great innovations that have improved the human quality of life are in fact urban innovations. Indeed when reading Cities in Civilization (Hall, 1998), one cannot escape the fact that all great arts, scientific discoveries and even social reform originated in urban environments. It may perhaps be said that the challenges and problems associated with the urban order, along with the creative milieu provided by the city, are exactly the ingredients that have pushed humanity to the quality of life that we enjoy today, albeit accompanied by an increased total human population number and increasingly challenging circumstances.

For millions of people around the world, migration towards the city provides an escape out of rural poverty. With regards to urban efficiency Jianguo Wu writes:

"The most remarkable thing about cities is that, even with urban sprawl, they take up merely 3% of the earth's land surface, but accommodate more than half the world's population. Cities have lower per capita costs of providing clean water, sanitation, electricity, waste collection, and telecommunications, and offer better access to education, jobs, health care, and social services (Wu, 2009)*"*

Even in modern times, cities provide the most efficient way to organize labor, including agriculture, and provide basic services and a minimum level of wealth to large populations. The future of the human race appears to be an urban one. Although cities cause their share of problems, they are also the kind of environment in which these problems may be more readily solved. As such, urbanization should not be viewed as a problem but as a process which, if handled correctly, may provide opportunity to solve a number of pressing issues.

2.4 Conclusion

This chapter has attempted to provide historical context to the process of urbanization. It may be clear that cities develop differently, depending on local circumstances and historical influences. As such, no two cities are exactly the same. Although urbanization brings along its fair share of challenges, the urban environment has also led to an extreme lift in the quality of life of humanity as a whole. As such, the cost of urbanization may be more than compensated by the benefits that the process brings.

The current challenge is to further increase the benefit of urbanization, while mitigating the cost of the process. In order to do so cities have to be designed and organized more efficiently. One trend in organization of our resources and environment is a shift from thinking in terms of open-loop economies, to thinking in terms of closed loop economies.

As has always been the case in history, technical innovation and adequate social organization are needed to create the desired urban environment and maintain the urban order. What the current thinking is in regards to the desired urban environment will be the content of chapter 3 of this report.

3. Conceptualization of a high quality sustainable urban environment

This chapter will present the answers to the first research question of this report.

> **How is urban quality and urban sustainability conceptualized in the current scientific literature?**

It may be clear that the concept of urban quality is a fluid one and heavily dependent on the "zeitgeist", the spirit and culture of people at a certain place in a certain time. One theme of our time is the concept of 'sustainability'. The word in essence means: "Meeting the needs of present generations without compromising the ability of future generations to meet their needs". (WCED, 1987).

Deriving from the often quoted triple-bottom-line notion of sustainability, a sustainable city should achieve a balance in economic development, environmental protection, and social wellbeing (L. Shen et al., 2013).

> *"Urban sustainability requires minimizing the consumption of space and resources, optimizing urban form to facilitate urban flows, protecting both ecosystem and human health, ensuring equal access to resources and services, and maintaining cultural and social diversity and integrity."* (Wu, 2009)

Although most current interpretations of urban sustainability conform to a balancing of the triple bottom line, the current literature is by no means in agreement on what such a place would look like. Attempts to either structurally describe or quantify such an environment are heavily influenced by either the (scientific) approach or values of the author, or the purpose to which the description is being made.

Furthermore, when expressing a sustainable urban environment in a number of variables it seems unavoidable that certain variables are functions of, or heavily influenced, by multiple other variables of the urban environment. This makes it complex to systematically categorize the relevant variables and present them in a clear and coherent way.

Instead, this chapter will follow a different approach. In the first paragraph we will investigate an all-encompassing model for the urban environment. This model will allow us to visualize and more systematically explore the different aspects of an urban environment. Although the model will not completely remove the difficulties foreseen when categorizing sustainability issues, it will at least provide us with a clear starting point from which we can further explore the related issues.

Using the presented model as a starting point the second section of this chapter will explore the basic principles and dimensions of urban sustainability as discussed by literature. Focus in this paragraph will be on bio-physical sustainability. The third section of this chapter will then focus on how urban quality can be defined. Section 3.4 will introduce the concept of the urban ecological space, and how this concept connects to both urban quality and sustainability. Section 3.5 introduces an all-encompassing framework, by which sustainability, quality and the urban ecological space may be linked. Finally, the principles and dimensions of sustainability combined with the proposed framework will then be used in the final paragraph of this chapter to define certain descriptions and guidelines for the (perceived) high quality sustainable urban form, thus answering the first research question.

3.1 Modelling the urban process

The purpose of this first paragraph is to provide us with some perspective in which to view the workings of the urban environment.

The urban environment from an ecological perspective

To capture the entirety of the urban process it has been chosen to take an ecological approach. Ecology in general has made significant contributions to the concepts of sustainability by researching the impact that human beings are having on the natural environment. Furthermore attention was drawn to the problem of excessive human consumption patterns and waste emission by expressing these in terms of the human ecological footprint, the total area of productive land and water required on a continuous basis to produce the resources consumed, and to assimilate the wastes produced, by a specific population. (Rees, 1997).

In regards to the study of the urban environment Richard Forman pleads (Forman, 2008):

> *"What would you use as the central foundation or perspective to change the land, shape the future, for nature and us? Economics? Water resources? Transportation? Housing and employment? Bio conservation? Engineering? Social structure? Agriculture? Architecture? Each has obvious strengths and major lacks for the challenge. No panacea exists. I keep searching and still can discover no better foundation than landscape ecology."*

Although the statement above is not fully substantiated in his own article, Forman's argument is further supported in a number of other articles concerning the study of urbanization from a geographical and ecological point of view. (Antrop, 2004; Gasparatos & Scolobig, 2012; Macchi, 1999; Newman, 1999; Rees, 1997, 1999; Roseland, 1997; Wu, 2009). The gist of the argument is that the urban environment may be evaluated as a complex chain of ecosystems comprising of both a city itself as well as the vast hinterlands from which it draws its resources. The field of landscape ecology does not wish to replace the mentioned studies. Rather, the field aspires to play an interdisciplinary role in the study of the urban environment.

Classical ecology studies both the form of biotic and abiotic features in an environment, as well as their interactions. Applying such a viewpoint to the urban environment allows researchers to work from a common foundation while studying either the form or the interactions of the urban systems. Studies such as architecture, agriculture, economics, transportation and bio-conservation, which can all be classified as studies of form and/or interaction, may find their place in the overarching model provided by the city as ecosystem.

Urban Metabolism model

To approximate the workings of the urban environment, this report will first apply the extended metabolism model of human settlements as presented by Peter Newman (Newman, 1999). A representation of the model can be seen in Figure 3. The benefits that this model provides over regular metabolism models of in- and output, are that the extended model accounts for livability factors, which for the purpose of this research may be interpreted as the “quality” of an urban environment.

While referring back to a concept presented in section 2.3, this model essentially depicts the classical approach to solving problems of the urban order. Increased ‘quality’ or ‘livability’ of the urban environment may be achieved by “throwing large amounts of energy and resources at the problem”. This viewpoint is accompanied by the classical economist’s viewpoint of an open-loop economy in which increased throughput leads to increased prosperity and a higher quality of life(Boulding, 1966; Rees, 1997, 1999).

In accordance with the laws of mass conservation, any resource input must either remain in a system or be released back into the environment at some point in time. In the model this will either occur as material buildup in the system through extension and expansion of the urban form, covered by the model under the heading ‘Livability’, or be released by the system, covered by the model under the heading ‘Waste Outputs’.

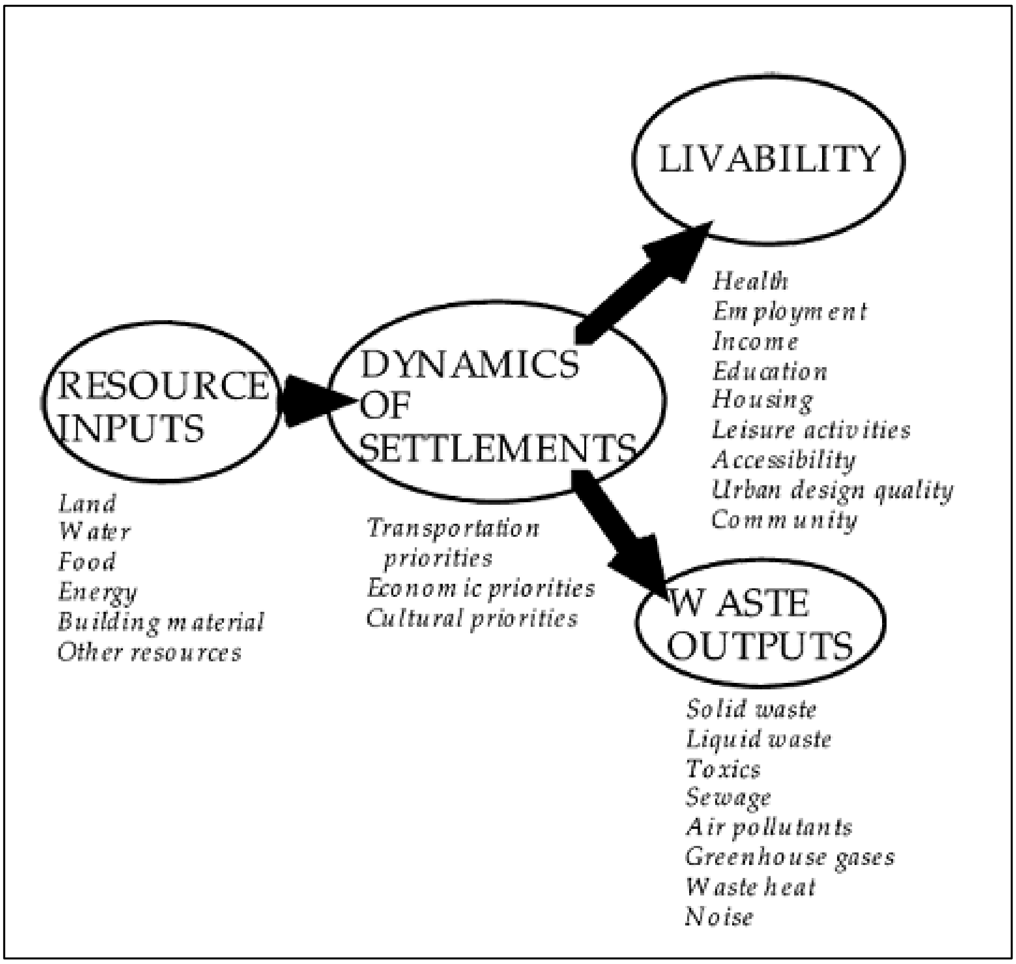

Figure 3 - The extended urban metabolism model as presented by Peter Newman

The terms ‘Resource Inputs’ and ‘Waste Outputs’ are purely physical attributes of the urban system and are thus quantifiable and relatively easy to grasp as concepts. Newman identifies ‘Land’, ‘Water’, ‘Food’, Energy’, ‘Building Material’, and ‘Other Resources’ as the relevant aspects of resource inputs. Aspects of waste outputs are; Solid waste, Liquid waste, Toxics, Sewage, Air pollutants, Greenhouse gases, Waste heat, and Noise.

“Dynamics of the Settlement’ on the other hand is a more complex concept. The concept basically covers the entire inner workings of the urban environment. As such, the concept covers multiple fields of study such as economics, politics and policy making, as well as societal makeup, population behavior and basic production and consumption patterns. The model lists these concepts simply as Transportation-, Economic-, and Cultural Priorities.

“Dynamics of the Settlement” is process and interactions orientated. As such, description of such processes and features usually requires a qualitative approach. “Livability” is concerned with the actual features of the urban environment and aspects of the physical form. As such, attributes that fall under the term ‘Livability’ can be quantified. The listed aspects of livability are; Health, Employment, Income, Education, Housing, Leisure activities, Accessibility, Urban design quality, and Community.

Extending interaction within the model

The model as presented by Peter Newman features only one-way flow of input and out-put as well as a clear path of cause and consequence from resource-input to aspects of livability and waste output. For the purpose of this research we will extend the interactions within the model to gain a better understanding of the entire urban process. This in turn will allow us to more accurately classify the different features of the sustainable urban environment.

Waste Outputs – Livability

A first consideration is that waste outputs can have an adverse effect on urban livability. Numerous studies link poor urban environmental quality to deteriorating health conditions. Other forms of pollution such as light and noise pollution affect people’s sleeping patterns, thus influencing comfort levels at the least, and public health at worst. On a more basic level, litter and trash negatively influence people’s interaction and enjoyment of the urban environment. As such it will be relevant to investigate the relationship between waste output and livability when investigating both the principles and the features of a high quality sustainable environment.

Waste Outputs – Sources

As argued by a number of researchers(Boulding, 1966; Rees, 1997, 1999), some of the produced waste streams of the urban environment may be viewed as resources themselves. The best examples of such reusable waste streams are the practice of recycling used materials and application of waste heat to heating of other processes.

Dynamics of Settlement – Livability

There is a complex interaction between the ‘Dynamics of the Settlement’ and the physical features of the urban environment. Peter Newman does not touch on this point himself when presenting his metabolism model. There is however research available (Williams & Dair,

2007) on the effect of design and the urban features, on people's behavior and by extension on the dynamics of a settlement in general. These interactions will be further substantiated when describing the physical aspects and features of the sustainable urban form

The extended model

Figure 4 depicts the extended metabolism model of the urban environment with inclusion of the proposed adaptations. This model will serve as an initial framework while exploring the principles of a high quality sustainable urban environment as described by the current scientific literature.

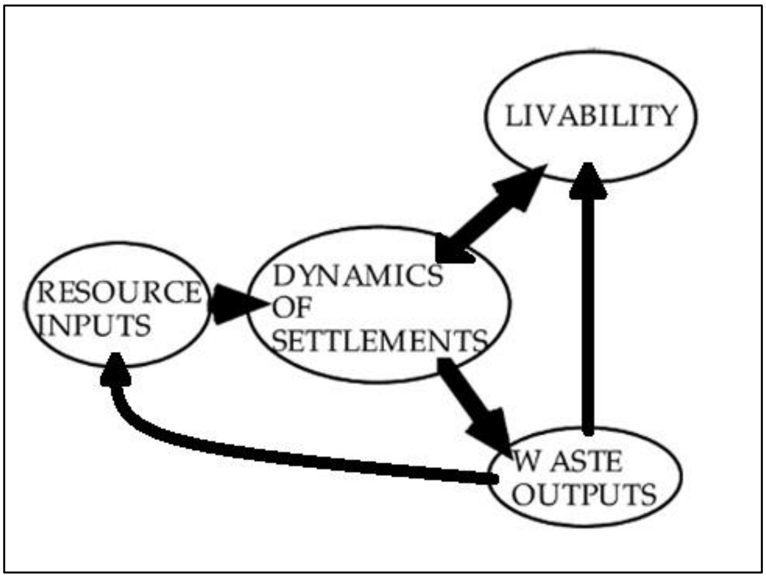

Figure 4 - Adaptations to the extended urban metabolism model

Taking the urban metabolism model as a starting point, the next two paragraphs will further expand on the principles and theories related to a high quality sustainable urban environment. Section 3.2 will focus on the bio-physical part of the metabolism model. The bio-physical part of the metabolism model includes resource inputs and waste outputs of the urban environment.

Section 3.3 will then focus on the guiding principles and dimensions of a high quality urban environment.

3.2 Principles and dimensions of a bio-physically sustainable urban environment

This paragraph will explore the concepts of bio-physical sustainability. The concept will first be explained in general. Various aspect of bio-physical sustainability will then be examined in greater depth.

3.2.1 Principles of sustainable urban metabolism

In the bio-physical sense of the word, sustainability refers to a process or condition that can:

> *"…be maintained indefinitely without progressive diminution of valued qualities inside or outside the system in which the process operates or the condition prevails."* (Holdren, Daily, & Ehrlich, 1995)

It has been recognized that on a global scale, resources are finite while external energy into the system, our planet, only comes from solar radiation[1]. Natural ecosystems have the capacity to assimilate waste streams while providing both natural capital in the form of (renewable) resources, and ecosystem services, such as CO_2 sequestering and oxygen production. However, global and local assimilation capacity is limited. Finally, some resources, most notably timber and food production are renewable if managed correctly but rely on external energy input, mainly solar.

Ecological economist Herman Daly (Daly, 1991)suggests three criteria to ascertain sustainability (Alberti, 1996):

- Rates of use of renewable resources do not exceed replacements rates.
- Rates of use of non-renewable resources do not exceed rates of development of renewable substitutes.
- Rates of pollution emission do not exceed the assimilative capacity of the environment.

In terms of the metabolism model of the urban environment, this indicates that resource input and waste output should be minimized and come from renewable sources. In the Netherlands, (Duijvestein, 1993)introduced a three step scheme for evaluation and ranking of sustainability measures in the building sector, relevant to both resource inputs and waste outputs(Entrop & Brouwers, 2010). Although the steps where specifically formulated for the building sector, the steps seem relevant for evaluation of a wide range of urban processes. Sustainability measures that are deemed most favorable are part of the first step, while less favorable measures fall under step two or three.

The steps for control of the resource inputs are;

1. Prevent unnecessary use;
2. Use endless (renewable) sources, such as wood, or solar energy;
3. Use sources which are not endless as efficient as possible.

The suggested steps for control of waste output are:

[1] It may be argued that heat from the earth can be viewed as an infinite resource. Even so, that source of energy is already part of the system and is not considered an external source.

1. Prevent waste
2. Reuse waste
3. Dispose of waste wisely

It can be seen that the focus of the strategy is aimed at reducing consumption patterns. Reduced and more efficient consumption provides benefits at both input and output side of the urban metabolism model.

In terms of resource input, the three steps as proposed by Duijvenstein only conform to Daly's criteria for sustainability when the rate of consumption of renewable resources as per step two, lies below replacement rates of the resource. Furthermore, consumption of non-endless resources, as per step three, must lie below the development rate of renewable substitutes. Concerning control of waste output, waste disposition as per step three must lie below environmental assimilative capacity.

Both Daly's sustainability criteria and Duijvenstein's steps may seem vague as general guidelines for sustainability. However, combining these general principles with Newman's extended urban metabolism model provides us with a starting point while analyzing the relevant dimensions of the bio-physically sustainable urban environment.

3.2.2 Dimensions of the urban metabolism - Urban resource inputs

In his model for urban metabolism, Peter Newman (Newman, 1999)notes energy, land, water, building materials, food, and other resources as the relevant aspects of urban resource inputs. Cross-reference of Newman's list with other articles has not yielded additional input categories, although the input categories "Building Materials" and "Other Resources" have been expanded in a number of articles.

In this report we will not discuss the heading 'other resources'. We will however discuss the topic 'transportation' as a resource, although Newman lists transportation under "Dynamics of the Settlement. As explained in chapter two of this report, transportation is of such influence to the urban environment that we discuss it as an input to the urban environment. This being said, it should be realized that transportation is dependent on energy- and material input.

It should be noted that food is not only a resource in the traditional sense of the word, but can also be viewed as a product of the resources land, water and energy. Nevertheless, increased food production has been identified, in chapter two, as one of the driving forces for increasing urbanization. As such, food as a resource will also be discussed separately.

The different input dimensions of the urban metabolism model will be discussed individually in relation to both Daly's criteria of sustainability and the three step strategy towards sustainability. Organization of sub-sections is listed in Figure 5.

Paragraph	Discussed resource
§3.2.2.1	Energy
§3.2.2.2	Land
§3.2.2.3	Water
§3.2.2.4	Building materials
§3.2.2.5	Food
§3.2.2.6	Transportation

Figure 5 - Organization of sub-paragraphs concerning urban resource inputs

3.2.2.1 Energy

Although effectively producing or obtaining food and water were the primary boundary conditions by which cities where able to grow, large scale urban expansion as we are seeing today was only possible by means of increased production and transportation increase, made possible by the energy obtained from fossil fuels as explained in chapter two.

Although studies often disagree on a timeframe and new sources of fossil fuel are still being found, all studies agree that fossil fuels are a finite resource and will therefor run out(Shafiee & Topal, 2009). As such, continued reliance of these resources is unsustainable in the long run. The unsustainability of the use of fossil fuels is further compounded by concerns about the effect of CO_2 on climate change.

Based on the term 'Trias Energica' coined by (Lysen, 1996), and application of the three step sustainability strategy proposed by Duijvenstein (Duijvestein, 1993), a common strategy for attainment of sustainable energy consumption has been formulated. The strategy is referred to as the 'Trias Energetica' and consists of the following three steps(Entrop & Brouwers, 2010):

1. *Prevent the use of energy by reconsidering the energy use (prevention)*
2. *Use sustainable energy sources as widely as possible (renewable)*
3. *When there still remains an energy demand, then use fossil fuels as efficiently as possible (efficiency)*

Considering current dependencies on fossil fuels, obtaining energy sustainability in the urban environment is still a long way off. In order to reach true sustainability in the bio-physical sense, urban- and indeed global energy consumption must drop below replacement rates provided by renewable energy sources.

3.2.2.2 Land

According to research done by the (Bringezu et al., 2014) approximately 36% of the global land mass was converted to human use by the year 2000. Another 34% of total landmass is covered by deserts, glaciers and tundra's, leaving 30% of the world's landmass for the remaining natural grasslands and forests. As was also mentioned by (Wu, 2009) settlements and infrastructure occupy a tiny percent of the earth's land surface. Land use figures can be seen in Figure 6.

Land as a global resource, is tightly interwoven with food production, living space, and ecological services provided by nature, such as rainwater management and carbon sequestering. These conflicting interests all put heavy pressure on land availability. Once natural land has been cultivated, complete reversal to its former state is deemed neigh impossible. Furthermore, built up urban land cannot readily be transformed back in to agricultural land due to soil degradation and contamination.

