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Analytical study on modeling of infrastructure for sustainable urban environment

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Abstract
In an increasingly urban planet, many cities and their inhabitants are facing multiple pressing threats within their borders, including heat stress, pollution and growing disconnection with the biosphere. Improving sustainability, resilience and livability in urban areas should be thus a major goal on the policy agenda, from local to global authorities. The operationalization of the ecosystem services framework, building on the concepts of 'green infrastructure' and 'nature-based solutions', is claimed by a mounting number of policy-makers, practitioners and scientists as the way forward to address many of these urban challenges. However, the extent to which urban green infrastructure can offer relevant solutions to these challenges are rarely considered in ecosystem service assessments, and therefore unknown to decision-makers. This dissertation critically examines the role and contribution of green infrastructure to cope with diverse urban challenges (with a focus on air pollution, greenhouse emissions, heat stress and opportunities for outdoor recreation) at different spatial scales. Building on the ecosystem services cascade model, an operational framework is proposed and applied across four original research chapters to inform planning and management decisions on the basis of the relationships between the green infrastructure's capacity to deliver ecosystem services, the actual provision or use of these services (flow), and the amount of services demanded by the urban population.

Keywords: sustainability, indicators, urban infrastructures, assessment, matrix

Introduction
The world population is predicted to rise from current seven to about nine billion by 2050. With global urbanisation trends being intact, scenarios predict that around 2/3 of the world population to live in cities 2050 (World Urbanization Prospect, 2011). Cities have a big environmental impact due to their demographic weight and the amount of natural resources they consume (Ranhagen, 2010). Worldwide, about 50 million people are moving into cities every year (Ranhagen & Groth, 2012) and with rapid movement into urban areas come sustainability issues. Therefore it is of great importance to, at an early stage, plan our future cities, existing as well as upcoming, in a sustainable manner. Cities cover less than 2 % of the earth's surface but consume 78 % of the energy and produce more than 60 % of the carbon dioxide in the world (UN Habitat, 2009). Ecocities is a commonly used expression when referring to sustainable urban development and the idea is to create a form of living pattern within the means of the environment. The objectives of Ecocities are to generate energy entirely through renewable sources without consuming more than it produces, to be able to assimilate the waste produced and to not be toxic to it or neighboring ecosystems. Furthermore the intentions are to stimulate economic growth, reduce poverty and create high population density thus offering better opportunities to public transport and recycling management (Ecocity Builders, 2011). Ecocities are a growing phenomenon and serve as an innovation-fostering platform for urban development worldwide. It is however, at present, several models and frameworks with varying interpretations of what criteria an Ecocity should incorporate. The models often tend to focus on specific aspects within a system or subsystems, instead of having a holistic point of view (Shafqat, 2014). The holistic point of view, or system thinking, has become important when discussing the interactions between social, economic and ecological aspects and the absence of such thinking is discussed by Richard Register, founder of Ecocity Builders, who claims that if only a part of a system is considered, sustainable development may support the longevity of an unsustainable path (Register, 2006). In 2011, in a global survey, 178 ecocity-profiled projects were presented. These are spread around the world but are mainly placed in Asia and Europe. Many of these are on-going projects where various models and frameworks are used (Joss, 2011). The fact that many projects still are in their planning and implementing phase implies that quite few have been evaluated in depth. Since that report was written, several projects have been initiated (one being Castleward, Derby, studied in Section 5.3.4) and in China only, around 250 Ecocities are planned (Stoltz & Shafqat, 2014).

Review of Literature
Climate Change
It is no longer just a scientific curiosity that climate change is occurring. As the Intergovernmental Panel on Climate Change states in its fifth Assessment Report: "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of green house gases have increased."

(IPCC, 2013) The increasing knowledge of human activities' impact on the environment in the continuous measurements of numerous areas provides alarming evidence (UNEP, 2010). The collected data provides information that forms clear patterns; the increase of GHGs is anthropogenic and is the only valid explanation of the last decades warming trends. It also states the likelihood of significant damage and irreversible consequences of accelerating emissions on global ecology (McGregor *et al*, 2013). The climate change and its impact on the ecology are hard to predict with high accuracy, but the scientific evidence indicate that the negative externalities are going to be larger the higher amount of GHGs that exists in the atmosphere. However, the circumstances of climate change may be avoided, or at least mitigated, if our dependency on hydrocarbon based energy systems is adjusted. The technology to do it is available, but must be applied aggressively and in close future (UNEP, 2010).

Sustainable Development

The theoretical concept for sustainable development was evolved during 1972-1992 when series of international conferences and collaborations were held (Drexhage & Murphy, 2010). During these years, several definitions were developed, some of them earning more recognition than others. They all originate from the same visionary paradigm, but differ among the opinions on what should be included and excluded.

Brundtland Commission

In the report Our Common Future by The World Commission on Environment and Development in 1987, sustainable development was defined as: "The development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The definition contains two key concepts; firstly the word "need" is particularly the essential needs of the world's poor to which priority should be evident. The other is the idea of limitations on the environment's ability to meet present and future needs (Brundtland. *et al*., 1987) [6].