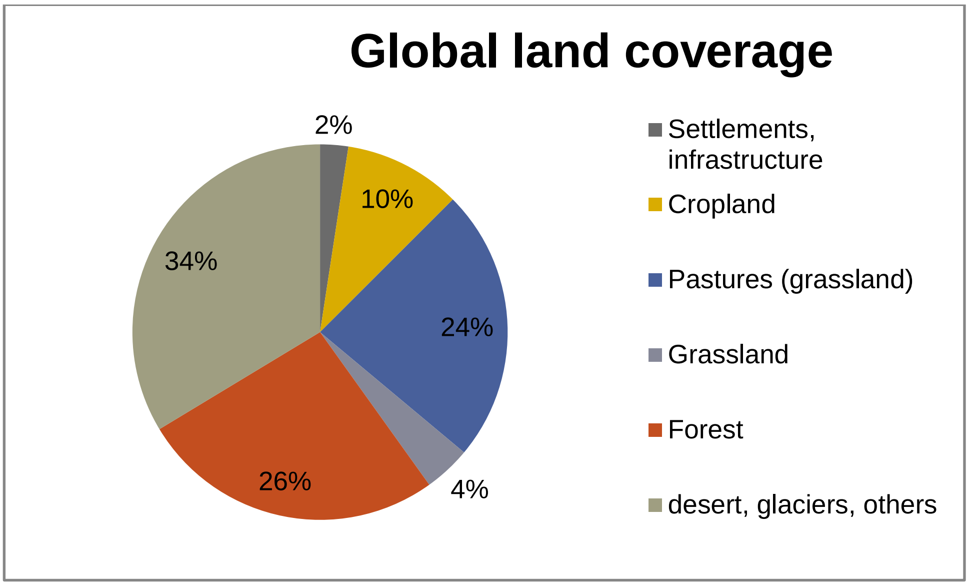

Figure 6 - Global land coverage in the year 2000

This near irreversibility of land use makes it clear that land as a resource may be expressed in more ways than square kilometers. One way of doing so is by classifying land in terms of its ‘naturalness’. One way of doing this is by applying the Hemeroby concept(Brentrup & Küsters, 2002). The Hemeroby scale is a measure for the human influence on eco-systems. The definition and descriptions of the different classes of the scale can been seen in Figure 7.

Based on the three steps for sustainable resource control and with application of the Hemeroby scale, (Entrop & Brouwers, 2010) have formulated a three step strategy for the assessment of sustainable land use and transformation in urban environments. Based on the three step approach for sustainable energy management, the Trias Energetica(Lysen, 1996), the researchers have designated their strategy Trias Toponoma. The three steps of the Trias Toponoma as formulated by (Entrop & Brouwers, 2010) are:

1. *In case of step 1 new building development takes place within the existing built-up area. (Hemeroby classification H9 to H10)Use as little ‘fresh’ natural space as possible by using the third dimension of buildings. In the city center it is necessary to build higher or deeper structures. Within this first step it is also possible to use the dimension of time by appointing more than one function to a building.*
2. *When it is not possible to achieve the necessary building volume in the already developed and built area, then the built up area can be enlarged to the country side of low natural importance (Hemeroby classification H4 to H8). Enlarge the city with a so-called ‘green vision’, which for recreational functions makes the relatively natural environment part of these new neighborhoods. This represents a kind of cascading of this non-renewable source.*
3. *The least sustainable option is to extend the built up area in a rather natural environment (Hemeroby classification H0 to H3). In this case, the construction of buildings could take place extensively or in other words spread buildings over a large surface in such a way that it has little effect on the main natural structures of the area.*

The focus of the presented strategy is on efficient high density urban planning and maximum preservation of the natural potential of the land. As such the researchers suggest that new building projects should be accompanied with wild land restoration projects to offset the loss of natural potential. New construction should mainly occur on previously built-up or brown-field sites while green-fields should be spared.

Sustainable land use, from an ecological perspective as described above, lays at odds with socio-economic pressures from growing population centers. Rising land prices around expanding urban areas force agriculture businesses further away from the city and into as of yet uncultivated natural areas (Bringezu et al., 2014). Natural reserves close to urban centers are becoming fragmentized, with negative consequences for species diversity and stability of the urban, rural, and natural ecosystems as a whole.

Attempts are being made to reconcile economic models for optimal land use with ecological models for maximum ecological stability of the environment for both the urban ecosystem and the hinterlands (Bockstael et al., 1995; Polasky, Nelson, & Lonsdorf, 2005). Focus of such research is on finding optimal spatial configuration of natural reserves, agricultural land and the built up area and the corresponding infrastructure to achieve a balance between food production, living space and ecological stability.

Hemeroby code (HX), use intensity (%) NDP*	Hemeroby class	Description (typical ecosystems and vegetation, types of human influence)
H0 **0%** **NDP = 0,0**	ahemerobic	**No human influence, e.g.:** -untouched rocky, peatbog and tundra regions in some parts of Europe
H1 **10%** **NDP = 0,1**	oligohemerobic	**Small human influence, e.g.:** • only indirect human influence through deposition of airborne emissions • salt meadows, growing dunes and peatbogs • hardly influenced primary forests and their natural succession levels (i.e. only cut of single trees, 'Plenterwald', no introduction of site-atypical species)
H2 **20%** **NDP = 0,2**	oligo- to mesohemeribic	**Small to moderate human influence, e.g.:** • extensively managed forests (i.e, only little removal of timber, trees of different age at the same site, 'Altersstufenwald', introduction of site-atypical species possible) • extensively drained wetlands • restored peat bogs • some wet pastures
H3 **30%** **NDP = 0,3**	mesohemeribicc	**Moderate human influence, e.g.:** • moors and heathland • managed forests • moderately managed nutrient-poor grassland and extensive meadows • shrubs and herbaceous vegetation along unspoiled lakes and rivers • permanent fallow land, fallow pasture (i.e. rare mulching and mowing (0.2-0.5/year))
H4	meso- to β-	**Moderate to strong human influence, e.g.:**

40% **NDP = 0,4**	euhemoribic	• intensively managed forests and young secondary forests, frequented forests near recreation areas, forest with unnatural high share of conifers • woods and bushes in parks, shrubs and hedges in agricultural areas, shrubs and herbaceous vegetation along rebuilt lakes and rivers • extensive orchard meadows • extensively used permanent grassland (i.e. 0.5-1.0 cuts/year, no fertilizer, no pesticides)
H5 **50%** **NDP = 0,5**	β-euhemoribic	**Strong human influence, e.g.:** • site-atypical coniferous forests, younger reforestation • orchard meadows • ruderal vegetation of perennials • permanent grassland (pasture or meadow) managed with medium intensity (i.e. 1.5-3.0 LU/ha (LU = livestock units), no ploughing, 1-2 cuts/year, fertilization according to nutrient removal)
H6 **60%** **NDP = 0,6**	β-eu- to α-euhemoribic	**Strong to very strong human influence, e.g.:** • plantation of hedges and bushes (e.g. in gardens, along roads etc.) • ruderal meadows, lawns with meadow species • permanent grassland (pasture or meadow) managed with higher intensity (i.e. 1.5-3.0 LU/ha, ploughing max. 0.2/year, 2-3 cuts/year, fertilization exceeds nutrient removal slightly)
H7 **70%** **NDP = 0,7**	α-euhemoribic	**Very strong human influence, e.g.:** • tree nurseries • intensive gardening and cultivation of special crops (e.g. fruits, vine) • annual ruderal vegetation pasture under rotation, arable land, gardens, which are managed according to the principles of organic or extensive integrated farming (i.e. >3 LU/ha, ploughing 0.2-3.0/year, >3 cuts/year, fertilization exceeds nutrient removal slightly, application of pesticides max. 0.3/year)
H8 **80%** **NDP = 0,8**	α-eu- to polyhemoribic	**Very strong human influence to mainly artificial, e.g.:** • larger relicts of vegetation within urban or industrial areas, vegetation of graveled surfaces • intensively managed land and gardens (ploughing >3/year, fertilization exceeds nutrient removal significantly, application of pesticides ~,0.3/year)
H9 **90%** **NDP = 0,9**	polyhemoribic	**Mainly artificial, e.g.:** • landfill and dump sites • partly built-up areas (railways, streets etc) • surfaces covered with new materials • strong and long-term modification of biotopes
H10 **100%** **NDP = 1,0**	metahymerobic	**Purely artificial, e.g.:** • completely sealed, built-up or contaminated surfaces (i.e. no habitat for plants)
*** NDP = Naturalness degradation potential**		

Figure 7 – Definition and description of Hemeroby classes and the Naturalness Degradation Potential (NDP). This figure was adapted from (Brentrup & Küsters, 2002)

3.2.2.3 Water

In terms of water as a resource there are currently two approaches to modelling water consumption in urban environments. Direct water consumption is water that is being consumed directly by the city and its population. Figure 8 depicts an estimation of the average Dutch persons daily water consumption divided over domestic activities (Novem, 2007).

Activity	Consumption (L/Day)
Food preparation	2
Dishes	6
Bathing	9
Laundry	28
Showering	38
Flushing of toilets	39
Other activities	12
Total	**134**

Figure 8 - Estimated water consumption per person in the Netherlands

Of this total consumption approximately 2 liter is used for food production and drinking purposes, while the rest is flushed down the drain. This puts strain on the supply of fresh water and sewage capabilities to clean the water waste streams. Since waste water treatment consumes energy, cutting down on water consumption will not only relieve pressure on freshwater supplies, but also save energy on the treatment side of the water flow.

There is often a mismatch between the quality of water needed for certain activities and the quality of water provided (Entrop & Brouwers, 2010). As such, energy is lost in both production of high quality water and eventual waste treatment of water.

For a more sustainable urban consumption of water, Entrop & Brouwers (2010) propose the Trias Hydrica, a tree step qualitative approach towards better water management. The three steps as suggested by the researchers are:

1. Reduce water consumption
2. Make use of renewable sources as much as possible, such as storm water use for gardening, toilets and washing machines.
3. Clean drinking (tap) water should be used as efficient as possible.

For more efficient use of clean drinking water, the authors suggest:

> *"Clean drinking water will be used as efficient as possible, for example, by installing water-saving toilets and shower. Water can, for example, be used in stages of quality, as a form of cascade: Firstly, it can be used for bathing and secondly, the same water can be used for the garden. During these stages of the cascade the application of constructed wetlands can provide a natural environment to improve the quality of the waste water."*

The second approach to modelling water consumption as a resource is by accounting for the fact that any product, not least of which agricultural products, requires large amounts of water to produce. This water can be referred to as virtual or embedded water (Allan, 1998). The concept of virtual water was further expanded by introduction of the water footprint (Hoekstra, 2006, 2009) with which the amount of consumed fresh water for the production of a product can be calculated. Since pollution of freshwater sources is an increasing problem, the method also accounts for production pollution by calculating the size of the body of water required to safely dilute released pollutants.

Reducing the urban water footprint from within the urban system can only be done by reducing consumption patterns, especially reducing consumption of products with a high water footprint. As such, priorities for achieving a sustainable urban environment with regards to water resources focus on reduction of direct water consumption, along with reduction of product consumption in general. Focus on water footprint reduction, although important in regards to global sustainability, lies beyond the scope of urban sustainability.

3.2.2.5 Building Materials

As was done for 'land', 'energy', and 'water', (Entrop & Brouwers, 2010) suggest a qualitative three step approach to a more sustainable material use for the building industry. The researchers dub the tree step strategy "Trias Hylica". Quoting directly from their paper, the three steps are:

1. *A first category of measures will prevent the unnecessary use of materials, such as smart and efficient designs of components (box girders, hollow floors, H-profiles) and of buildings, and combinations of functions.*
2. *The second step is to use local renewable materials for the use in buildings and/or production of building materials. Examples of this category include loam, shells, shell lime, flax, wood and cork.*
3. *The last possible step is to use non-sustainable sources in the most effective way, for example the use of cement, high strength concrete and steel, better use of remainders of materials and the cascade use of materials.*

Increased material efficiency has a two-fold advantage towards an increased sustainable urban environment. Firstly, most materials are a finite resource and should be properly managed to attain true sustainability. Secondly, processing materials is often an energy intensive process. Increased material efficiency will in turn lead to a decrease in energy consumption.

Although Entrop and Brouwer focus their work specifically on construction of the built environment, it is quite possible to extrapolate their method to all material consumption in the urban environment. Focus of the three step methodology would then focus on efficient production of consumer products and limiting consumption of products.

3.2.2.4 Food

As evaluated in chapter 2 of this report, adequate food acquisition has been a major driving force for increasing urban size. Especially in industrialized countries, agriculture is an energy intensive process. Furthermore, agriculture requires large amounts of land and water. In industrialized countries intensive use of chemicals has led to deterioration of ecological systems(Altieri, 1989). Unsustainable agricultural practices have led to soil erosion. Fertile top soil has been lost, leading to degradation of agricultural productivity as a whole(Diamond, 2005). Other challenges facing agriculture include loss of nutrients in the soil due to water leakage or degrading soil quality due to acidification or salinization.

Due to the development of transport technology, agricultural production has been pushed further away from population centers. As such, the transportation and distribution of food also requires a great deal of energy.

Researchers stress the need for more sustainable agricultural practices. Food as a resource differs from other urban resources in the urban metabolism model, in that it is not by definition a finite resource. Production of food however, depends on other resources that are finite, such as water, land and energy. Sustainable agriculture therefore strives for ecological sustainability as well as sustainable application of these finite resources.

The three step strategy is again applicable to increasing the sustainability of food production. The three steps are:

1. *Prevent unnecessary use*
2. *Make use of renewable resources as much as possible*
3. *Use sources that are not endless as efficient as possible*

Although food production is almost exclusively confined to the urban hinterlands, some strategies have been developed to in increase food sustainability from within the urban environment (Moragues et al., 2013). A number of these strategies will be shown in relation to the three step strategy.

Prevent unnecessary use

Currently a large amount of produced food is being wasted. Figure 9 depicts estimated food loss for a number of agricultural products in the United States as an indication of the quantity of wasted food (Buzby, Wells, & Hyman, 2014). Prevention of these losses would significantly decrease pressure on agricultural production capacity. This in turn would significantly decrease pressure on land use, water-, and energy consumption, and transportation cost.

Commodity	Total food supply in billion pound	Percentage lost in retail	Percentage lost at consumer level	Total loss in billion pound	Total loss in percentage
Grain Products	60,4	12%	19%	18,5	31%
Fruit	64,3	9%	19%	18,4	29%
Vegetables	83,9	8%	22%	25,2	37%
Dairy products	83	11%	20%	25,4	31%
Meat &fish	58,4	5%	22%	15,3	26%
Eggs	9,8	7%	21%	2,8	28%
Tree nut and peanuts	3.5	6%	9%	0,5	15%
Added sugars and sweeteners	40,8	11%	30%	16,7	41%
Added fats and oils	26	21%	17%	9,9	38%
Total food loss	430	10%	21%	132,9	31%

Figure 9 - Food loss in the United States for the year 2010 (Buzby et al., 2014)

Make use of renewable resources as much as possible

Strategies coinciding with this step include promotion of specific sources of food. Promotion of local produce saves on transport cost and energy, as well as giving urban centers more influence and control over the food production chain. On larger scale, vertical farming projects provide potentially highly energy and water efficient farming practices close to urban centers.

Use sources that are not endless as efficient as possible

As mentioned food production, if correctly managed is an endless resource. In that context this step does not readily apply to food production. One could however draw a parallel to the third step for sustainable water management. Instead of throwing food away, the organic material could be used to produce bio-gas for energy production, or composted. These measures would significantly increase the efficiency of the food value chain.

3.2.2.6 Transportation

Transportation is not a resource in and of itself, unlike the other resources and commodities discussed in this report. However, as Chapter 2 has illustrated, transportation technology has been an important driver for urban development and the trend of urbanization. The ancient city of Rome would not have achieved its size if it had not invested in the logistic components required to efficiently distribute food and commodities. Logistic capacity included transportation technology as well as communication technology and social organization. City size could not have increased as it has today, without the invention of new, albeit energy intensive, transport technology.

Historically, urban focus has always been on the logistic component of transportation. This is illustrated by Peter Hall (Hall, 1998), when he describes the choices made by the city of New York and the city of Los Angeles with regards to their transportation policies. New York opted to invest heavily in an underground metro system, while Los Angeles chose to build an elaborate network of freeways.

In terms of sustainability however, focus is on reducing the impact that transportation has on the environment in terms of exhaust gasses and pollution, along with a reduction in transport energy consumption. For a strategy towards increasingly sustainable transportation we turn again to the triad approach as discussed by (Entrop & Brouwers, 2010). They dub their proposed strategy 'Trias Poreutica'.

1. *The first step reduces the need for transport by placing different types of activities close to each other, so shortening the travel distances. In general, the use of motorized transport has to be reduced. Especially, short distances enable the most sustainable alternatives: walking or cycling.*
2. *Try to make use of sustainable transport methods. The general idea is that public transport is the most sustainable way of transport, when it is not possible to walk or bike. However, public transport still can be improved in terms of fuel consumption, speed, flexibility and price. Over recent years, the environmental advantages of public transport relative to personal vehicles have been decreasing. There will always remain a need for personal motorized transport. To render this form of transport more sustainable than conventional (fossil fuel-based combustion) engines the use of electric cell, bio fuels or hydrogen cars needs to be stimulated. Even in that case, the required electric energy should preferably be generated in a sustainable way completely fulfilling this second step of the Trias Poreutica analogue to the principle of the Trias Energetica.*
3. *When a demand for motorized transport still remains, then the third step suggests trying to make the non-sustainable transport as efficient as possible without creating traffic jams or long diversions. Cars are becoming more and more efficient through for example, the use of hybrid engines of computerized engine control. The driver can influence the fuel efficiency by carrying more passengers, driving less aggressively and at a lower speed. The government could reduce the environmental impact of personal transport by facilitating carpooling, green waves and so on. When carpooling would be common practice, there should be fewer traffic jams and less pollution.*

3.2.3 Dimensions of the urban metabolism - Urban waste outputs

On the other side of the urban metabolism model we find urban waste outputs. The aspects of waste output as identified by Newman (Newman, 1999) can be seen in Figure 10. Waste management has been around at least as long as urban settlements. The prevailing thought throughout the history of urban waste management may well have been: 'Not In My Back Yard'. As such, in pre-modern times, sewage and garbage was often dumped into the streets or river. In modern times, extensive sewage systems and elaborate collection schemes make it possible to keep our vast cities relatively waste free, by transporting the waste elsewhere.

Aspects of urban waste outputs
Solid waste
Liquid waste
Toxics
Sewage
Air pollutants
Greenhouse gasses
Waste heat
Noise pollution
Light pollution

Figure 10 - Aspects of urban waste output according to the extended urban metabolism model

However, removal and disposal of waste management seems more relevant to the quality of the urban environment. This is especially true for the aspects noise pollution and light pollution. In relation to bio-physical sustainability we are more concerned with keeping waste output such as toxins and greenhouse gases within assimilative capacity of the environment.

In regards to increasing the sustainability of waste management, Duijvensteijn (Duijvestein, 1993) proposes a three step strategy:

1. Prevent waste
2. Reuse waste
3. Dispose of waste wisely

A more extensive strategy similar to the three step strategy is provide by the hierarchy of waste management (Hansen, Christopher, & Verbuecheln, 2002). The hierarchy is presented in Figure 11.

In essence the hierarchy method provides more detail to the waste management strategy proposed by Duijvenstein. This will be shown by discussing the individual aspects of the hierarchy in relation to the three step strategy.

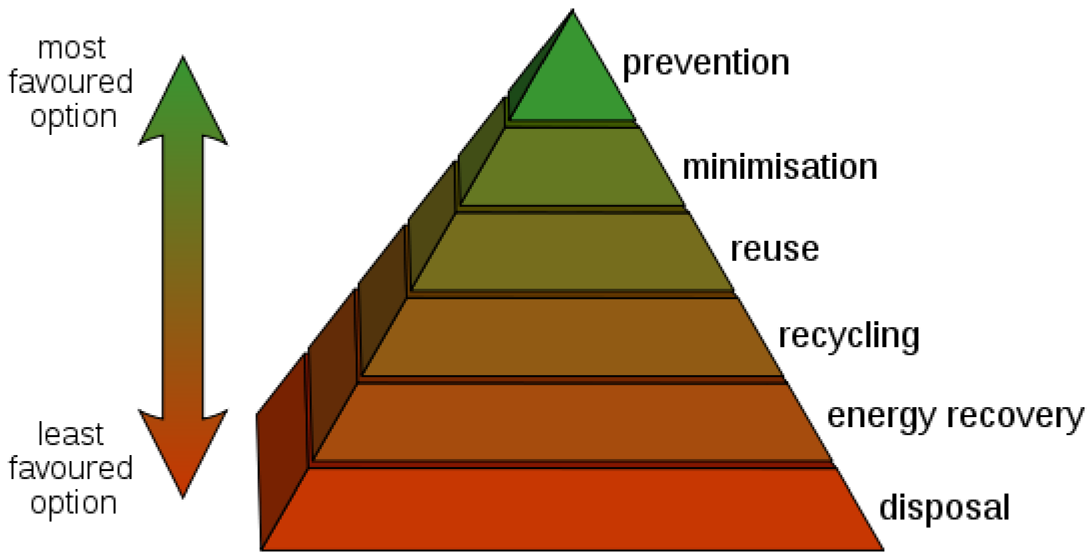

Figure 11 - The hierarchy of waste management. Source: http://en.wikipedia.org/wiki/File:Waste_hierarchy.svg

Step 1 - Prevent waste

Prevention

The prevention step in waste management focusses on lowering urban consumption patterns. Lower consumption patterns would mean fewer resources would be required and as a consequence less waste would be produced.

Minimization

Minimization works on the principle that if consumption is still necessary, production should at the very least be efficient, thus requiring less resources.

Step 2 – Reuse waste

Reuse

Reusing products reduces both resource input and waste output of the urban environment. The principle is applicable to a wide range of issues concerning the sustainable urban environment. One significant example is the practice of retrofitting old buildings, in lieu of demolition and new construction to avoid solid waste.

Recycling

The difference between reuse and recycling is that recycling is only concerned with reuse of the materials, and not of reuse of the product as a whole. Thus, recycling costs more energy to reclaim and process materials.

Energy recovery

As final alternative for waste disposal, waste may be burned for energy production.

Step 3 – Dispose of waste wisely

Disposal

Wise disposal of waste strategies should strive to dispose of waste in such a way that the waste may be assimilated by the natural environment. Wetlands may function as a sink for sewage, breaking down and assimilating the organic matter over time.

Final remark

The urban environment produces such a vast range of waste products, that evaluation of the various waste products along with the relevant strategies to manage the waste stream in a sustainable way, is deemed far beyond the scope of the research presented in this report. It is enough to be aware of the various waste products relevant to urban quality and sustainability, in order to properly implement an urban monitoring system. In regards to bio-physical sustainability the most important issue to grasp is that waste production should lie within assimilative capacity of the environment.

3.3 Principles and dimensions of urban quality

Historically, urban development has always been focused on urban quality and livability. Sustainability as an issue is a rather recent concept. Urban quality has always been a relative subject. In the process of describing the golden ages of a number of cities, Peter Hall (Hall, 1998) also describes the priorities of the respective cities in terms of urban and cultural development. For example, ancient Athens was far more concerned with the public theatres, the facilitation of public discourse, and maintaining their temples and statues, then in providing a standard of living conditions for their inhabitants. Focus of urban quality in ancient Rome was on adequate sewage systems and water supply and less so on building quality.

3.3.1 Quality of Life (QOL) versus urban quality

According to Maslow’s theory of a hierarchy of needs (Maslow, 1943), humanities needs and desires can be ranked into distinct levels, often expressed as Maslow’s pyramid (Ventegodt, Merrick, & Andersen, 2003) as seen in Figure 12. Maslow argues that although human beings can focus on many of the basic needs at the same time, the priority will be on firstly fulfilling needs at the bottom of the pyramid. Once these basic needs have been fulfilled, more energy will be devoted to fulfilling needs higher in the hierarchy.

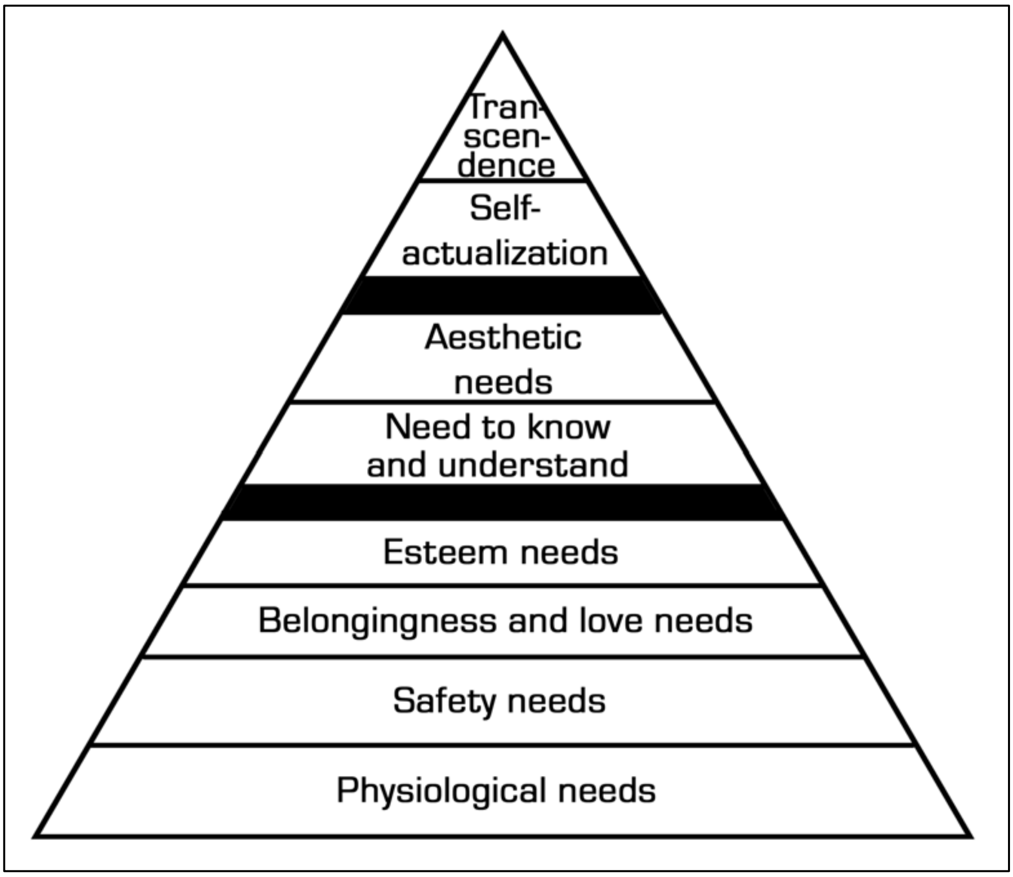

Figure 12 - Maslow's hierarchy of needs (Ventegodt et al., 2003)

From this hierarchy of needs (Sirgy, 1986) develops a theory for the quality of life of an individual and of a society. Sirgy defines the quality of life of an individual in terms of the need satisfaction level on the pyramid. Applying this theory to an entire society, societies with a higher quality of life have managed to achieve a higher need satisfaction level for the majority of that society.

Extending this theory to the urban environment, a high quality urban environment may be described as providing high need satisfaction levels for the majority of its inhabitants. Validation of this theory is supported by typical lists of variables, applied to ascertain urban quality. The list of indicators in Figure 13 for instance, was used to determine quality of life indexes for a number of large cities across the world (Sufian, 1993).

Variable of QOL	Corresponding hierarchy level
Public safety	Level 2 – Safety
Food cost	Level 1 – Physiological
Living space	Level 2 – Safety
Housing	Level 2 – Safety
Communication	Level 3 – Love/Belonging
Education	-
Infant mortality	Level 2 – Safety
Noise level	Level 2 – Safety (health)
Traffic flow	-

Figure 13 - Variables used to determine urban Quality of Life index of various cities (Sufian, 1993)

Other significant lists of urban quality indicators include lists from the Urban Indicator Guideline(UN Habitat, 2009). Focus in these guidelines is foremost on shelter, food- and water security, health issues and economic opportunity, all aspects of the first and second tier of the pyramid.

Sirgy further suggests that more developed societies, that have attained adequate need satisfaction levels on the lower tiers of the pyramid, increasingly focus on needs higher up in the hierarchy. Well-developed urban centers increasingly focus on aesthetics (Meyer, 2008), culture, community-building and heritage. This trend does also seem to be noticeable when studying current best practice guides on the development of so-called high quality places such as the urban design compendium (Davies, 2000).

Statistical research into nation quality of life and societies need fulfillment levels according to Maslow’s hierarchy does seem to indicate a strong correlation between the two(Hagerty, 1999). Furthermore it was shown that the sequence in which nations fulfill population needs is strongly correlated to the hierarchy of needs as proposed by Maslow.

For the purpose of this report we define aspects of urban quality as aspects that relate to the need fulfillment of the urban population as proposed by Maslow.

3.3.2 Subjective versus objective urban quality

The concepts and topics of relating to a high quality urban environment and urban quality of life can be clearly defined by means of Maslow’s hierarchy. Urban quality of life is usually measured by either subjective indicators using surveys of residents' perceptions, evaluations and satisfaction with urban living or by objective indicators using secondary data and relative weights for objective indicators of the urban environment(McCrea, Shyy, & Stimson, 2006). Examples of such objective indicators can include urban population density, healthcare statistics, crime rates, or urban green space surface area.

(McCrea et al., 2006) find that subjective and objective indicators for quality of life are very weakly linked to each other. This suggests that areas that may score very well on resident’s surveys score badly on objective quality of life indicators and vice versa. As an example of this, quality of life in a neighborhood may be increased more effectively in a neighborhood by increasing the sense of security, for instance by having police patrol more often, then by actually improving security, reflected by decreasing crime rates. Research has indicated that increasing patrol frequencies does indeed have the effect of increasing community satisfaction with the police, along with an increased sense of security, without actually improving on objective indicators, namely a decrease in crime rates(Hawdon, Ryan, & Griffin, 2003)

In conclusion, when discussing urban quality it is important to realize that urban quality is a relative concept with large discrepancies between subjective and objective quality indicators.

3.3.3 Urban quality in terms of sustainability

Besides urban quality in relation to quality of life, there is a second way in which to approach the concept of urban quality. In her research (Alberti, 1996) identifies seven concepts of urban quality that she finds relevant to a sustainable urban environment. The seven categories and their explanation can be seen in Figure 14.

Concepts of urban quality	
Environmental quality	Clean air, water, and soil – adequate food supplies, housing, and infrastructure as well as green areas and open space.
Human health	Builds on environmental quality
Efficiency	Resource allocation must maximize the economic output per unit of resource input.
Equity	Resource allocation must maximize social benefit per unit of economic output, across social groups, regions and generations
Diversity	Diversity of actors (communities, cultures, and individual's behavior) and diversity of built and natural landscapes is crucial to urban resilience and flexibility.
Accessibility	Increased access to goods and services leads to decreased impact on local environment.
Learning	Increased learning at local and community level leads to increased flexibility and the ability to modify behavior in response to changing (environmental) circumstances.

Figure 14 - Concepts of urban quality in relationship to urban sustainability (Alberti, 1996)

On the one hand there is significant overlap between these concepts and urban quality according to Sirgy's quality of life approach as proposed in 3.3.1. However, Alberti's approach to urban quality in relation to sustainability focusses more on the ability of the urban environment to cope with the challenges that come with increasing sustainability and environmental change. In essence, Alberti describes a healthy, happy, resilient and flexible community.

In essence, the criteria 'Environmental Quality', 'Human Health' and 'Equity', as proposed by Alberti, directly relate to attaining suitable need satisfaction levels for the greater part of the community in the lower regions of Maslow's hierarchy. Only when these needs have been met, can a community effectively begin to work on needs higher up the hierarchy and assume a long term vision, specifically with regards to sustainability.

Urban quality in regards to sustainability according to this approach is an urban environment that has met basic needs, is flexible and resilient and is therefore in a position to effectively implement and maintain increased sustainability measures.

3.4 Urban ecological space

The urban environment is dependent on natural systems beyond the city limit, but also benefits from internal urban ecosystems(Bolund & Hunhammar, 1999). Ecosystem services are defined as "*the benefits human populations derive, directly or indirectly, from ecosystem function*" (Costanza et al., 1997) . In the article from Costanza et al., 17 categories of ecosystem services are identified. These categories can be found in Figure 15.

	Ecosystem service	Ecosystem functions	Examples
1	Gas regulation	Regulation of atmospheric chemical composition.	CO2/O2 balance, O3 for UVB protection, and SOx levels
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.
3	Disturbance regulation.	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	Water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.
5	Water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.
6	Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, starage of stilt in lakes and wetlands.
7	Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, and detoxification.
10	Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.
13	Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.
14	Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.
15	Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	Cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

Figure 15 - Services provided by natural ecosystems (Costanza et al., 1997)

Ecosystem services are relevant to both to bio-physical sustainability as described in section 3.2 and urban quality as described in section 3.3. The identified categories are relevant on both a global and a local level. Selecting which ecosystem services are specifically relevant for the urban environment is dependent on which urban environment is under evaluation.

Specific aspects of an urban ecosystem often perform multiple ecosystem services at the same time. Figure 16 lists a number of urban ecosystem aspects and the respective functions that they fulfill (Bolund & Hunhammar, 1999). Due to the complex interaction of ecosystems it is often hard to predict what kind of effects replacement of ecosystems will have on an environment.

	Street tree	**Lawn parks**	**Urban forest**	**Cultivated land**	**Wetland**	**Stream**	**Lakes/sea**
Air filtering	X	X	X	X	X		
Micro Climate regulation	X	X	X	X	X	X	X
Noise reduction	X	X	X	X	X		
Rainwater drainage		X	X	X	X		
Sewage treatment					X		
Recreational cultural value	X	X	X	X	X	X	X

Figure 16 - Urban ecosystems generating local and direct services, relevant to the city of Stockholm (Bolund & Hunhammar, 1999)

Natural and capital stock

The sum of existing ecosystems and the services they provide can be expressed in the economic term ‘natural capital’. The essence of the concept of capital is that it is a stock that possesses the capacity of giving rise to flows of goods and/or services (Ekins, Simon, Deutsch, Folke, & De Groot, 2003).

When studying the list of ecosystem services from an economist point of view, it can be seen that a number of the services provided by natural systems can also be provided by technological innovation or work, referred to as manufactured or human capital. A simple example is that water treatment can be performed by treatment centers, but that certain plants, like seaweed or reed beds have similar basic water filtering properties. A fourth type of capital is identified as social/organizational capital. The sum of natural, human and manufactured capital is referred to as the capital stock.

“*Wealth creation is the process of using the four types of capital in combination to give rise to flows of goods and services which people want, in such a way that the capital stocks and the non-monetary flows of services from natural capital are maintained or enhanced in quantity or quality. If the capital stock is not maintained, then eventually the flow of goods and services to which it gives rise will decrease, i.e. any level of flow that is associated with a reduction in the capital stock is unsustainable. Put another way, a declining capital stock is an unambiguous indicator of unsustainability in the flow of goods and services that derive from it.”* (Ekins et al., 2003).

Currently there is discussion relating to the interchangeability of the different types of capital Relevant to this research is the interchangeability between natural capital and manufactured capital, providing the same services. From the example regarding water filtration it is obvious that some interchangeability is possible. However the discussion still continues on the extent to which interchangeability is possible, and indeed desirable.

Opinions on the matter can be placed on a scale ranging from the ‘strong sustainability’ to ‘weak sustainability’ viewpoint. Proponents of ‘strong sustainability’ argue that substituting natural capital is mostly an irreversible process, as was explained in section 3.2.2 on the naturalness of land. Weak sustainability on the other hand assumes that any kind of capital is freely interchangeable, and that sustainability depends primarily on maintaining overall capital stock.

The discussion of reversibility notwithstanding, interchanging natural capital with manufactured or human capital, and vice versa, requires energy input. As such, based both on the precautionary principle with regards to the unanswered question of reversibility as well as conserving energy, it is assumed that ‘strong sustainability’ is to be preferred over the ‘weak sustainability’ viewpoint, as is argued by (Ekins et al., 2003). As such it is important for a high quality sustainable environment to maintain and improve upon its natural capital and the urban ecological space.

3.5 Categorizing urban quality and sustainability dimensions

The previous paragraphs have provided a description of the guiding principles as well as the various dimensions, relevant to a high quality sustainable urban environment. It is the purpose of this paragraph to provide an overarching framework that places the relevant dimensions as well as the guiding principles in relation to each other. This will be done in two ways. Firstly, a framework will be proposed that captures the aspects of the sustainable urban environment, as well as their influence on each other, based on the extended urban metabolism model. The second method of capturing the urban environment will be based on a division by different domains of the urban environment.

Dimensions of the urban environment and their interconnection

The first framework we propose to use has been taken from the work of (Alberti, 1996) and can be seen in Figure 17. Alberti proposes three dimensions that have to be examined in order to determine urban sustainability. The dimensions are 'urban patterns', urban flows', and 'urban quality'. These three dimensions both influence, and are influenced by the fourth dimension 'urban ecological space' which Alberti defines as:

> "*…the total natural capital and flows on which a city depends to meet the long-term needs of its inhabitants. This capital includes both the sources and sinks, as well as the ecological support systems and services they provide to the human population."*

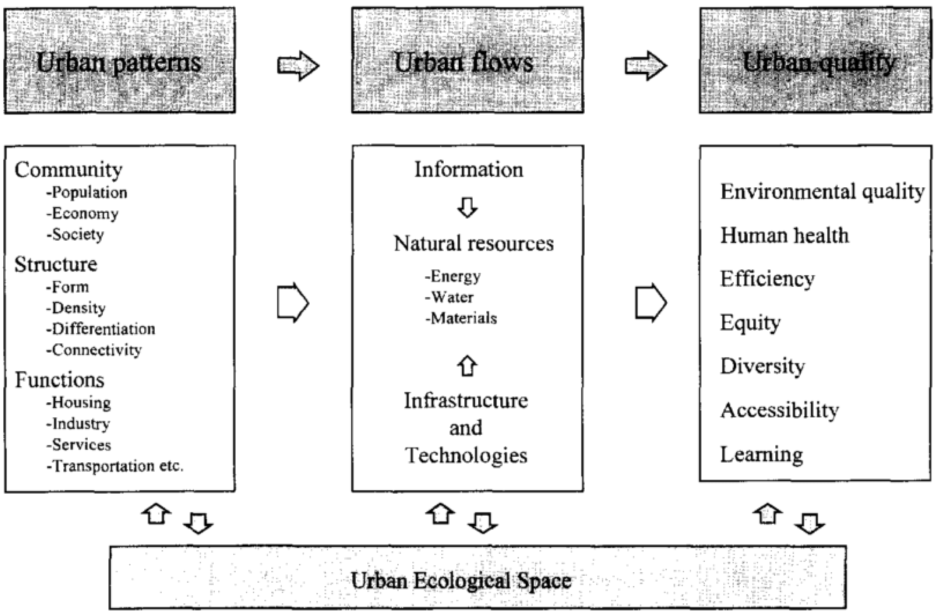

Figure 17 - A framework for the interrelations of the urban -pattern, -flows, -quality, and - ecological space

The extended urban metabolism model as introduced in paragraph 3.1, suggests that urban flows (biophysical sustainability) as per paragraph 3.2 and urban quality, as per paragraph 3.3 are determined by the dynamics of the settlement. As examples of the dynamics of the settlements Newman lists 'Transportation Priorities', 'Economic Priorities', and 'Cultural Priorities'.

Alberti takes a similar approach, but argues that the physical urban form as well as the social structures and policy priorities, determine the urban flows as well as urban quality. This argument is easily understood and well researched. For instance, (Williams & Dair, 2007) propose a framework by which sustainable behavior can be enabled through neighborhood scale technical innovations. Technical innovations include energy efficient housing, facilitating recycling and designing biker friendly neighborhoods. (Tweed & Sutherland, 2007) argue that preserving cultural heritage enhances quality of life in neighborhoods by creating a sense of community and belonging in its inhabitants. From an ecological point of view it is especially clear that landscape features determine (urban) flow (Musacchio, 2009). And finally, from an economic point of view, the combination of human-, manufactured-, organizational, and natural capital "…*gives rise to flows of goods and services…"*(Ekins et al., 2003), thus also confirming that (urban) form and patterns dictates urban flow. All these aspects are categorized by Alberti as 'Urban Patterns'.

Urban quality as proposed by Alberti, as well as urban quality in relation to quality of life has been discussed in section 3.3 of this report. The dimension and principles of bio-physical sustainability as discussed in section 3.2, can be classified as urban flows in the model proposed by Alberti. Finally, the ecological space, and its interaction with the dimensions of urban sustainability has been covered in section 3.4. As such we feel justified to say that the framework as presented in Figure 17 correctly covers and represents all of the aspects and dimensions relevant to a high quality sustainable urban environment, as well as adequately representing interaction and influence between the various dimensions.

Domains of the urban environment

Alberti writes in her article:

> "…*urban and environmental systems are so tightly interrelated that they make any classification of their interrelationships quite arbitrary."*

Indeed when browsing the literature we encounter numerous approaches to modelling, monitoring, and categorizing the aspects of the urban environment(Kamp et al., 2003). All of the approaches have in common that they attempt to reconcile the complex relationships between urban flow, urban form, the concepts of sustainability, and the quality of life.

From the article by (Kamp et al., 2003) we find a second model that seems useful in characterizing the urban environment. This framework is depicted in Figure 18. Whereas the framework provided by Alberti focusses on the interaction between aspects of the urban environment, as well a cause and effect between the different dimensions, the overview provided in Figure 18 divides the different dimensions of the urban environment in to a set of independent domains. Performance in each domain can be evaluated separately in relation to current best-practice principles, regulations, and set benchmarks, regarding each specific domain.

The domain approach to urban quality and sustainability can make it easier to both measure and implement improvements in the urban environment. It allows for researchers, policy makers, and other stakeholders to assess specific aspects of the urban environment without getting lost in the often complicated web of cause and consequences. Furthermore, low performance in certain domains compared to best-practice methods and benchmarks can be more easily assessed and targeted for improvement.