The Ecological Footprint

Another definition of sustainability is the so-called ecological footprint. W. Rees and M. Wackernagel published the book Our Ecological Footprint: Reducing Human Impact on the Earth in 1996. They define the Ecological Footprint as: "A measure of 'load' imposed by a given population of nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharge by that population." This means that the ecological footprint for a city is represented by the total area that is essential for the continued existence of the city (Rees & Wackernagel, 1996).

The Three Spheres of Sustainability

Although the concepts and definitions of sustainable development differ in scope, they are all ways of approaching sustainability and share the fundamental thought of improving the environment and setting restrictions for human influence. Furthermore they are designed for governments, businesses and civil society to have premises to draw conclusions from. A summarised way of describing sustainability in a comprehensive manner is by introducing the three interdependent "spheres of sustainability" (see Figure 2) that are described in various chapters in Agenda 21†, these being; Ecological, Economic and Social sustainability (Rodriguez, *et al*, 2002). Ecological Sustainability: Agenda 21 states that energy supplied is used in ways that may not be sustained if overall demand continues to increase and technology remains constant. The conclusion is that energy sources need to be provided by renewable energy sources and used in a manner that does not exhaust natural resources (Rodriguez *et al*, 2002). Economic Sustainability: The economic sustainability is a complex term with lots of variables and interdependencies to take into account when describing it. However, in economic debate, sustainable development is often described as "the need to maintain a permanent income for humankind, generated from non-declining capital stocks." (Spangenberg, 2005) Social Sustainability: There is no clear definition on social sustainability. The definitions that exist tend to derive from discipline-specific criteria rather than being general (Weingaertner & Moberg, 2011). However, one definition, defined by sociologists Beate Littig and Erich Greissler, is: "Social sustainability is a quality of societies. It signifies the nature-society relationships, mediated by work, as well as relationships within the society. Social sustainability is given, if work within a society and the related institutional arrangements:

- Satisfy an extended set of human needs
- Are shaped in a way that nature and its reproductive capabilities are preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled." (Littig & Griessler, 2005)

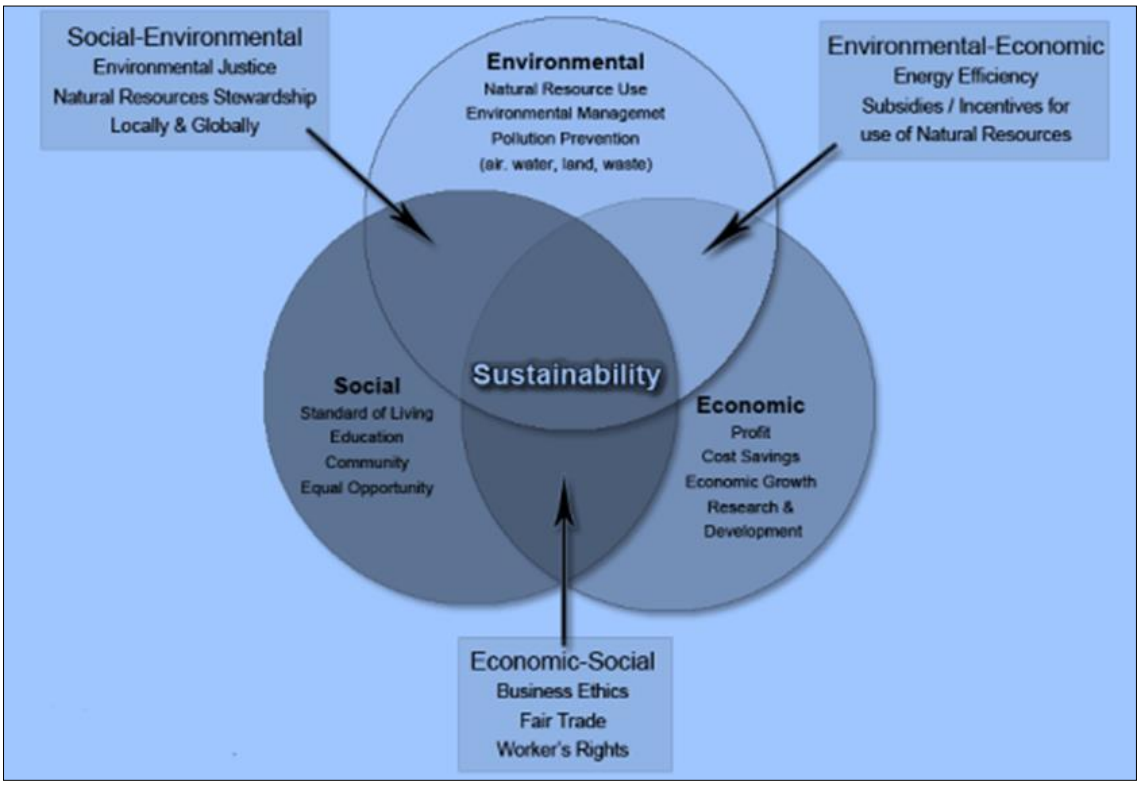

Fig 1: The Three Spheres of Sustainability (Rodriguez *et al*., 2002).