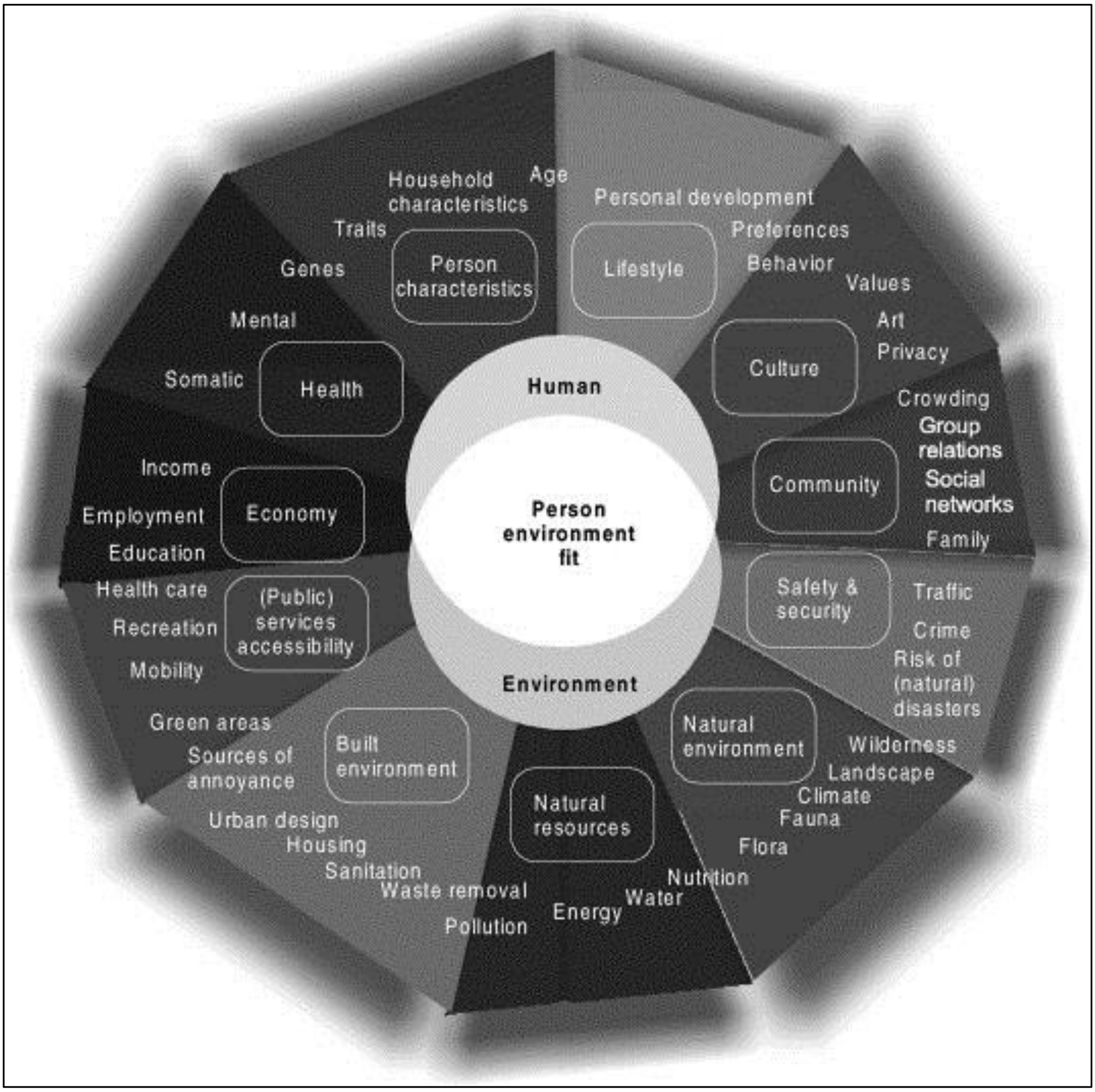

Figure 18 - Various domains and aspects of a high quality sustainable urban environment

Combined application of the presented frameworks

Effective modelling of the urban environment should incorporate both approaches to categorizing the built environment. While the domain approach allows for more comprehensive assessment of the urban environment, a framework such as the one proposed by Alberti is essential to grasp the complex interaction of aspects of the urban environment from within their respective domains.

This is best illustrated with an example. Suppose that overall population health is low in a certain area. One approach to improve overall health is by focusing specifically on the domain ‘health’ by improving access to healthcare and improving local hospitals. However, more extensive knowledge of the complex interactions within the environment, might lead instead to policy to improve traffic conditions in the city and improve bicycle accessibility. Improvement in the domain of ‘public service accessibility’ as depicted in Figure 18 would lead to improvement in the domain ‘safety and security’ by reducing traffic risk. Furthermore, limiting motorized urban traffic would improve air quality, represented in the domain ‘natural environment’. Less traffic would also decrease energy consumption, in the domain of natural resources. Finally, improved air quality would lead to a higher population health. In this way, changes in a single domain may have ramifications in a large number of other areas.

The above example demonstrates the usefulness of working within the framework as proposed by Alberti and the system approach to capturing the urban environment. Improvements to one aspect of the urban environment may have far reaching benefits to other aspects of the urban environment. The challenge in this regard is to fully understand the complex interactions that occur within the urban environment and to correctly anticipate how changes to the environment will affect the quality and sustainability of that urban environment.

3.6 Conclusion: Conceptualization of a high quality sustainable urban environment

This section will provide answers to the research question proposed at the beginning of this chapter:

> *How is urban quality and urban sustainability conceptualized in the current scientific literature?*

During the course of this chapter it was determined that a high quality sustainable urban environment must attempt to conform to the following criteria and principles:

1. A sustainable urban environment must achieve bio-physical sustainability. (section 3.2)
2. A high quality urban environment must provide a high level of need satisfaction on the hierarchy of Maslow for the majority of its inhabitants. (section 3.3)
3. Urban quality in regards to sustainability is an urban environment that is flexible, resilient, and is therefore in a position to effectively implement and maintain increased sustainability measures. (section 3.3)
4. A high quality sustainable urban environment must maintain (and improve) upon the urban ecological space, its natural capital. (section 3.4)

By applying a framework for modelling of the sustainable urban environment(Alberti, 1996), it was argued that these four criteria may be achieved by correctly designing and implementing suitable urban patterns. Urban patterns consist of both social and economic structures as well as the physical form of the urban environment (section 3.5).

Finally, there are a vast number of themes relevant to the topics of urban quality and sustainability. A comprehensive, but by no means complete range of these topics has been presented in section 3.5, Figure 18.

The first three criteria presented above are not refuted by literature. Irrefutability of the fourth criteria depends on the stance taken on the interchangeability of natural capital and manufactured capital, the discussion between strong sustainability and weak sustainability. The work in this research adopts a de facto strong sustainability stance as argued by (Ekins et al., 2003) thus preferring natural capital over manufactured capital, unless interchangeability concerning specific aspects of natural and manufactured capital is proven beyond doubt.

High quality sustainable urban patterns

The principles, dimensions and goals of a high quality sustainable urban environment have now been established. However, this report has not yet gone into much detail on what the form and patterns of the urban environment should be in order to achieve these, other than in brief explanatory examples. One reason for this is that there is by no means consent on what the ideal urban pattern should look like. Furthermore, the ideal urban form is often dependent on local conditions and development history (chapter 2), thus making a general description less useful. Nevertheless we will attempt to draft some guidelines for a high quality sustainable urban form.

(Haughton, 1997) identifies four approaches to sustainable urban environments. On one end of the scale he describes a city that has become self-reliant by internalizing economic and environmental activities and implemented circular metabolism. Moving down the scale he describes re-design of entire regions, meaning the city and its hinterlands, to establish regional self-sufficiency. On the far side of the scale he describes two scenarios' in which highly efficient but specialized cities are externally dependent on resources as well as trading of natural 'carrying capacity'.

Another problem, apart from different approaches, in defining the desired urban patterns is that these patterns are highly context dependent. High quality sustainable urban patterns that work for European countries may be unrealistic or even unpractical for cities in the Unites States. Even cities in the same country may have vastly different development histories, making universal urban patterns inappropriate. It is therefore important for each city to investigate how the general guidelines for a high quality sustainable urban environment may be best implemented locally.

We are however not entirely without guidance for the design and creation of appropriate urban patterns. As with the urban metabolism model, we again turn to the field of urban ecology to find ten principles for the design and creation of ecological cities(Roseland, 1997).

1. *Revise land-use priorities to create compact, diverse, green, safe, pleasant and vital mixed-use communities near transit nodes and other transportation facilities;*
2. *Revise transportation priorities to favor foot, bicycle, cart, and transit over automobiles, and to emphasize 'access by proximity';*
3. *Restore damaged urban environments, especially creeks, shore lines, ridgelines and wetlands;*
4. *Create decent, affordable, safe, convenient, and racially and economically mixed housing;*
5. *Nurture social justice and create improved opportunities for women, people of color and the disabled;*
6. *Support local agriculture, urban greening projects and community gardening;*
7. *Promote recycling, innovative appropriate technology, and resource conservation while reducing pollution and hazardous wastes;*
8. *Work with businesses to support ecologically sound economic activity while discouraging pollution, waste, and the use and production of hazardous materials;*
9. *Promote voluntary simplicity and discourage excessive consumption of material goods;*
10. *Increase awareness of the local environment and bioregion through activist and educational projects that increase public awareness of ecological sustainability issues.*

Although the principles stated here are still rather theoretical, they do provide a clearer image on how individual cities might develop urban patterns towards increased sustainability, without compromising quality. It goes beyond the scope of this research to describe in depth the specific form and structure of the high quality sustainable urban environment. As mentioned, detailing of the urban environment is unique to each city and should therefore be solved locally.

However, as working principles, the ten principles of the ecological city, and the four principles of the high quality sustainable urban environment provide us with a foundation on which to continue our research into measuring both quality and sustainability of the urban environment.

4. Monitoring the urban environment by means of systems of indicators

Now that the principles and dimensions of a high quality sustainable environment have been identified, it will be possible to turn to the second research question of this report:

> **What methods are being proposed in current literature to systematically monitor the urban environment?**

Along with increased awareness and a shared vision of what a high quality sustainable urban environment should look like, there has come an interest and a demand for tools that are able to quantify these aspects of the urban environment. One line of research of the last twenty years, has been focusing on the development of systems of indicators (Holman, 2009).

From the English dictionary we find a definition of an indicator as:

> *"An instrument used to monitor the operation or condition of an engine, furnace, electrical network, reservoir, or other physical system; a meter or gauge.*

Interpreting this definition in the broadest sense of the word, we define the entire urban environment as a physical system. Different aspects of the system can then be described in either a qualitative or quantitative way. Doing so provides policy makers, researchers and engineers with insight into the workings and performance of the urban environment.

> *"By measuring specific phenomena in the community, such as waste recycling rates, water quality, vehicle miles traveled, acres of parkland, teen pregnancy rates, voter turnout, etc., indicators provide critical information about current trends and conditions and help to track progress toward community goals. Indicators are also valuable because the process of developing them serves as a vehicle to generate community consensus about what is important and engages community members in working toward shared goals."* (Gahin et al., 2003)

Within the context of the urban environment we identify existing systems of indicators and their associated tools on three distinct levels of scale: The building level, neighborhood level and city scale level. Furthermore we identify a temporal dimension in tool classification and application. Indicator systems differ in focus, depending on which stage in the building cycle is being monitored (Nguyen & Altan, 2011).

Indicators applied during the design and building stage focus, among other things, heavily on (sustainable) material selection, energy efficient design of buildings and minimizing of environmental impact. These are all considerations that are less relevant for existing building stock. Focus of indicator tools here is on efficient operation and management of building stock and the urban environment.

Formulating it another way:

> *"The terms "urban sustainability, sustainable city and sustainable community" refer to the desirable state, while "sustainable urbanization and sustainable urban development" refer to the process towards the desirable state."* (Sharifi & Murayama, 2013)

As such the various tools are able to do one of three things. The first category of tools assists in the process towards a certain `desirable state´, a high quality sustainable urban environment. The second category of tools helps evaluate how close to that state a project is in reality. The final category of tools evaluates the sustainability of processes themselves, irrespective of the end result.

The focus of this research has consistently been on neighborhood and urban scale level. As such the focus of the work in this chapter will be on indicator tools that operate at that scale. Furthermore we are specifically interested in the ´desired state of affairs´ of the urban environment and how that may be achieved. The sustainability of the process itself is of lesser interest and will therefore not receive extensive attention.

4.1 A general introduction to indicator tools

This section will provide an overview of the workings and the basic building blocks of indicator tools. The contents of this section will be further expanded with an example in section 4.2 of this report.

4.1.1 Goal and scope of indicator tools

Generally speaking, the purpose of indicator tools is to assist users in the performance assessment of the project under consideration, be it a building, a neighborhood, or an entire city. Indicator tools are either used to assess current performance, or assist in design of objects, by modeling alternate design choices or reporting on expected (sustainability) performance.

Referring to the model proposed by Alberti (1996) and presented in Figure 17 in chapter three, indicators can be chosen to capture the pattern, the flows, the quality or even the ecological sphere of the urban environment.

Alberti (1996) suggests four characteristics relevant to the success of indicators:

- Policy relevance;
- Scientifically sound;
- Readily implemented;
- Usable for decision making;

As a consequence, individual urban sustainability indicator tools have their own focus on the various domains of the urban environment, depending on the target users and purpose of the specific indicator tool. The characteristics of successful indicators can be translated in to three basic design questions for indicator selection:

- Policy relevance: Who is going to use the tool?
- Readily implemented: How is the tool going to be used?
- Usable for decision making: Why is the tool going to be used?

Answering the three questions should lead to a formulation of the goal and scope of the too be developed tool. The characteristic “scientifically sound” functions as quality control for the individual indicators and the system of indicators as a whole.

4.1.2 Indicator tool structuring

Depending on the purpose of the urban assessment tool, the answers to the three design questions, indicators are selected across the various domains of urban sustainability as presented in Figure 18. Specific design tool indicators may focus specifically on Life Cycle Analysis to assist in sustainable material selection. More advanced indicator systems attempt to include more aspects of the urban environment.

Due to the vast number of indicators that may be included in a single tool, systems of indicators can become rather complex (Ding, 2008). In order to maintain an overview, systems of indicators are usually ordered according to selected domains, sometimes referred to as sustainability issues or impact categories. Each domain comprises of a number of criteria. Each criterion in turn is comprised of a number of individual indicators. An example of part of such a hierarchy is depicted in Figure 19**.**

Work by (Gil & Duarte, 2010) suggests that the general evaluation tool structure consists of five levels with increasing detail and specificity, namely:

1. **Sustainability dimensions –** The core goals of sustainability, often based on the three dimensions of environmental preservation, social equity and economic vitality;
2. **Urban sustainability issues –** The topics of concern to sustainable urban development, that need to be addressed to achieve the core goals, e.g. improve access to socio-economic opportunities;
3. **Evaluation criteria –** A set of aspects that need to be assessed in order to verify the response of the plan to the issue, e.g. access to public transport, access to jobs and access to local services;
4. **Design indicators –** A variable whose value is indicative of the performance of the design, with a unit and often a specific measurement method, e.g. percent of residents within 300m walking distance of a public transit stop, average distance to the nearest doctor;
5. **Benchmarks –** Reference values that the indicators need to meet to correspond to quality levels, often in different range groups.

These five levels encompass the basic building blocks of which indicator systems are comprised.

As was mentioned in the previous chapter, classification of aspects of the urban environment is quite arbitrary. The hierarchy and the domain selection depicted in Figure 19, has been based on the assessment tool BREEAM-NL In-Use, for the assessment of the sustainability performance of existing buildings in the Netherlands. In this case it can be seen that the tool skips the level of 'Sustainability Dimensions' and immediately introduces various Sustainability Issues. The tool does work with benchmarks. However, benchmarks are directly linked to individual indicators and have therefore not been included in the figure.

For the example, only a single branch of the hierarchy has been expanded, and then not even completely. The entire assessment tool consists of nine domains or impact categories, 36 criteria and over a 150 individual indicators (DGBC, 2014). Furthermore, the method makes a second distinction between various indicators by assessing ‘Asset Features’, ‘Asset Management’, and ‘Asset Operations’ separately. As such, the features of the building, management of the building, and operations of the building can be evaluated on sustainability performance individually. In our example in Figure 19, ‘Mechanical Ventilation’ is a building feature, while ‘Liter Fresh Air/ Minute’ is an operation characteristic.

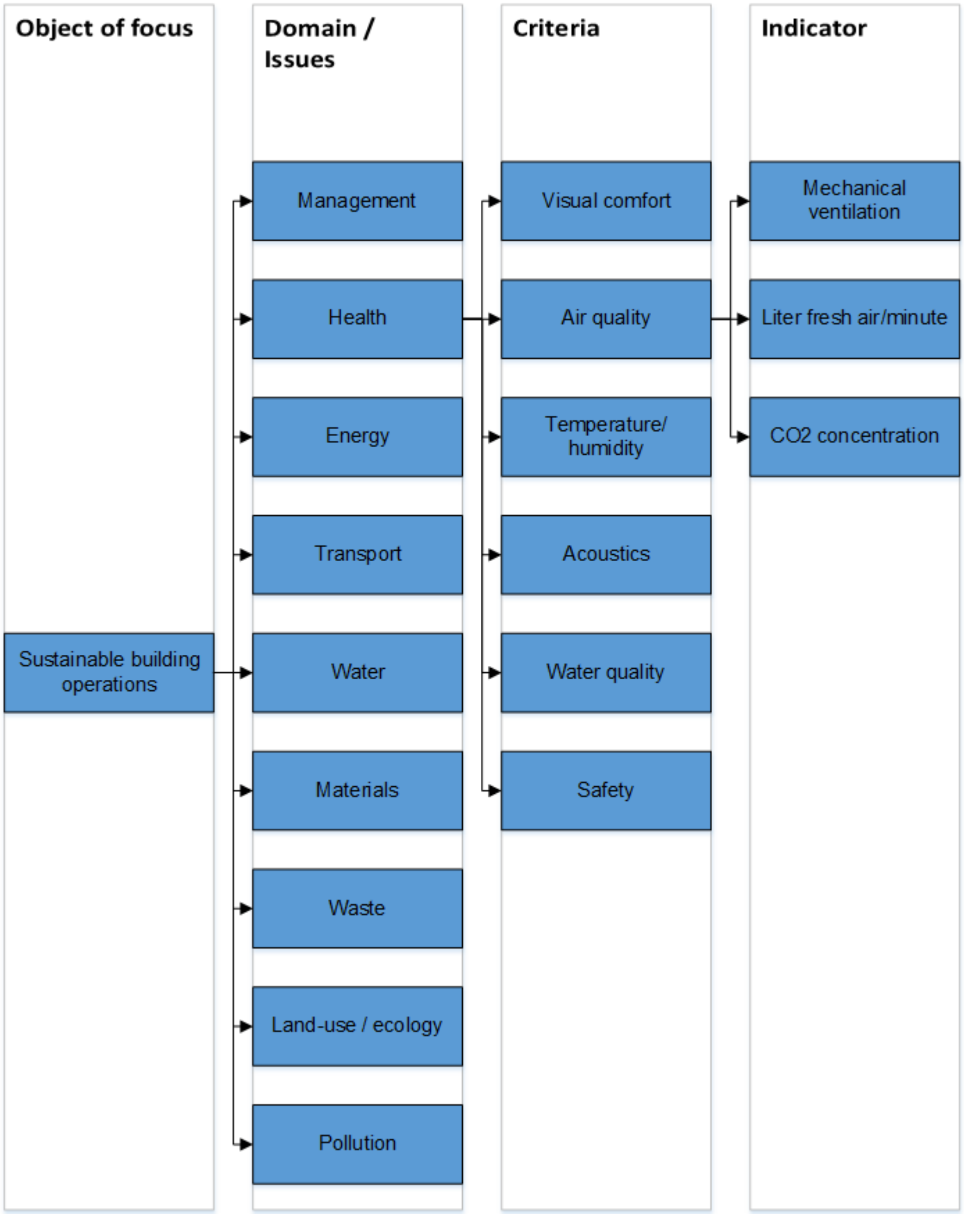

Figure 19 - Partial hierarchy of a system of indicators, BREEAM-NL In–Use

4.1.3 Operationalization of indicator tools

Qualitative and quantitative indicators

Most indicator tools comprise of both qualitative and quantitative data. Examples of quantitative data include energy consumption in KJ, gas or water consumption, greenhouse gas emission, etc. Qualitative data includes, local wind patterns, ecological impact, or as in the example in Figure 19**,** installation of mechanical ventilation(Ding, 2008).

Quantitative data provides for easy control parameters and is readily comparable to benchmarks. However, ecological impact or description of impact on local wind patterns can only be evaluated on a feature specific basis. Turning again to our example in Figure 19 we can see that the criteria 'air quality' is evaluated by both feature description, the presence of a mechanical ventilations system, and by quantitative data, liter of fresh air per minute.

Weighting of indicators

The purpose of indicator systems is often to provide an overall performance score for the object under assessment. In order to do so, indicator schemes apply various forms of weighting to the individual indicators by means of point allocation. This is where the fifth level in the indicator tool hierarchy, 'Benchmarks' becomes relevant. In the case of qualitative indicators, points are scored when the project under consideration complies too certain features. For instance, points are awarded when a building has mechanical ventilation installed, in the BREEAM-NL In-Use assessment.

Points for quantitative data are usually awarded when performance of the object falls within a certain benchmark scale. For instance, an increasing number of points are awarded in the BREEAM-NL In-Use scheme, depending on how much the energy consumption of the building under consideration, lies below the national average.

Presentation of results

Depending on the tool in use, points scored for the various indicators are added up according to tool specific formulas and presented as an overall score. Various tools translate that overall score into a final rating. For instance, LEED methodology translates the final score into a bronze/silver/gold/platinum rating. Similarly, the BREEAM methodology awards projects with a three to five star rating. Figure 20 depicts an alternate method for the display of results of a neighborhood assessment from the EcoCity assessment methodology. In this case scores are given for the different domains independently, providing a more transparent overview of the strengths and weaknesses of the neighborhood under assessment.

Figure 20 – Example of result presentation of an assessment: Criteria and issues of Urban Planning according to EcoCity assessment method

4.1.4 The reason for application of indicator tools

As mentioned, indicator tools are available in a broad range of shapes and sizes. The application of indicators and systems of indicators in various projects can have a number of reasons.

One reason for the inclusion of indicators is that it is required by regulations. As an example, single indicators have long been used to measure and limit the amount of exhaust emissions produced by automobiles. On a larger scale, new construction is now required to estimate energy performance of new projects and provide an energy label for the house or building.

However, systems of indicators may also be implemented on a voluntary basis. Commercially available assessment tools that cover all aspects of sustainability are implemented in various construction projects, on both building and neighborhood scale, to promote the quality and sustainability of such projects. This is done either for PR and commercial purposes or even out of idealistic deliberations.

On a larger scale, the quest for high quality sustainable urban environments is taken up by local communities and cities. Various cities around the world have developed their own system of indicators to identify points of improvement to the city and measure overall improvement and policy success on the road towards more sustainable cities.

4.1.5 Conclusion

Indicator tools are a method by which vast amounts of complex data can be captured in relatively easy to understand information. As such the tools can help stakeholders in the evaluation of the quality and sustainability performance of a wide array of projects and assist in the comparison of performance of different projects relative to each other.

4.2 An example of a sustainable neighborhood assessment method: BREEAM Communities

To illustrate the points made in the previous paragraph, we will briefly explore the workings of the commercially available neighborhood sustainability assessment (NSA) tool, BREEAM Communities. Extensive information on BREEAM Communities can be found in the BREEAM Communities Manual 2012 (BRE, 2012). Although the details vary greatly between neighborhood assessments methods, BREEAM Communities may be considered as representable for the general methodology of neighborhood assessment, for the purpose of illustration.

The goal of BREEAM communities has been neatly summarized with the following statement;

> *"BREEAM Communities is an assessment method that helps professionals design places that people want to live and work in, are good for the environment and are economically successful*".

The method focusses on the design and planning phases of urban development. Post-construction certification is not included in the assessment due to the long timescale associated with large-scale development. The indicators applied in the assessment therefore focus on the design processes, planning decisions and commitments made to achieve certain goals and do not often include result based indicators. The design and planning process has been divided into three steps. The following description of these steps has been taken from the BREEAM Communities Manual 2012:

"There are three steps involved in the assessment of sustainability at the master planning level:

1. *Following site selection there is a process whereby the developer must show the suitability and need for specific types of developments on the site as part of a planning application. Strategic plans for the wider area, usually contained within the local authority's planning document, should indicate the housing, employment or services that are required. The new development will need to respond to these local requirements in order to receive planning permission. In this scheme the process described above is assessed under 'Step 1 - Establishing the principle of development'. During this step BREEAM assesses the degree to which the design team understand the opportunities to improve sustainability that necessitate a site-wide response, such as community-scale energy generation, transport and amenity requirements. All issues must be covered to ensure a holistic strategy for the site.*
2. *The next step in the master planning process determines the layout of the development. This will include detailed plans for how people will move around and through the site an where buildings and amenities will be located. This is called 'Step 2: Determining the layout of the development' in BREEAM Communities.*
3. *'Step 3: Designing the details 'involves more detailed design of the development including: the design and specification of landscaping, sustainable drainage solution, transport facilities and the detailed design of the built environment. The latte includes the use of whole building assessment methods such as the building related BREEAM schemes."*

These steps run parallel to the master planning phases that all big urban development projects go through, before actual construction starts. Because of this, the BREEAM Communities label enhances the planning process and can be fully integrated into this process, instead of just consisting of extra steps that have to be taken in order to ‘get a positive sustainability review’.

The sustainability issues addressed in BREEAM Communities are divided into five different impact categories. The categories and their aims are again taken directly from the BREEAM Communities Manual 2012:

Impact category	Aim
Governance (GO)	To ensure community involvement and leadership in running the development.
Social and economic wellbeing (SE)	
-Local economy:	To create a healthy economy (employment opportunities, and thriving business).
-Social Wellbeing:	To ensure a socially cohesive community.
-Environmental conditions:	To minimize the impacts of environmental condition on the health and wellbeing of occupants.
Resource and energy (RE)	To reduce carbon emissions and ensure wise use of natural resources.
Land use and ecology (LE)	To improve ecological biodiversity.
Transport and movement (TM)	To create an efficient and safe system for movement.

Figure 21 - Impact categories in BREEAM Communities assessment methodology

Sustainability issues

Different sustainability issues, the criteria, within each category help to further flesh out the aims described above. Different issues are relevant during different phases of the planning process. A complete overview of the different issues, in which domain they belong, and at what stage of the planning process they become relevant, can be seen in Figure 22.

Just as each category has an overarching aim, so to do the individual issues have a purpose of their own. As an example we will examine issue SE 08 – Microclimate.

The microclimate of a region relates to the environmental conditions of an area in regard to the health and wellbeing of the inhabitants and users of an area. The aim of this particular issue is defined as follows;

> ***Aim:*** *To ensure the development provides a comfortable outdoor environment through the control of the general climatic conditions.*

To achieve this aim, a number of individual criteria have been selected. In order for a project under assessment to comply with this issue, it has to fulfill a minimum amount of the selected criteria. These criteria are in fact the sustainability indicators used in the assessment method. In the case of “Microclimate” the indicators are;

Step 1	Step 2	Step 3
Governance		
GO 01 – Consultation plan	GO 02 – Consultation and engagement GO 03 – Design review	GO 04 – Community management of facilities
Social and economic wellbeing		
SE 01 – Economic impact SE 02 – Demographic needs and priorities SE 03 – Flood Risk Assessment SE 04 – Noise pollution	SE 05 – Housing provision SE 06 – Delivery of services, facilities and amenities SE 07 – Public realm SE 08 – Microclimate SE 09 – Utilities SE 10 – Adapting to climate change SE 11 – Green infrastructure SE 12 – Local parking SE 13 – Flood risk management	SE 14 – Local vernacular SE 15 – Inclusive Design SE 16 – Light pollution SE 17 – Labour and skills
Resources and energy		
RE 01 – Energy strategy RE 02 – Existing buildings and infrastructure RE 03 - Water strategy		RE 04 – Sustainable buildings RE 05 – Low impact materials RE 06 – Resource efficiency RE 07 – Transport carbon emissions
Land use and ecology		
LE 01 – Ecology strategy LE 02 – Land use	LE 03 – Water pollution LE 04 – Enhancement of ecological value LE 05 – Landscape	LE 06 – Rainwater harvesting
Transport and movement		
TM 01 – Transport assessment	TM 02 – Safe and appealing streets TM 03 – Cycling network TM 04 – Access to public transport	TM 05 – Cycling facilities TM 06 – Public transport facilities

Figure 22 - Sustainability issues in BREEAM Communities assessment methodology

One point

1. A Microclimatic simulation/study shows the effect of urban morphology on the external microclimate of the development and surrounding area.
2. The development is designed to minimize adverse conditions, including negative microclimatic factors.

Two points

3. Criteria 1 and 2 are achieved.
4. The development is designed to increase positive conditions throughout the year.

Three points

5. Criteria 1 to 4 are achieved.
6. An appropriate and diverse range of favorable microclimatic conditions have been provided throughout the development to cater for a wide range of personal preferences.
7. The design of public space optimizes microclimatic conditions at all times of the year.
8. The location and design of pedestrian/cycling routes takes full account of microclimatic conditions.

It should be noted that the indicators in this case take the form of; "A study should be done…." And "The results of the study should be applied appropriately". By applying indicators in this way it is possible for different projects in different geographical areas, to come to different solutions and results with regard to how they handle the aspect of microclimate. This falls in line with one of the ideas behind the Communities assessment method, that each area is unique and that all projects should look for local solutions to design questions instead of relying on universal rules. The indicators described here are typical qualitative features.

Scoring method in BREEAM Communities

When applying the Communities assessment method, projects are awarded a final score between 0 and 100 %, depending on their performance. Points towards this final score are achieved by fulfilling the requirements of the various sustainability issues. Each issue is worth a certain percentage of the total score. The issue "microclimate", used as an example in the previous section, is worth 1.8% of the total score.

The issue "Microclimate" is further divided into 3 points. Fulfilling the first two criteria of this issue earns the project 0.6 % for the total score. Fulfilling criteria three and four earn the project an additional 0.6%. Fulfilling the final set of criteria earns the project the full 1.8 % allocated to this sustainability issue.

A number of issues and criteria in "Communities" are mandatory in order to achieve a passing grade, and do not earn a project any points. This is because these criteria usually cover issues that require state mandatory research and plans that have to be drafted for any big project anyway. The "Communities" assessment method only awards points to sustainability measures that go beyond the basic requirements. Two examples of mandatory requirements are the execution of a study of the demographics of an area and execution of a flood risk assessment.

BREEAM Communities in a hierarchal model

The description of BREEAM Communities is basically a description of a hierarchal model for a system of indicators. A hierarchal model is used to organize large amounts of data, or in this case, large amounts of indicators in to a model that is easier to oversee. Figure 23 depicts part of the system of BREEAM Communities. The model has been partly worked out for a branch of the impact category "Governance". Each impact category has their own set of sustainability issues under them in the model, just as each individual sustainability issue has a number of criteria.

The first three layers of the model, the impact categories, the sustainability issues and the criteria have been discussed in the previous three sections. The last layer of the model contains the so called verifiers. BREEAM Communities contains compliance notes for each criteria or indicator. These compliance notes cover the evidence that is required for projects to prove that criteria have been met in the correct way.

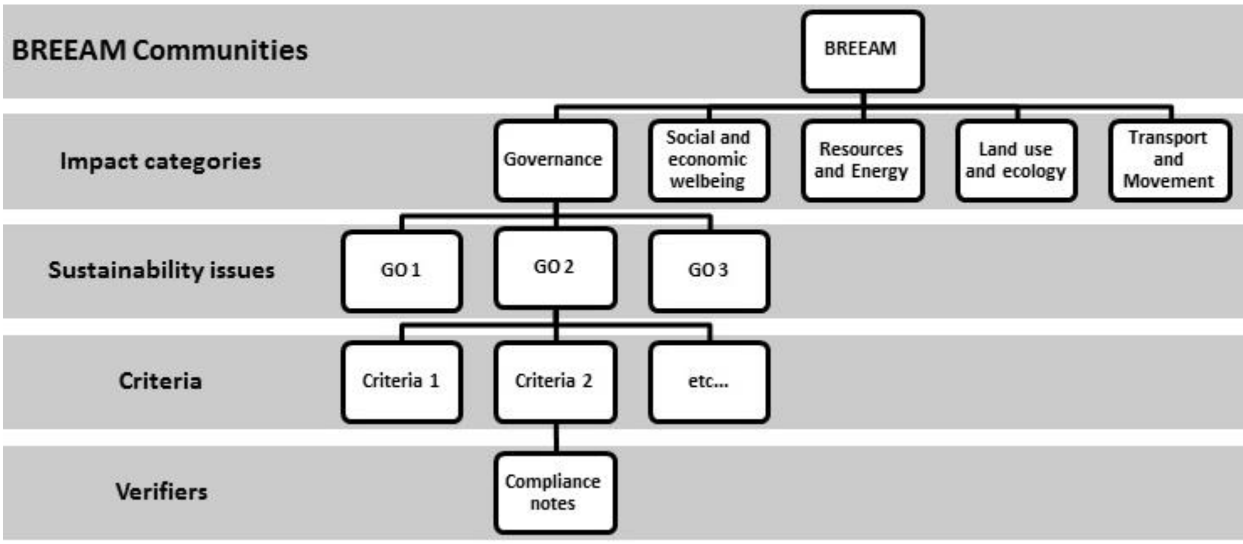

Figure 23 - Part of the hierarchal model incorporated in BREEAM Communities

Application of BREEAM Communities

As previously stated; BREEAM Communities has been specifically designed as a tool to help professionals design places that people want to live and work in, are good for the environment and are economically successful. Furthermore, the assessment method works best on medium to large scale area development. Since this can still be rather vague, the BREEAM Communities manual 2012 list a number of questions that can help determine if a project is suitable for Communities assessment.

- Will the development place significant extra burdens on public transport systems r highways requiring extra capacity or new transport infrastructure (cycle/pedestrian routes, roads, parking, etc.)?
- Does the development include or make use of adjacent area of public realm that occupants and visitors will use?
- Will the development lead to the enhancement, diversification or addition of local employment, social mix or ecological value?
- Will the development include dwellings that trigger additional capacity or require new provision of medical centers, schools and retail centers, places of religious worship, or other similar facilities and services?
- Is the development of a scale that could create opportunities for community level utility provision including energy, water and waste services or where there would be potential for linking to other new or existing developments in the area to make such option viable?
- Is the development likely to have a significant impact on existing communities?

Answering yes to most of these questions means that the project could benefit from a Communities assessment.

When is BREEAM Communities not suitable?

BREEAM Communities is specifically designed to assess medium to large scale development and redevelopment projects. Smaller construction projects are covered by another BREEAM assessment method; BREEAM New Construction. As stated in previous sections, BREEAM Communities covers only the design and planning stages of the development. Lifecycle assessment and result assessment is specifically not included in the assessment method.

In terms of scale, BREEAM Communities is to large scale projects, what BREEAM New Construction is to smaller projects. BREEAM New Construction also focusses specifically on the design and development of projects. Lifecycle assessment and result assessment for smaller constructions is covered by another BREEAM scheme; BREEAM In-use.

Assessment of sustainability performance of an urban area during use is explicitly not covered by any BREEAM scheme. Furthermore, in-use activities and design and planning of an urban area may have some overlap, but also have certain focus areas that are inherently different. Just as with small scale construction, where the design/planning phase and the in-use phase are evaluated by separate methods, so too should larger areas be evaluated with different methods, depending on which phase is under evaluation.

4.3 Availability of indicator tools of ranging goal and scope

Now that we have a clear idea of what an indicator tool is and can do, we will investigate what kind of indicators are currently available according to literature. BREEAM Communities is just one of the many indicator tools available to assess the urban environment. Indicator tools for the assessment of the quality and sustainability of the urban environment are available on three distinct levels of scale. This paragraph will provide a short overview of the various tools.

Building scale indicators

On building scale alone more than a hundred tools are available for any part of the project lifecycle, spanning from initial design and construction, to efficient operations, to demolition and recycling of building materials(Nguyen & Altan, 2011).

An extensive list of building assessment tools and their characteristics can be found in the article by (Ding, 2008). The list is by no means complete but does list the most popular tools available. Each tool has its own specific method and area of focus.

Neighborhood scale indicator tools

Tools on neighborhood scale can be regarded as the latest generation of sustainability assessment tools (Sharifi & Murayama, 2013). Whereas city scale indicators focus on operational aspects of the built environment, the focus of current neighborhood assessment tools is mainly on the design and construction fazes of the building lifecycle. Putting it another way: The current generation of Neighborhood Sustainability Assessment (NSA) tools assists specifically in the process towards a desirable state and not on compliance to the ´desirable state´ itself.

The tools operate on the principle of back casting. Based on a certain vision of a high quality sustainable urban environment as discussed in chapter three (the desirable state), the indicator tools encourage designers and project managers to consider and incorporate all the relevant principles and dimension in to the (re)development of new neighborhoods.

In their research (Sharifi & Murayama, 2013) identify seven Neighborhood Sustainability Assessment (NSA) tools that are fully developed, readily available, and encompass all three pillars of sustainability, social, economic, and environmental. The seven tools are:

- LEED-ND
- EarthCraft Communities (ECC)
- BREEAM Communities
- CASBEE-UD
- HQE^{2}R
- Ecocity
- SCR

Except for BREEAM Communities, which has been used as an example in the previous paragraph, we will not discuss the individual indicator tools. It is sufficient to know that there are a number of tools available to assist in the sustainable development of neighborhoods. As such these tools can be referenced for inspiration in designing a new tool. It should however be kept in mind that these tools have been developed to assist in large scale (re)development of areas and not in the assessment of existing ones.

City scale indicator tools

On the far end of the scale, city scale indicator tools have also gained some popularity. Sustainable community indicator systems are custom designed specifically for the city under assessment. There are currently dozens, if not hundreds of community indicator programs in existence (Gahin et al., 2003)

Whereas building scale tools may focus on any stage in the building lifecycle, community indicator programs tend to focus specifically on the current state of the urban environment, the operation of the city. Indicator selection of the various programs differs, depending on the priorities of the city implementing the indicator program. A comprehensive list of indicators for the various programs is composed by using various sets of indicators promoted by local or international organizations such as the World Bank, the United Nations or UN Habitat.

International Urban Sustainability Indicator List (IUSIL)

Environmental		**Social**	
En1	Geographically balanced settlement	So1	Energy Acces
En2	Freshwater	So2	Water Access
En3	Wastewater	So3	Education
En4	Quality of ambient air and atmosphere	So4	Health
En5	Noise pollution	So5	Safety
En6	Sustainable land use	So6	Fire & Emergency Response
En7	Waste generation and management	So7	Poverty
En8	Effective and environmentally sound transportation systems	So8	Transportation
En9	Mechanisms to prepare and implement environmental plans	So9	Natural hazards
En10	Biodiversity	So10	Adequate housing
		So11	Shelter
Economic		So12	Security of tenure
Ec1	Consumption and production patterns	So13	Access to credit
Ec2	Economic development	So14	Access to land
Ec3	Finance	So15	Promote social integration and support disadvantaged groups
Ec4	Water	So16	culture
Ec5	Strengthen small and microenterprises	So17	Recreation
		So18	Availability of local public green areas and local services
Governance			
Go1	Participation and civic engagement		
Go2	Transparent accountable and efficient governance		
Go3	Government		
Go4	Sustainable management of the authorities and businesses		

Figure 24 - International Urban Sustainability Indicator List (IUSIL

To illustrate this, Figure 24 depicts a composite list of the criteria proposed by the various indicator programs. This list has been composed by (Shen et al., 2011) and is referred to as the International Urban Sustainability Indicator List (IUSIL). The table only depicts the various criteria and dimensions of urban quality and sustainability. How the various criteria have been operationalized using individual indicators has not been included in the list.

Community indicator tools in general, are inherently different from building and neighborhood assessment tools in that they tend not to apply scoring or weighting to the various indicators and criteria. Focus of the various programs is entirely on the indicators, and what they signify, and not on obtaining a certain overall score according to arbitrarily determined rules and weightings. As a result, more energy may be put in actively improving the quality and sustainability of the urban environment and less in obtaining a good score or review.

4.4 Issues concerning current indicator tools

Although the usefulness of indicator tools has been widely acknowledged, there are still quite a number of issues related to both the development and application of the tools. Sharifi & Murayama, 2013) identify seven key considerations related to the design of indicator tools that are often the source the greatest contention in discussion of the various tools. The researchers use the seven issues as a framework to review the NSA tools identified in the previous paragraph. The framework consists of:

- ***Sustainability coverage:***
  What are the major themes included in the NSA tools and how successful are they in assessing neighborhoods' performance in a comprehensive and integrated way?
- ***Inclusion of pre-requisites:***
  Whether there are strategies to assure the achievement of a certain level of performance.
- ***Adaptation to locality:***
  Have the NSA tools considered the context-specific needs and priorities in their assessments.
- ***Scoring and weighting:***
  What methods are used by NSA tools to score and weigh different criteria and how rigorous is this process?
- ***Participation:***
  What mechanisms are utilized by the NSA tools to involve different stakeholders during the development and operational stages?
- ***Presentation of results:***
  How do NSA tools report the results of assessment and to what extent are they useful as decision support systems?
- ***Applicability:***
  How practical are the NSA tools and what strategies can be taken to increase their applicability?

Although Sharifi & Murayama, 2013) use these seven issues to discuss the quality of the NSA tools, one can not simply apply their framework to select te most succesful or useful indicator tool. As they write themeselves:

> *"It should not be forgotten however, that they (*the seven issues) *are all interconnected and must be regarded as complementary elements which should not be used in isolation."*

How NSA tools contend with the seven issues is dependant on the scope and goal of the tool, more simply put, dependant on the three suggested design questions:

- Who is going to use the tool?
- How is the tool going to be used?
- Why is the tool going to be used?

The seven points of the framework will be discussed individually. The work presented below is based on the research by (Sharifi & Murayama, 2013)

Sustainability coverage

The issue of sustainability coverage relates to the completeness of the tool when assessing the quality and sustainability of a project. More extensive tools attempt to assess most if not all issues relevant to sustainability as discussed in chapter three. However, including an increasing number of issues in the tool can make the tools overcomplicated, and therefore less accessible. Inclusion of quality and sustainability aspects is therefore a tradeoff between aspects, selection of which depends on the purpose of the tool. One cannot expect any one tool to cover all the issues of a high quality sustainable environment while still remaining practical. However, not including enough criteria may damage the integrity or completeness of the tool.

Inclusion of pre-requisites

Inclusion of all aspects of a high quality sustainable environment in a NSA tool does not imply that all these aspects will be adequately included in the project under assessment. Projects that apply NSA tools may opt to pick and choose among the quality and sustainability options and focus on only a few of those, leading to opportunistic behavior. A number of tools address this issue by making a number of sustainability criteria mandatory requirements for a project. Projects will not receive a passing score if these mandatory criteria are not completed.

Adaptation to locality

Although NSA tools are designed based on the priorities and conditions of their countries and regions of origin, differences in climatic, social, and economic settings and also size and type of developments, can make further customization of NSA tools desirable. One way of addressing this is by awarding points for compliance to certain protocol instead of specific features or results.

For instance, points in BREEAM can be earned by executing simulations of change to local climate by the project and adapting the projects accordingly to recommendations of the research. In this way, climatic conditions are compared to local conditions, and are not held up to a general benchmark that may be unattainable for certain areas or projects.

Some tools have as specific goal that they provide objective comparison of quality and sustainability of projects. Increased adaptability to locality may negatively influence a tool's usefulness as comparison method.

Scoring and weighting

A huge area of contention is the way in which the various criteria of NSA tools are weighted. Weighting implies the significance and importance of certain sustainability criteria above others, even though it is extremely difficult to compare different elements. This is especially true when comparing, and thus weighting, qualitative and quantitative criteria. As such, weighting of criteria is always subjective. Since weighting of criteria and indicators is the single means by which calculation of the sustainability 'score' of a project is done, this score is by extension also subjective.

To compensate for subjectivity of weighting of criteria it is important to acknowledge that this is the case and provide transparency in how weighting has been achieved. Usually weighting of criteria is executed by means of expert judgment. By providing transparency in the weighting procedure and making use of expert judgment, NSA tools attempt to ensure that assessment of projects is, if not completely objective, than at least consistent. This consistency makes it possible for projects to be compared to each other on performance.

On a different note, critique has been given to the fact that most NSA tools only award points for positive contributions to sustainability but do not penalize bad performance. As such most tools tend to be too optimistic in assessment. This issue is partly, but not completely, countered by the inclusion of pre-requisites in assessment tools.

Participation

The importance of participation of stakeholders in a project, during any stage of a project is widely recognized. This is recognized by a number of NSA tools. As such, criteria have been formulated concerning the involvement of stakeholders in projects. Whether or not inclusion of such criteria is adequate is a matter concerning individual NSA tools.

On a different level there is discussion concerning the involvement of stakeholders during the design of indicator tools themselves. Community or urban indicator programs, such as Sustainable Seattle, sometimes provide a platform by which interested citizens and other stakeholder can provide input on indicator selection. Such practices are harder to realize for the design of 'stock' neighborhood indicator tools. Stakeholder participation for the design of NSA tools is usually limited to experts, academics and project developers. However, active involvement of potential users of the assessment could contribute to increased uptake of the tool.

Presentation of results

The presentation of results has to some extent been discussed in the first paragraph of this chapter. The goal of NSA tools is often twofold. On the one hand the tools provide stakeholders with insight in the performance of projects. To achieve this, the presented results should be transparent and provide instant feedback on the specific strengths and weaknesses of a project.

The second purpose of NSA tools is to provide a means by which projects may be compared on performance. For this reason results of the assessment are often compacted into a single rating. Although this provides for quick comparison, this composite score often comes at the cost of transparency. Individual NSA tools should carefully consider how to incorporate presentation of results in their own framework, depending on the purpose the tool.

Applicability

Current NSA tools are not mandatory for projects. As such, NSA tools need not only be useful and correct; they also need to be appealing to projects wishing to implement them. As such the tools in question have to be practical. Practicality of tools can be limited by the cost of the NSA tool, the complexity of the tool, or the limited usefulness of the results.

Moreover, results of NSA tools are often used for the purpose of communicating the sustainability of a project to consumers and other stakeholders. NSA tools that apply to stringent conditions for assessment may thus reflect badly on the performance of projects. In that case NSA tools with less stringent conditions may be preferable to implement in the project. By raising the bar of sustainability to high, NSA tools may effectively make themselves ineffective. However, NSA tools with low passing standards will contribute less to increased quality and sustainability in projects and will thus only be useful for 'green washing'.

4.5 Conclusion: setting the foundation for a successful neighborhood indicator tool

This section will provide answers to the research question proposed at the beginning of this chapter:

> *What methods are being proposed in current literature to systematically monitor the urban environment?*

Indicator tools and their components

In the first paragraph of this chapter we have given a general description of systems of indicators as a method by which the urban environment may be monitored. As a general rule, indicator tools are structured according to a hierarchal structure of five levels, comprising the basic building blocks of the tool. The five levels are (section 4.1.2);

1. **Sustainability dimensions** – The core goals of sustainability, often based on the three dimensions of environmental preservation, social equity and economic vitality;
2. **Urban sustainability issues** – The topics of concern to sustainable urban development, that need to be addressed to achieve the core goals, e.g. improve access to socio-economic opportunities;
3. **Evaluation criteria** – A set of aspects that need to be assessed in order to verify the response of the plan to the issue, e.g. access to public transport, access to jobs and access to local services;

4. **Design indicators –** Variables whose value is indicative of the performance of the design, with a unit and often a specific measurement method, e.g. percent of residents within 300m walking distance of a public transit stop, average distance to the nearest doctor;
5. **Benchmarks –** Reference values that the indicators need to meet to correspond to quality levels, often in different range groups.

Availability of indicator tools discussed in literature

We have ascertained that the built environment can be monitored on three levels of scale; the building-, the neighborhood-, and the city wide scale. Furthermore, indicator tools are available to assess quality and/or sustainability across stages of the building life cycle. Indicator tools may be able to assess sustainability of a project in reference to a certain 'desirable state', as discussed in chapter three, or assist in the assessment of the process towards such a 'desirable state' by facilitating in design choices.

Tools on building scale are available for any stage of the building lifecycle, evaluating projects in reference to, or the process towards a desirable state.

Readily available tools for the assessment of quality and sustainability on a neighborhood scale, as discussed by literature, focus exclusively on the process towards a 'desirable state'. There are currently no easily implementable tools discussed in literature, for the evaluation of the current quality and sustainability of the urban environment on a neighborhood scale.

On city scale, methodologies are available by which communities can implement their own system of indicators to monitor the urban environment. These urban systems of indicators focus on the operation of the urban environment in reference to certain benchmarks, the desired state.

Goal and scope of an indicator tool

Success of indicator schemes can be determined in relation to four characteristics (section 4.1.1). Three of these characteristics can be translated into design questions for an indicator tool:

- Policy relevance: Who is going to use the tool?
- Readily implemented: How is the tool going to be used?
- Usable for decision making: Why is the tool going to be used?

Answering the three design question should lead to formulation of the goal and scope of an indicator tool. The fourth characteristic "scientifically sound" functions as quality control for the individual indicators and the system of indicators as a whole.

Seven considerations for the development of an indicator tool

There are a number of issues that should be considered in the development of an indicator tool, dependent on the goal and scope of the tool. The points to be considered are (section 4.4):

- ***Sustainability coverage:***
  What are the major themes included in the NSA tools and how successful are they in assessing neighborhoods' performance in a comprehensive and integrated way?
- ***Inclusion of pre-requisites:***
  Whether there are strategies to assure the achievement of a certain level of performance.
- ***Adaptation to locality:***
  Have the NSA tools considered the context-specific needs and priorities in their assessments.
- ***Scoring and weighting:***
  What methods are used by NSA tools to score and weigh different criteria and how rigorous is this process?
- ***Participation:***
  What mechanisms are utilized by the NSA tools to involve different stakeholders during the development and operational stages?
- ***Presentation of results:***
  How do NSA tools report the results of assessment and to what extent are they useful as decision support systems?
- ***Applicability:***
  How practical are the NSA tools and what strategies can be taken to increase their applicability?

Towards the framework for the development of a new indicator tool

This chapter has focused attention on an explanation of the basic building blocks (section 4.1) and the general principles (section 4.4) of a system of indicators and illustrated this with an example (section 4.2). An overview of available indicator tools on the various scales of the urban environment has been provided in section 4.3, without going into any detail.

This chapter forms the basis for the framework constructed in the next chapter. This framework can be applied to develop indicator tools for the assessment of the quality and sustainability of existing urban environment in a structured way.

5. Framework for the development of a neighborhood assessment tool

In this chapter we turn to answering the final research question of this report:

> **How can the answers, to the previous two research questions be applied to develop an indicator assessment tool for the existing urban environment in a systematic and structured way?**

It is the purpose of this chapter to demonstrate how the lessons of the previous chapters might be applied to the development of indicator tools. The conclusions of chapter 4 have been combined into a framework for the development of an assessment method for the quality and sustainability of the urban environment. The framework can be seen in Figure 25. The numbers in the boxes refer to the sections in this report where the relevant background information can be found, that has led to the construction of the framework as presented.

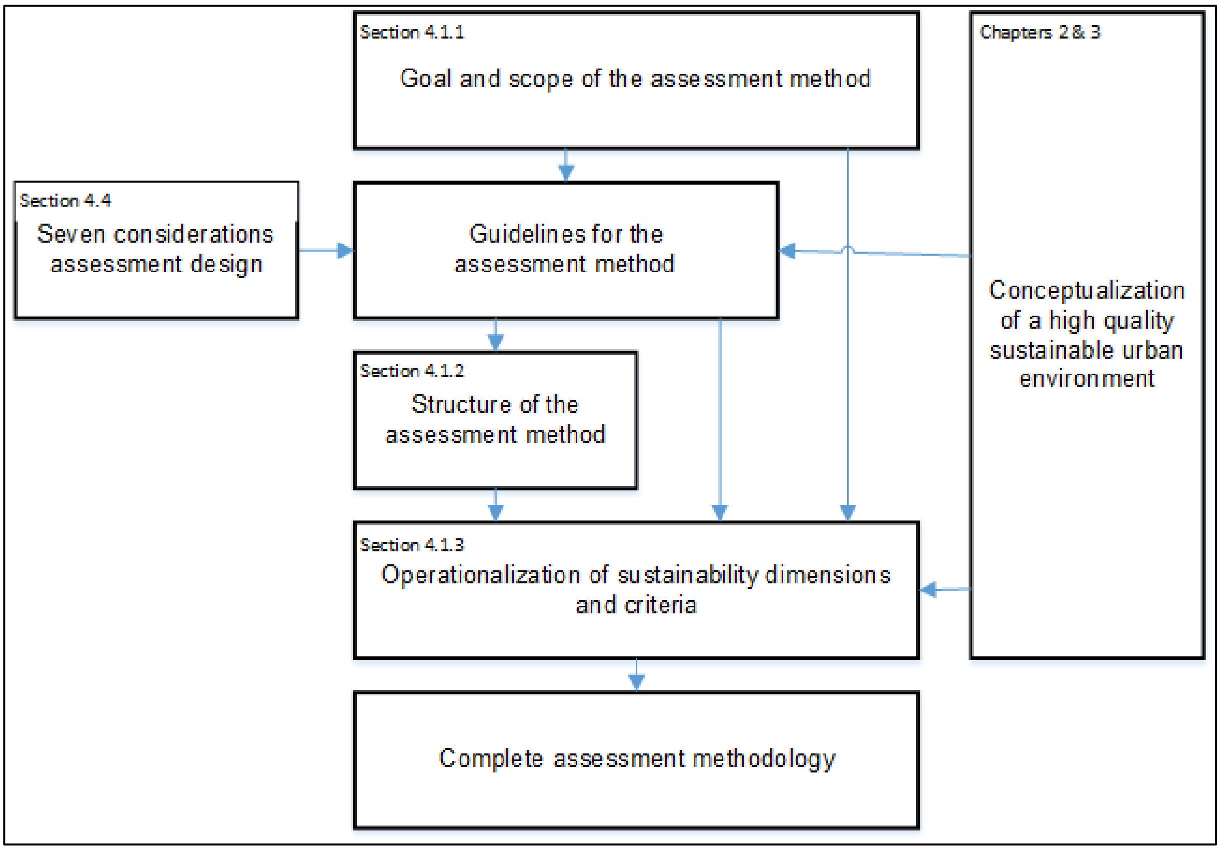

Figure 25 - Framework for the development of neighborhood assessment methods

The framework in Figure 25 depicts how a sound knowledge of a high quality sustainable urban environment as researched in chapter 3, may be translated in to a goal and scope for an assessment methodology of such an environment. The goal and scope may then be translated into a set of guidelines for development of such a tool by means of seven design considerations. These guidelines can be used to draft a hierarchal structure of sustainability criteria. Knowledge of the urban environment may then be applied again to operationalize the various criteria and develop the actual assessment tool by selection and weighting of indicators.

Demonstration of the proposed framework will be done in the following paragraphs. Paragraph 5.1 will formulate the goal and scope of a to be developed assessment methodology. Paragraph 5.2 will demonstrate how the goal and scope of an assessment methodology may be translated into a number of design guidelines by means of the design considerations. Formulation of these guidelines was based on our understanding of a high quality sustainable urban environment. How the developed guidelines might be incorporated in a structure of indicators and integrated into assessment methodology will be the contents of paragraph 5.3 of this report. This will be done in relation to a commercially existing neighborhood assessment methodology, DPL.

An important step in the framework is the translation process from development guidelines to a full-fledged assessment method. This step is referred to as “operationalization” in Figure 25 and refers to how criteria might be quantified by means of weighting of either qualitative or quantitative indicators. This step will be discussed in paragraph 5.4. A general reflection on the presented framework for indicator tool development will be the content of paragraph 5.5 of this report. A visual representation of the structuring of this chapter can be found in appendix 1B of this report.

5.1 Goal and scope of a neighborhood assessment tool

During the course of the research it was found that assessment tools for geographical areas like city areas, neighborhoods etc., are able to do one of three things. Firstly, tools may assist in the process towards a certain `desirable state´, a high quality sustainable urban environment. A second category of tools helps evaluate how close to that state a certain area is in reality. The final category of tools evaluates the degree of sustainability of processes themselves, irrespective of the end result. Our interest in this research was on tools of the second category: tools to evaluate the distance between the actual state of an area and the desired state of an area. In development of the goal, scope and guidelines of the tool, it was assumed that the tool would be applied by municipalities, on a district management level.

Goal of the assessment tool

An adequate tool should have three functions: Firstly the tool should be able to provide a clear overview of the actual quality and sustainability of the area under assessment. Secondly, the tool should be able to indicate which improvements need to be made where, in order to reduce the distance between the actual and desired quality of the area. Finally, the assessment tool should be usable to compare the sustainability performance of different areas respective to each other.

Scope of the assessment tool

It was found that a scientifically grounded high quality sustainable urban environment can be conceptualized by modelling the urban environment as an ecological system. Four aspects in particular were found to be relevant to characterize the quality and sustainability of a neighborhood. A high quality sustainable urban environment must:

- achieve bio-physical sustainability
- provide a high level of need satisfaction on the hierarchy of Maslow for the majority of its inhabitants.
- be flexible, resilient, and therefore in a position to effectively implement and maintain increased sustainability measures.
- maintain (and improve) upon the urban ecological space, its natural capital.

The next section will translate the goal and scope discussed in this section in to design guidelines according to the seven considerations of indicator design.

5.2 Development of design guidelines for an assessment tool

This paragraph will apply the research presented in this report, as well as the seven design considerations, to demonstrate the development of a set of general guidelines for a neighborhood assessment tool, considering the goal and scope presented in paragraph 5.1. The guidelines for the tool we will develop in this paragraph are only applicable in the Netherlands. The tool guidelines might be useable in other contexts, but this should be analyzed upfront.

Sustainability coverage

What are the major themes included in the NSA tools and how successful are they in assessing neighborhoods' performance in a comprehensive and integrated way?

The first challenge in developing guidelines for a tool is to select the relevant aspects of a high quality sustainable urban environment. The dimensions of biophysical sustainability have been summarized in Figure 26.

Dimensions of urban resource input	Dimensions of urban waste outputs
Energy	Solid waste
Land	Liquid waste
Water	Toxics
Building materials	Sewage
Food	Air pollutants
Transportation	Greenhouse gasses
	Waste heat
	Noise pollution
	Light pollution

Figure 26 - Dimensions of the biophysical urban environment

In the discussion of the quality of the urban environment we linked urban quality to Maslow's hierarchy of needs. By defining the quality of the urban environment in relation to the sustainability of the environment we found that a high quality sustainable urban environment is an urban environment that has met basic needs on Maslow's hierarchy, is flexible and resilient and is therefore in a position to effectively implement and maintain increased sustainability measures. The relevant dimensions of such an environment have been summarized in Figure 27. Here we also find overlap with the aspects of a bio-physically sustainable environment, especially with regards to efficiency of resources and adequate disposal of waste.

Dimensions of urban quality	Aspects of urban quality
Environmental quality	Clean air, water, and soil – adequate food supplies, housing, and infrastructure as well as green areas and open space.
Human health	Builds on environmental quality
Efficiency	Resource allocation must maximize the economic output per unit of resource input.
Equity	Resource allocation must maximize social benefit per unit of economic output, across social groups, regions and generations
Diversity	Diversity of actors (communities, cultures, and individual's behavior) and diversity of built and natural landscapes is crucial to urban resilience and flexibility.
Accessibility	Increased access to goods and services leads to decreased impact on local environment.
Learning	Increased learning at local and community level leads to increased flexibility and the ability to modify behavior in response to changing (environmental) circumstances.

Figure 27 - Dimensions of a high quality urban environment

In order for the NSA tool to provide a comprehensive overview of the quality and sustainability of a neighborhood, the dimensions and aspects in Figure 26 and Figure 27 should be integrated in some form in the tool.

Inclusion of pre-requisites

Whether there are strategies to assure the achievement of a certain level of performance.

This principle refers to the presence of a methodology in the assessment tool by which projects are compelled to achieve a minimum level of sustainability performance. It is suggested not to include pre-requisites but to develop a scale by which projects can receive a negative evaluation. The best scale is a standardized scale, with values ranging from 1 (very poor performance) to 10 (excellent performance). Grade six is a passing grade.

Because of the possibility of scoring badly on an assessment, it is not necessary to set minimum requirements for levels of performance. It is up to the stakeholders of projects themselves to determine what grades are acceptable for their project.

For the sake of comparison of neighborhoods and areas, it should however be mandatory to make both the assessment and the evidence for the assessment results publicly available. Public availability of this information would accommodate two things. Firstly neighborhoods could learn from each other's experiences. Secondly, public availability of records would accommodate social control on the correctness of presented results of evaluation.

Adaptation to locality

Have the NSA tools considered the context-specific needs and priorities in their assessments.

Assessment of a neighborhood is done in comparison to a hypothetical reference neighborhood, the desired state. What the desired state should look like for the area under assessment can be adapted from area to area. This could be done by designing various hypothetical reference areas, corresponding to various types of neighborhoods. In this way suitable comparison material will be available for any type of neighborhood.

The new assessment method should include a single hypothetical reference neighborhood representative of the desired state of affairs that all projects will be compared to. This will mean that an area in a city center may be compared to a suburban area on quality and sustainability performance. Due to the differences in project type, this will mean that local conditions are less relevant during comparison between areas. On the other hand, performing such comparisons will facilitate research in to what kind of urban setting performs better in regards to quality and sustainability. This will give policy makers and developers a better idea of what kind of projects we should be striving for in future development.

Scoring and weighting

What methods are used by NSA tools to score and weigh different criteria and how rigorous is this process?

Scoring and weighting of the various issues and criteria of the assessment tool should be kept as separate as possible. Aggregate scores should be avoided, as they inhibit transparency of the assessment results. As such an area should receive a score for each aspect of a high quality sustainable urban environment separately.

It is however necessary to apply weighting to individual indicators in order to obtain scores for each criteria. Weighting of the indicators should be done using expert judgment. The decisions and argumentation should be well documented to provide transparency to the process.

Participation

What mechanisms are utilized by the NSA tools to involve different stakeholders during the development and operational stages?

The proposed assessment methodology works on the basis of self-assessment, although it should be possible to retain an expert to execute the evaluation. As such, feedback of the users of the methodology should provide valuable insight for further development of the tool.

It should be considered how data provided by self-assessment is to be verified on correctness. For this we propose a system of peer review. As per pre-requisite, data of the assessments should be publicly available. Interested parties applying the methodology should be required to perform a peer-review of a different project as well as receive a peer-review in order to increase validity of the assessment.

Introduction of a system of peer-reviews would increase participation and interaction between the various projects implementing the proposed methodology.

Presentation of results

How do NSA tools report the results of assessment and to what extent are they useful as decision support systems?

For a one-on-one comparison of projects, results could be either displayed as bar charts, or displayed as radar charts. An example of presenting results can be seen in Figure 28. The way in which the results of the assessment are represented, provides a clear and transparent overview of the quality and sustainability performance of a project under assessment. Furthermore, evaluation of the individual tool spreadsheet provides stakeholders with a clear idea how quality and sustainability can be improved in an area, and are therefore very useful as decision support system. Presentation of results in a radar chart, as seen in Figure 28 would allow interested parties to overlay results of different projects for quick analysis of performance differences.

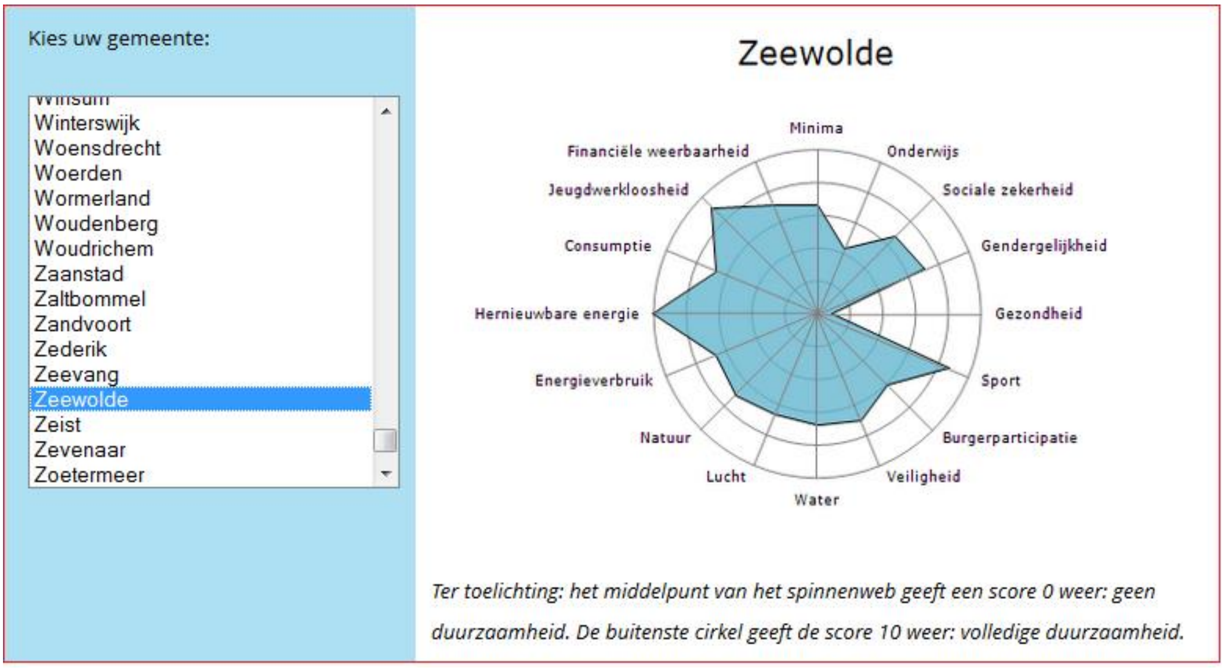

Figure 28 - Example of a radar chart for the display of results of a neighborhood sustainability assessment. Source http://www.gdindex.nl/

An example of comparing neighborhood performances throughout the country is displayed in Figure 29. Applying this method of result representation on a neighborhood scale would allow stakeholders to evaluate the current state of sustainability for the various projects in the same community as well as across the Netherlands. Results should be presented for each individual aspect; aggregate scores should again be avoided.

Implementation of result presentation in such a way would also facilitate communication between various stakeholders across the Netherlands. Projects looking to improve performance of a single aspect would be able to quickly identify well performing areas for that specific aspect. This could lead to better sharing of knowledge and experience regarding increased quality and sustainability on neighborhood scale. Increased communication between various projects could facilitate increased feedback on the tool itself and foster participation for further development of the tool.

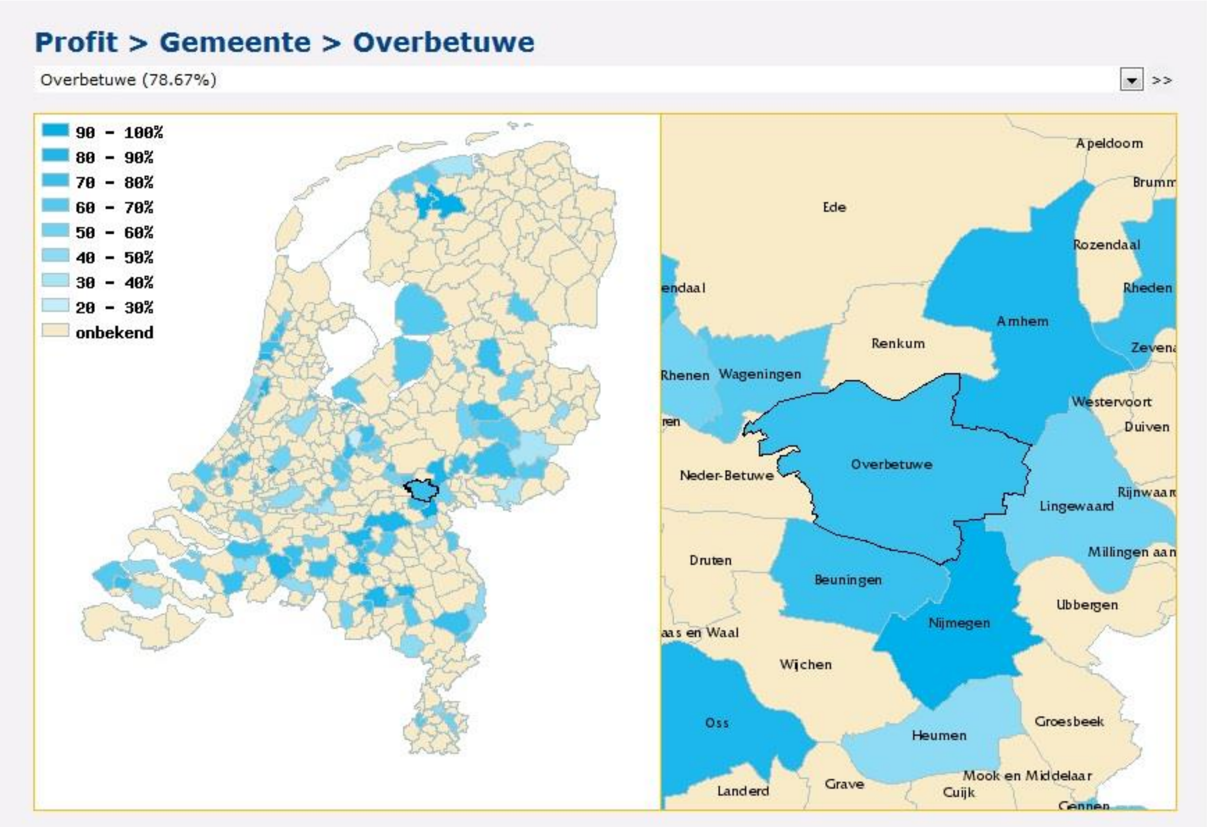

Figure 29 - Display of results of neighborhood assessments on a national level

Applicability

How practical are the NSA tools and what strategies can be taken to increase their applicability?

In development of the new tool it is important to keep the tool simple enough for self-assessment of interested parties. Furthermore, required data and evidence should be standardized so as to accommodate fast and efficient peer-review of evaluations. In order to accommodate this, the developed tool should incorporate a standard protocol and methodology for data identification, collection and analysis.

This can be achieved by programming the assessment tool in a program like Microsoft Excel. Application of standardized spreadsheets makes it possible that users of the tool have only to insert the relevant information of the project under assessment. Performance of the area is immediately calculated based on the collected information. Including protocols for standardized filing of evidence for the data would allow for easy peer-review of projects.

Summarization of the proposed guidelines

The proposed guidelines have been summarized in Figure 30. The challenge in the development of an assessment tool is to combine the developed guidelines discussed in this paragraph in such a way that a useful tool is created. A demonstration of how this may be done will be the subject of the next paragraph of this report.

Design considerations	Developed guidelines
Sustainability coverage	The assessment tool should have a comprehensive coverage of the various aspects and criteria as presented in this report, summarized in Figure 26 and Figure 27
Inclusion of pre-requisites	Pre-requisites for specific criteria should be avoided. It should however be possible to receive a 'failing' grade for assessment of individual criteria. Areas undergoing assessment should make their assessment data publicly available.
Adaptation to locality	The assessment tool should have two sets of benchmarks. The first set of benchmarks should reflect the local 'desired state of affairs'. The second set of benchmarks should reflect the general 'desired state of affairs'. This second set is necessary for comparison of projects on sustainability performance.
Scoring and weighting	Scores should be given for the various sustainability criteria separately. Application of weighting should be limited to individual indicators. Scoring of the selected criteria should be done on a scale from 1 to 10.
Participation	Validation of assessment results should be done by means of peer-review. Sharing of results would facilitate participation.
Presentation of results	Results should be displayed as a bar or radar chart for each separate criteria.
Applicability	The tool should be practical and easily accessible. This could be done by programming the tool in Microsoft Excel. Protocol should be established to facilitate peer review.

Figure 30 - Guidelines for the development of a neighborhood assessment method

5.3 Translating of the guidelines in to a neighborhood assessment tool

It is the purpose of this paragraph to demonstrate how the guidelines of the previous paragraph might be combined to develop a method by which the quality and sustainability of the urban environment might be evaluated. According to the proposed framework, the first step would be to translate the guidelines into a structure of sustainability dimensions and criteria. The structure and guidelines could then be developed into a complete tool through the process of operationalization.

After formulating the guidelines in regards to the seven considerations, as presented in the previous paragraph, it was found that there is in fact already an assessment tool commercially available that has combined these guidelines quite successfully. Since that tool is commercially available, that specific assessment methodology has been developed into far greater detail than ever was the intention of the work in this report. We will therefore use this tool to investigate how integration of the proposed guidelines may lead to a working tool. We will then discuss the discrepancies of the tool in regards to the presented guidelines and demonstrate how adjustments to the tool can amend these discrepancies.

5.3.1 Sustainable Profile of a Location

The tool we suggest to use as a reference for correct integration of the proposed guidelines is called Duurzaamheids Profiel van een Locatie (DPL). The tool translates to English as ‘Sustainability Profile of a Location’. DPL is a commercially available tool and has already been implemented at some 130 locations in the Netherlands. The tool was developed by TNO and IVAM research and consultancy, under commission of the Ministry of Housing, Spatial Planning and Environment of the Netherlands. Development was done in participation with a number of Dutch municipalities. The tool is currently being exploited by IVAM research and consultancy(IVAM, 2008).

5.3.2 Goal and scope of DPL

DPL as a methodology can be used to assess the quality and sustainability of a neighborhood, an area, or a business park. DPL can be applied by municipalities, project developers and urban planners. The tool has been developed to assist in:

- Carrying out a strength/weakness assessment of an area or neighborhood;
- Identifying opportunities for improvement of sustainability in a neighborhood;
- Setting sustainability goals and ambitions in the development of an area;
- Comparison of alternative design scenario’s in the development of an area;
- Monitoring of the achieved sustainability performance in relations to initial targets in a development project.

The tool has been specifically designed to operate on neighborhood level.

It can be seen that the DPL tool fulfills two of the goals set out in paragraph 5.1, namely; The tool provides an overview of the actual quality and sustainability of the area under assessment, and the tool is able to indicate which improvements need to be made where, in order to reduce the distance between the actual and desired quality of an area. However, the tool does not offer the possibility to compare performances of different areas to each other.

5.3.3 Explanation of the tool

Organization of the tool follows the five step hierarchy structure, common for most indicator tools, as identified in chapter 4 of this report. The tool has a broad sustainability coverage encompassing environmental, social, and economic aspects. The dimensions, issues and criteria of the tool can be seen in Figure 31**.** A visual representation of the tool structure has been added in Figure 32.

Dimension	Urban sustainability issues	Evaluation criteria
Planet	a) Stocks	1. Space use
		2. Materials
		3. Waste collection
	b) Climate	4. Energy consumption
		5. Renewable energy sources
		6. Rainwater disposal
		7. Flood Risk
	c) Green space and Biodiversity	8. Green space and water in the neighborhood
People	d) Nuisance	9. Soil quality
		10. Air quality
		11. Noise
		12. Smell
		13. External safety
	e) Safety	14. Security
		15. Traffic safety
	f) Home and neighborhood quality	16. Quality of home and surroundings
		17. Cultural and historical value
	g) Social cohesion	18. Social cohesion
Profit	h) Amenities	19. Shops and services
		20. Sustainable transportation
	i) Economic Vitality	21. Local job creation
		22. Divers commercial activity
	j) Sustainable entrepreneurship	23. Sustainable businesses
	k) Future prospects	24. Diversification of function
		25. Flexibility

Figure 31 - Sustainability coverage of the DPL assessment method

The tool has been built up using a modular approach. Each criterion has been operationalized using a number of indicators. These indicators have been combined into a single Microsoft Excel spreadsheet for each individual criterion. Weighting of the various indicators allows the program to calculate a score for each sustainability criteria separately. Projects under assessment are scored on a scale from one to ten for each individual aspect. Scoring of the various aspects is kept separated and there is no aggregate sustainability score. The assessment method does not require a minimum passing score.

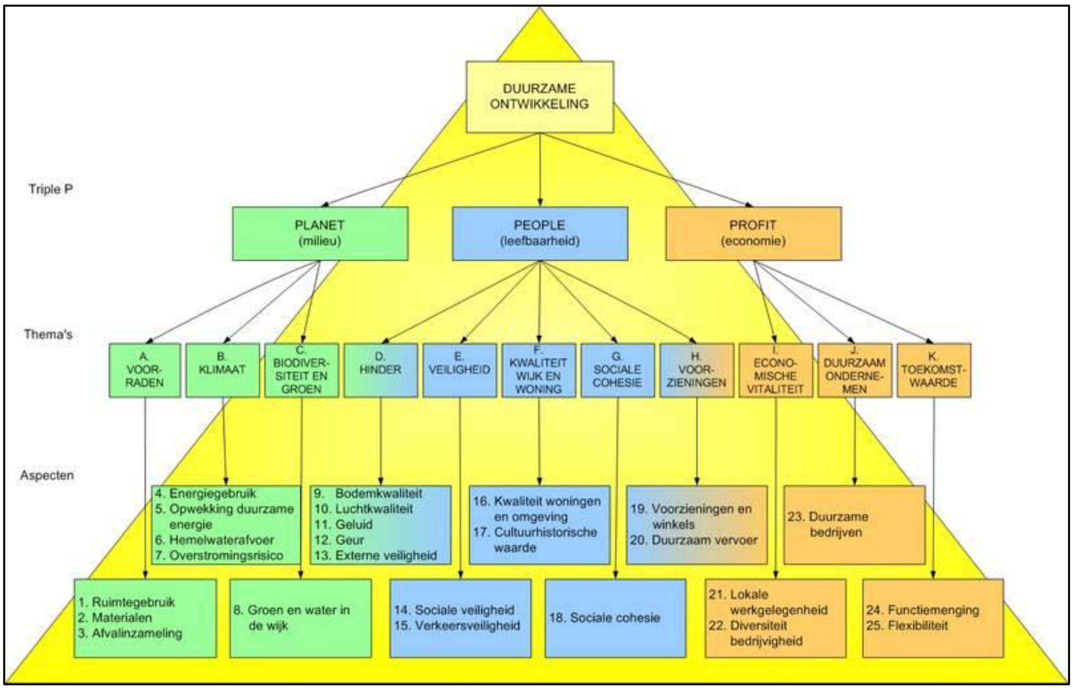

Figure 32 - Hierarchal structure of the DPL assessment methodology

Projects under assessment are rated in comparison to a reference neighborhood. The (theoretical) reference neighborhood scores a six (pass) on every aspect. The program includes a number of different reference neighborhoods, depending on what kind of neighborhood or area is under assessment. Scaling of score is based on this benchmark. Figure 33 depicts an example of a Sustainability Profile of a project. The red line represents the score of the reference neighborhood. The blue bars represent the score of the neighborhood under assessment for each individual aspect.

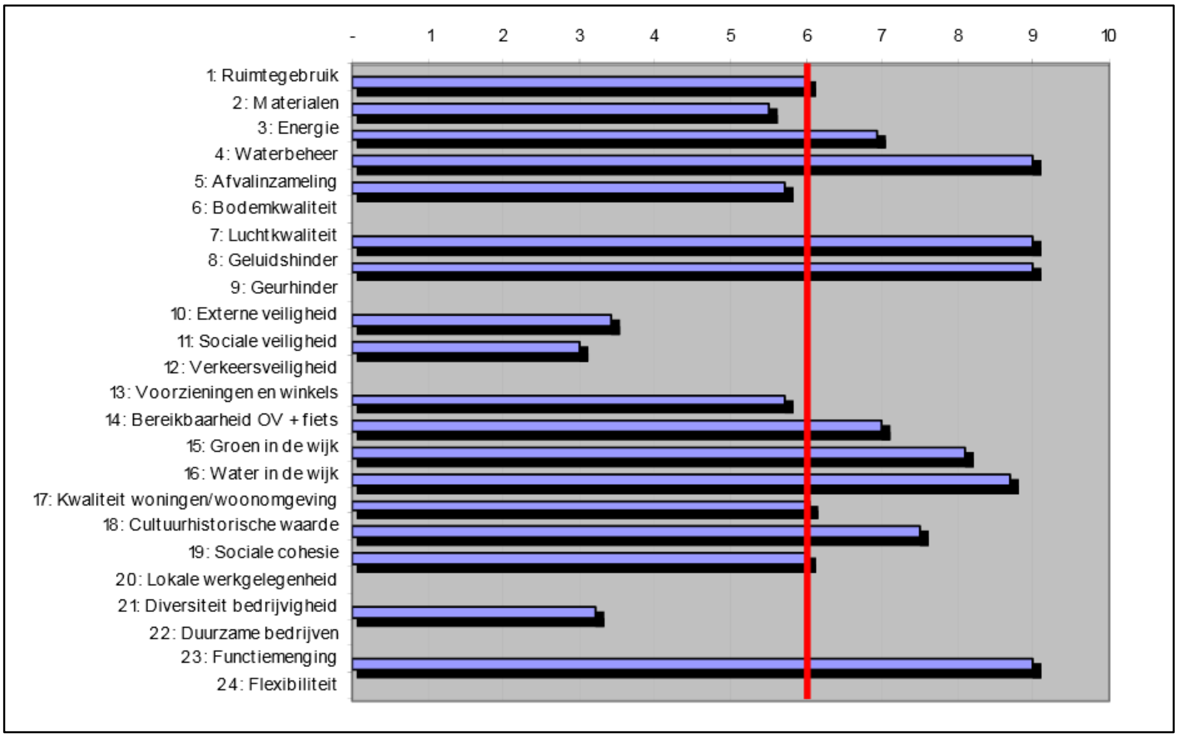

Figure 33 - Presentation of results of the DPL assessment method

The modular approach of the method makes the tool flexible. Existing modules can be continuously updated and new modules can be added to include more aspects of the urban environment. This also makes it possible to easily implement feedback from users.

In some cases individual indicators can provide information that is relevant for multiple sustainability criteria. This has been incorporated in the tool. As an example, a score for “Functiemenging” (Flexibility of function) is calculated by using the information provided for the criterion “Ruimtegebruik” (space use). Combining various indicator inputs in such a way allows the tool to provide a clear and seemingly extensive analysis of the quality and sustainability of an area using a minimum amount of input information.

5.3.4 DPL compatibility in regards to the developed guidelines

It may be clear that DPL has considerable similarities to the guidelines for a neighborhood assessment method as proposed in in paragraph 5.2 and summarized in Figure 30. This is not entirely surprising since the goal and scope of DPL are similar to the first two goals for an assessment tool as proposed in this report.

The main difference between the proposed guidelines and the DPL tool is a result of the difference in the third goal. The guidelines proposed in paragraph 5.2 were developed based on the goal to compare performance of different neighborhoods to each other. DPL however focusses solely on local assessment and is not concerned with either verification of correct assessment of an area or comparison to other neighborhoods. As such, no methods have been devised in the tool to make this possible.

The tool adheres to a clear hierarchy as can be seen in Figure 32. This makes the tool accessible and transparent. Less transparent however, is how individual criteria are operationalized with indicators. It is also unclear exactly how weighting of indicators was determined.

Discrepancies between DPL and the proposed guidelines;

Sustainability coverage

In regards to sustainability coverage of DPL, a comparison was made between the relevant dimensions and criteria of a high quality sustainable urban environment as determined by the research in this report, and the coverage by DPL. The result of the comparison can be seen in Figure 34. The left column depicts the dimension and criteria determined to be relevant by this research. The right column depicts the various criteria of DPL.

Aspects of high quality sustainable urban environment as identified by the research in this report	Relevant evaluation criteria in DPL
Urban resource input	
Energy	4. Energy consumption
	5. Renewable energy sources
Land	1. Space use
	8. Green space and water in the
Water	6. Rainwater disposal
	7. Flood risk
Building materials	2. Materials
Food	-
Transportation	20. Sustainable transportation
Urban waste outputs	
Solid waste	3. Waste collection
Liquid waste	6. Rainwater disposal
Toxics	9. Soil quality
	10. Air quality
Sewage	6. Rainwater disposal
Air pollutants	10. Air quality
Greenhouse gasses	10. Air quality
Waste heat	5. Renewable energy sources
Noise pollution	11. Noise
Light pollution	-
Environmental quality	
Clean air	10. Air quality
Clean water	-
Clean soil	9. Soil quality
Adequate housing	16. Quality of home and surrounding
	18. Social cohesion
Green areas and open space	8. Green space and water in the
Efficiency	4. Energy consumption
	19. Shops and services
Equity	18. Social cohesion
	21. Local job creation
Diversity	18. Social cohesion
	22. Divers commercial activity
	24. Diversification of function
Accessibility	19. Shops and services
	20. Sustainable transportation
	22. Divers commercial activity

	24. Diversification of function
Learning	23. Sustainable businesses
Various aspects relevant to Maslow's hierarchy of needs, not covered by previous categories	
Comfort	12. Smell
Safety	13. External safety
	14. Security
	15. Traffic safety
Sense of belonging/community	17. Cultural and historic value

Unclassified	25. Flexibility

Figure 34 - Sustainability coverage of DPL versus the relevant dimensions and criteria of urban quality and sustainability as presented in this report

Although the dimensions and criteria used in DPL seem to be quite comprehensive, three important aspects where found to be missing: Water as a resource, food, and light pollution.

Clean drinking water is a finite resource and of vital importance for human wellbeing. Furthermore, processing and distribution of water is an energy intensive process. As such water consumption should be monitored and excessive use should be avoided.

With respect to food, it was found during the course of the research that food production and transportation is one of the most important driving functions for urban expansion. As such, increasing the sustainability of the food production should be an important step towards overall increased sustainability. We have argued that although food production is mainly a rural activity, the sustainability of the process can be influenced from within the urban environment. As such, monitoring of both policy and activity towards increased food sustainability should be part of a monitoring tool for a high quality sustainable urban environment.

Along with noise and smell, light pollution can be considered a nuisance in urban environment. Light pollution has been found to have a negative effect on human sleeping patterns and thus to human health, and to negatively influence the urban ecological space (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011). Furthermore, use of unnecessary lighting means unnecessary energy consumption. As such monitoring of light pollution should make a useful addition to the monitoring of the urban environment.

Discrepancies between DPL and the proposed guidelines;

Project comparison and result verification

Although DPL has no method by which projects can be compared to each other, implementation of the relevant guidelines for peer-review and project comparison is quite possible within the current confines of the tool. Comparison of different projects could be facilitated by developing a general 'desired state of affairs' to which individual projects can be compared, as proposed in the guidelines. Projects that are rated in relation to the general 'desired state of affairs' can by extension be ranked in relation to each other for each separate criterion. Once this has been implemented, results could also be presented on a national level as depicted in Figure 29

Implementing a protocol by which neighborhoods that apply DPL are requested to make their information publicly available and perform peer reviews of other assessments would close the gap between the proposed guidelines in this report and the current state of the DPL tool.

5.3.5 Conclusion: Integration of guidelines into an assessment tool

This paragraph has illustrated how developed guidelines might be combined in a working assessment method for the quality and sustainability of the urban environment. Furthermore, we argue that a difference in selected goal and scope of a tool may lead to different design guidelines and thus to a different realization of an assessment tool. In the case of DPL we have demonstrated that the difference in guidelines might be easily adjusted within the current confines of the tool.

It is important to realize that the example used in this paragraph, DPL, is just one way in which the proposed guidelines for an assessment methodology might be translated into an actual tool. As mentioned repeatedly throughout this report, structuring of sustainability criteria is an arbitrary process. Furthermore, operationalization of exactly the same criteria may happen in different ways. This will be discussed in the next paragraph of this report.

5.4 Operationalization of sustainability criteria

Although we have demonstrated how guidelines for an assessment tool might be incorporated in an actual tool, we have only briefly touched on the subject of operationalization in this report. Operationalization refers to the process of expressing a sustainability criterion by means of a number of individual indicators. This has previously been demonstrated in paragraph 4.1 and 4.2. We will demonstrate the principle again by discussing how the criterion "energy" might be operationalized.

Example

As discussed in paragraph 3.2.2.1 of this report there are three steps towards sustainable energy consumption.

1. *Prevent the use of energy by reconsidering the energy use (prevention)*
2. *Use sustainable energy sources as widely as possible (renewable)*
3. *When there still remains an energy demand, then use fossil fuels as efficiently as possible (efficiency)*

Based on these three steps and our knowledge of urban quality and sustainability on a neighborhood scale, covered by chapter 3, there are a number of ways in which the criterion energy might be operationalized. Examples of indicators could be:(BRE, 2012; DGBC, 2014; IVAM, 2008).

- Average energy label of buildings in the neighborhood
- Average energy consumption in kW per inhabitant
- % of energy consumption in neighborhood from renewable sources

The second challenge in the operationalization process is to translate the selected indicators into a score ranging from one to ten in accordance with the proposed guidelines. For the sake of the example we suggest to only use the percentage of energy consumption in the neighborhood from renewable sources to determine the score for the criterion energy. Figure 35 depict a hypothetical scoring scale depending on the amount of renewable energy consumed in the neighborhood.

Percentage renewable energy	**≥0**	**≥4**	**≥8**	**≥12**	**≥16**	**≥20%**	**≥40%**	**≥60%**	**≥80%**	**≥100%**
Score	1	2	3	4	5	6	7	8	9	10

Figure 35 - Hypothetical scoring scale for the amount of renewable energy consumption in an urban neighborhood

As with development of the entire assessment method, operationalization of the individual tool criteria should conform to identified factors for indicator tool success. The way in which criteria are operationalized should be:

- Policy relevant;
- Scientifically sound;
- Readily implemented;
- Usable for decision making;

In essence this indicates that operationalization should be executed with a sound knowledge of a high quality sustainable urban environment, and based on the guidelines deducted from the goal and scope of the tool. This is line with the framework proposed in the introduction of this chapter.

It should be realized that operationalization of the criteria constitutes the bulk of the work needed to develop a system of indicators. We have chosen to operationalize ´energy´ as an example because it is a relatively easy criterion to quantify. However, applying weighting to qualitative indicators can become a complex and often arbitrary process, lacking clear scientific motivation. This can become especially true when attempting to measure social aspects of a neighborhood such as perceived safety of an area. As such, operationalization and benchmarking of a single criterion may warrant specific research of its own.

5.5 Limitations of the proposed framework

Operationalization

Application of the framework was demonstrated by devising a goal and scope for an assessment tool and devising a number of design guidelines for such a tool. It was demonstrated how the guidelines might be incorporated in an assessment tool. This was done by discussing the proposed guidelines in relation to an existing neighborhood assessment tool, Duurzaamheids Profiel van een Locatie (DPL).

However, the framework does not assist in the operationalization step, the translation from guidelines for an assessment method into an actual tool. Application of the framework merely provides boundary conditions to the process of operationalization. What is meant by this is that a tool developer may decide to implement a scoring scale of 1 to 10 for individual criteria. This in turn means that operationalization of the criteria should result in a method by which such an end score may be obtained. Exactly how this should be done is not covered by the framework.

Operationalization of developed guidelines and selected sustainability criteria remains a complex and often arbitrary process. There is of yet no methodology to facilitate in this process, and operationalization remains a puzzle, in which trial and error remains the most used approach. More research is recommended in this area.

Ensuring uptake of the assessment method

The proposed framework does not consider how practical uptake of a developed tool should be realized. As such it might be possible to develop an excellent tool by means of this framework, which does however not get implemented in any project. As such development of an assessment tool should run parallel to the development of a business plan for the tool. This should be considered in the formulation of the goal and scope of a to be developed assessment tool.

Feedback within the framework

The proposed framework has been presented as a linear process with clear inputs and outputs. In reality however it may occur that unanticipated difficulties in operationalization of criteria may lead to adjustment of guidelines for the tool or alteration of the tool structure. As with any design process it may be necessary to come back on previously made decisions. How these changes to the design of the tool may occur is almost impossible to anticipate at the start of a development project and is therefore not captured in the proposed framework.

5.6 Conclusion

This section will provide answers to the research question proposed at the beginning of this chapter:

> *How can the answers to the previous two research questions be applied to develop an indicator assessment tool for the existing urban environment in a systematic and structured way?*

In answering this question, a framework was constructed for the development of neighborhood assessment indicator tools. The framework can be seen in Figure 36.

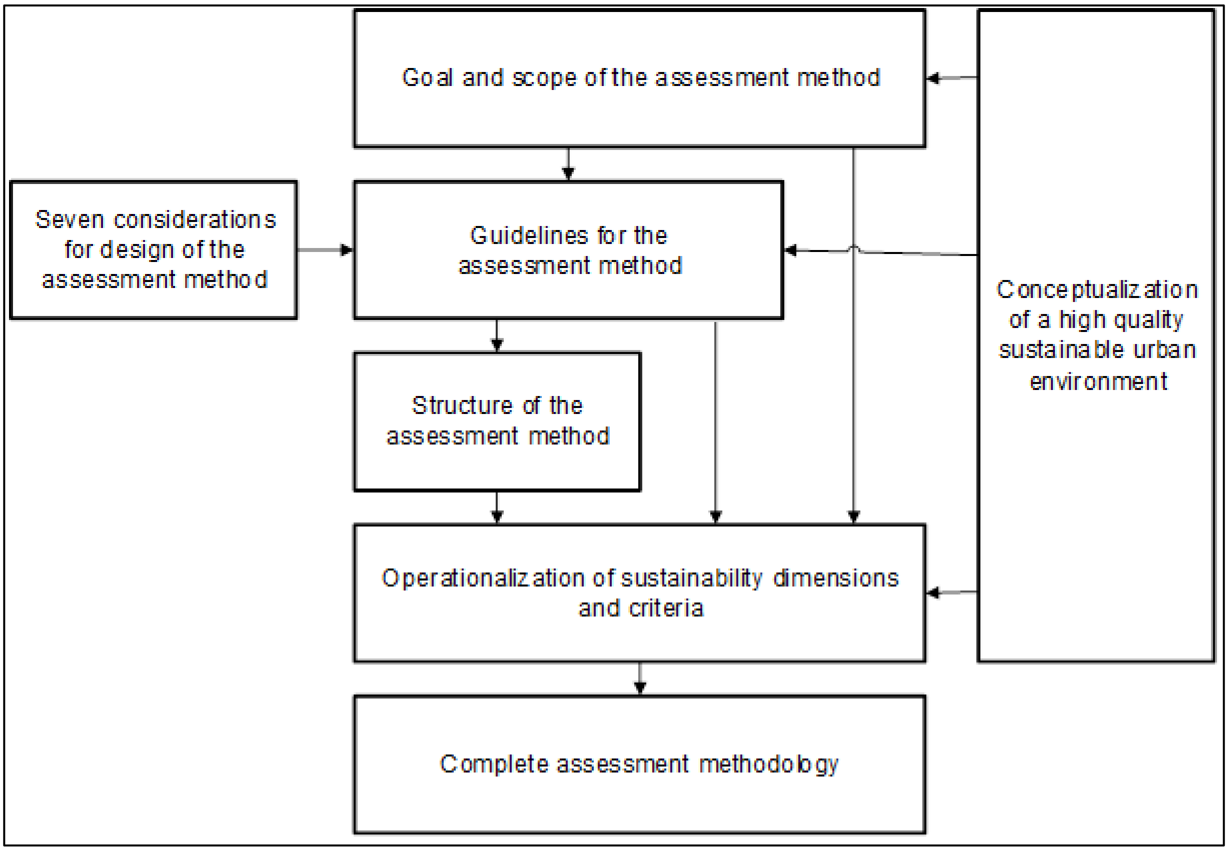

Figure 36 - Framework for the structured development of a neighborhood assessment method

It was demonstrated how the goal and scope of a to be developed assessment method may be translated in to a set of guidelines for indicator tool design by means of seven design considerations. How the developed guidelines might be applied in an actual assessment methodology was demonstrated using DPL as an example. Finally, it was explained how the process of operationalization translates the developed guidelines and selected structure of sustainability dimensions and criteria into an actual indicator tool.

Although the framework does provide a structured way of working for the development of indicator tools, the framework has only limited application when it comes to practical design decisions such as how operationalization should be executed, or what exactly the developed guidelines should be, given a certain goal and scope of a to be developed tool. These limitations are partly addressed by providing the conceptualization of a high quality sustainable urban environment as presented in chapter 3 of this report. The presented analysis in that chapter should assist tool developers in design decisions and criteria selection. Further inspiration for criteria selection and operationalization can be obtained by studying the various existing indicator tools as discussed in chapter 4. Nevertheless, practical application of the presented analyses in concert with the proposed framework remains a somewhat arbitrary process in which no single 'right' answer can be deduced. As such, although the framework does provide developers with a structured development method, the framework is unable to assist in specific design of an indicator assessment method.

6. Limitations of the presented research

The framework presented in this report was designed, based on sound knowledge of a high quality sustainable urban environment, as well as sound knowledge of indicator systems. As such, the validity of the framework can be defended, based on the foundations as laid out in chapters 2, 3, and 4 of this report. Furthermore, applicability of the framework was demonstrated in chapter 5 of this report.

However, the research in this report has not attempted to assess validity of the framework in an alternative way, other than with a demonstration of applicability. We suggest three ways in which validity of the framework might be verified. Initial verification of the framework might be done by means of an expert's assessment of the framework. This validation would be given form in a series of interviews, or may also take place in the form of a workshop.

A second method for assessment of validity of the framework would be by comparing the design and development process of a number of existing indicator systems to the development process as proposed by the framework. Differences between the framework and specific tool development processes may be cross-referenced with various other tool development tracks. Cross-referencing in such a way would allow researchers to determine is any noted difference are due to shortcomings of the proposed framework or due to flaws in the actual design and development tracks of the existing tools.

A final means for validation is by developing an actual tool by means of the proposed framework instead of limiting demonstration of applicability of the framework to an already existing tool. However, this would only determine specific validity of the framework, and not demonstrate general validity of the framework, i.e. that the framework would be suitable every time.

7. Conclusion

This chapter will present the conclusion of the work in this report in light of the formulated research goals and questions.

Goal of the study

This study set out to accomplish the following four goals:

- Provide a historical perspective of the phenomenon of urbanization;
- Define the concepts of urban quality and urban sustainability;
- Identify current and relevant knowledge regarding the measuring and monitoring of the quality and sustainability of the existing urban environment;
- Propose a conceptual framework by which a quality and sustainability assessment tool may be developed, specifically suited for the evaluation of the existing urban environment on a neighborhood scale.

The corresponding research questions where;

1. How is urban quality and urban sustainability conceptualized in the current scientific literature?
2. What methods are being discussed in current literature to systematically monitor the urban environment?
3. How can the answers to the previous two research questions be applied to develop an indicator assessment tool for the existing urban environment in a systematic and structured way?

Conceptualization of a high quality sustainable urban environment

Historically, city size has always been limited by food production capacity, transportation capacity, and social and technical organization. Rapid urban increase of the last decades has been due to an increase in energy capture per capita. Although urbanization is the cause of numerous problems, the theory of the city as ‘creative milieu’ suggests that the urban environment is the kind of environment that facilitates finding solutions to such challenges as they arise.

A high quality sustainable urban environment can be conceptualized by modelling the urban environment as an ecological system, and described using four characteristics.

- A sustainable urban environment must achieve bio-physical sustainability.
- A high quality urban environment must provide a high level of need satisfaction on the hierarchy of Maslow for the majority of its inhabitants.
- Urban quality in regards to sustainability is an urban environment that is flexible, resilient, and is therefore in a position to effectively implement and maintain increased sustainability measures.
- A high quality sustainable urban environment must maintain (and improve) upon the urban ecological space, its natural capital.

Monitoring of the urban environment

Operationalization of the four characteristics of a high quality sustainable urban environment can be done by means of systems of indicators. It was found that successful implementation of such methods is not only a technical challenge but also context dependent. Successful tools should be scientifically sound while addressing the following issues:

- Policy relevance: Who is going to use the tool?
- Readily implemented: How is the tool going to be used?
- Usable for decision making: Why is the tool going to be used?

Correct interpretation of the issues should lead to formulation of the goal and scope for an indicator assessment method.

Seven design considerations are relevant in the development of an indicator tool, dependent on the goal and scope of the tool. The points to be considered are:

- Sustainability coverage
- Inclusion of pre-requisites
- Adaptation to locality
- Scoring and weighting
- Participation
- Presentation of results
- Applicability

Framework for the development of a neighborhood assessment tool

A framework was constructed by which indicator assessment methods can be developed, suitable for quality and sustainability performance evaluation of the existing urban environment on a neighborhood scale level. The framework is presented in Figure 37.

Although the framework does not assist in specific design of indicator tools, the framework does provide a structural approach to the development of assessment methods. As such, application of the framework will provide developers with a basic platform from which to work and assist in keeping track of design decisions and considerations in a systematic way. This in turn will contribute to transparency of developed tools and coherency of assessment methods. Application of a structured development track will result in higher quality assessment methods overall. However, both experience in relevant fields of study and a sound knowledge base, part of which has been presented in chapters 2, 3 and 4 of this report, remains essential, to successfully develop indicator assessment tools.

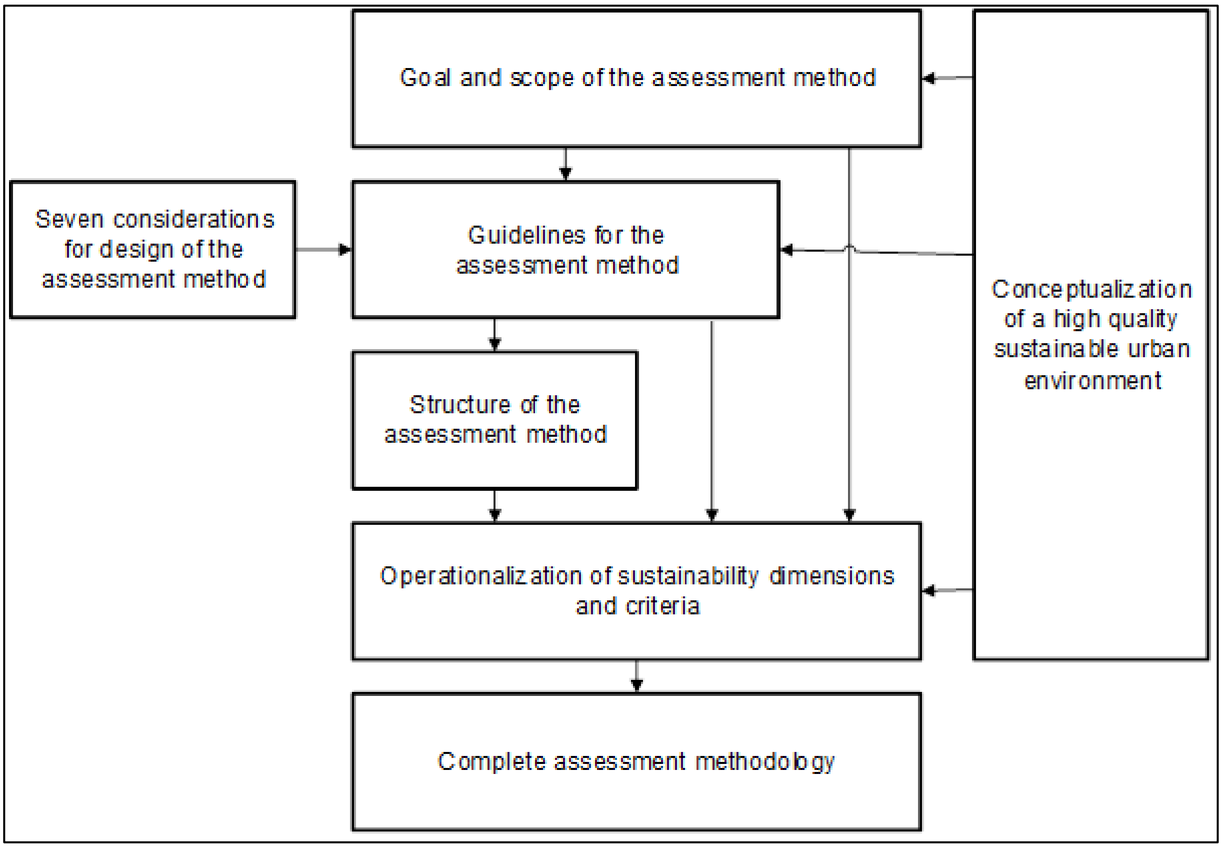

Figure 37 - Framework for the structured development of a neighborhood assessment method

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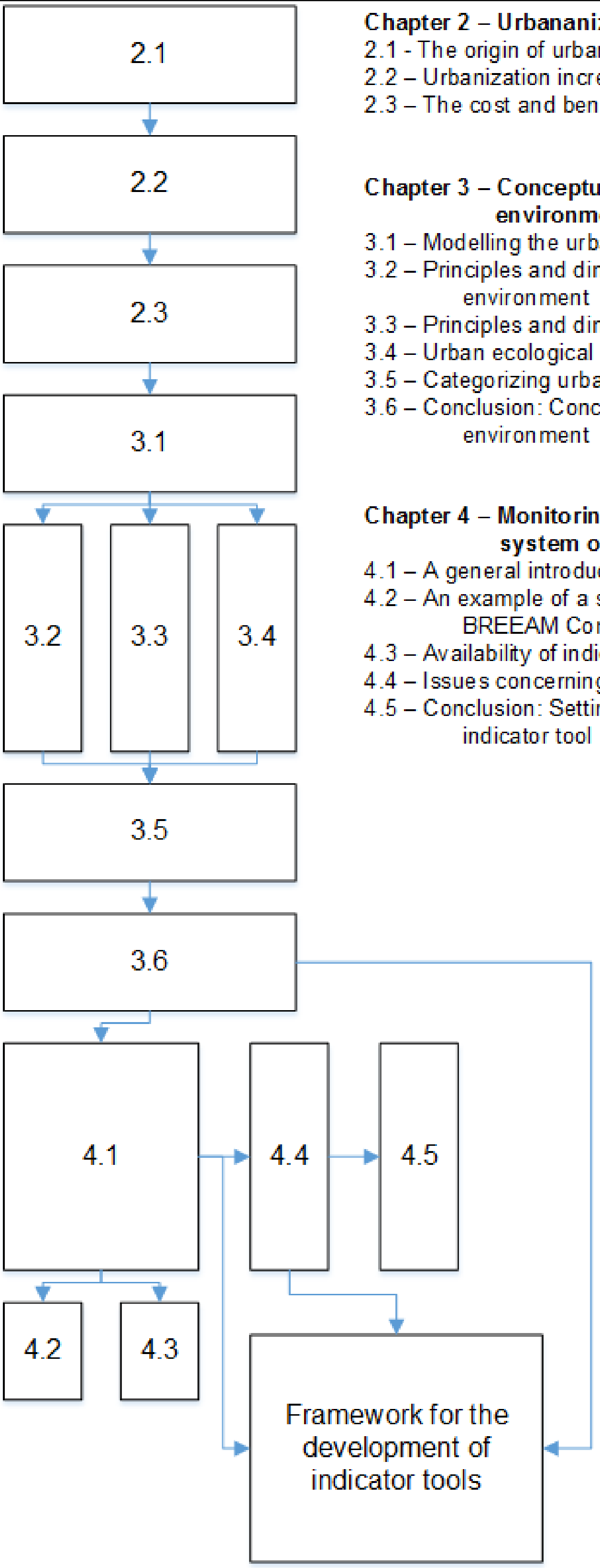
Appendices

Appendix A – Report structure leading to development of a framework



Chapter 2 – Urbananization in histroical perspective
2.1 - The origin of urbanization
2.2 – Urbanization increase
2.3 – The cost and benefit of urbanization

Chapter 3 – Conceptualization of a high quality sustainable urban environment
3.1 – Modelling the urban process
3.2 – Principles and dimensions of a biophysically sustainable urban environment
3.3 – Principles and dimensions of urban quality
3.4 – Urban ecological space
3.5 – Categorizing urban quality and sustainability dimensions
3.6 – Conclusion: Conceptualization of a high quality sustainable urban environment

Chapter 4 – Monitoring the urban environment by means of a system of indicators
4.1 – A general introduction to indicator tools
4.2 – An example of a sustainable neighborhood assessment method: BREEAM Communities
4.3 – Availability of indicator tools of ranging goal and scope
4.4 – Issues concerning current indicator tools
4.5 – Conclusion: Setting the foundation for a successful neighborhood indicator tool

Appendix B – Report structure covering the demonstration of the framework