Urbanisation

Urbanisation has gone much faster and reached larger proportions between 1800 and 1950 than at any previous time in history (David, 1955) [9]. Since that paper was written in 1955 the urbanisation has continued and the urban population is expected to increase by 72 % by 2050, from 3,63 billion in 2011 to 6,25 billion in 2050. However, the rate of population growth in urban population is declining both in developed and less developed regions. Table 1 illustrates that between 1950 and 1970 the average annual growth rate was 2,98 % in developed regions and 4,04 % in less developed regions, the average annual rate of change between 2030 and 2050 is expected to be 0,29 % in developed regions and 1,34 % in less developed regions (World Urbanization Prospect, 2011).

Table 1: Urban populations by development group, selected periods, 1950-2050

	Population (billions)					Average annual growth rate (%)			
Year	1950	1970	2011	2030	2050	1950-1970	1970-2011	2011-2030	2030-2050
World	0,75	1,35	3,63	4,98	6,25	2,98	2,41	1,66	1,13
Developed regions	0,44	0,67	0,96	1,06	1,13	2,09	0,89	0,52	0,29
Less developed regions	0,30	0,68	2,67	3,92	5,12	4,04	3,33	2,02	1,34

With an expected world population year 2050 of 9,31 billion compared with expected urban world population of 6,25 billion, around 67 % of the world's population is expected to live in urban areas (World Urbanization Prospect, 2011).

Approximately 40 % of carbon emissions can directly be associated with residential and commercial buildings globally (McGregor *et al*. 2013). With an increase of urbanisation around the world it is acknowledged that minimising emissions associated with urban areas presents one of the most urgent challenges of the 21st century. For the current, existing built environment it is of great importance to strive to become more energy and resource sufficient, less pollutant, and more self-reliant in balancing needs and consumption if conditions for a healthy and enduring human civilisation on Earth is to be fulfilled (Ecocity Builders, 2011). What drives urbanisation is often described in terms of push and pull factors and are divided in economic, social and environmental aspects. Examples of economic push factors are agricultural failure, income variability, surplus labourers and loss of employment. Social push factors could be ethnic or other discrimination and displeasure with traditional lifestyle. Environmental push factors could be administrative displacement (e.g. in China, due to the construction of Three Gorges Dam, over a million people have been displaced (BBC, 2012), drought or flood, resource depletion, loss of land. These are factors that push or force people from the rural land to urban areas. Pull factors,

on the other hand, are attracting people to urban areas where economic pull factors could be job opportunities, prospects for higher income, improved housing and access to health care. Social pull factors could be educational opportunities, prospects of meeting new people, get closer to relatives and environmental pull factors could be a resource finding, e.g. mining findings (Gong, *et al*, 2012) [6].

Urban Development in a Broader Sustainability Perspective

Sustainable development is presented first and it is of interest since buildings affect both the environment and the people living in them. Buildings use energy when produced and during operation, which implies there are impacts both locally and trough the energy systems they depend on. While we are becoming more aware of the environmental and climate consequences of human development on our planet, the building sector is highlighted since there is a great potential of improvements for sustainable urban development.

Sustainable Development Theory

The concept of sustainable development is a general principle for the entire United Nations system and the international community. It was first in 1972 where Sweden took initiative to host the first environmental conference in the history of the UN, to discuss and to set the first milestone in the work for sustainable development and global environmental policies. The definition of sustainable development was introduced many years later by the American environmental scientists and author Lester Brown in 1981, to be spread internationally in 1987 when the World Commission on Environment and Development or also called the Brundtland commission used it in its report "Our common future". The Brundtland commission made the definition that sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (FN, hållbar utveckling 2015). Today sustainable development is a highly contested subject. One interpretation is that sustainable development is "Development that meets the needs of the present while safeguarding earth's life-support system, on which the welfare of current and future generations depends" (David Griggs *et al*., 2013). They thus argue that planetary stability must be integrated with United Nations targets to fight poverty and human well-being. The United Nations Rio+20 summit in Brazil in 2012 committed governments to launch a process to develop a set of Sustainable Development Goals (SDGs) built upon the Millennium Development Goals (MDGs) (United Nations, 2015). There were 17 SDGs defined and 163 targets that are integrated and balance the three dimensions of sustainable development which are: social, economic and environmental. The 11th goal is about sustainable cities and communities with the intention to make cities inclusive, resilient and sustainable (UN 2015, 2030 Agenda). Defining these goals was challenging since there could be conflict between individual goals such as energy provision and climate-change prevention. Griggs *et al*. (2013) show that it is possible by combining the MDGs with global environmental targets taken from science and existing international agreements and proposes six SDGs with provisional targets for 2030 (Griggs *et al*., 2013).

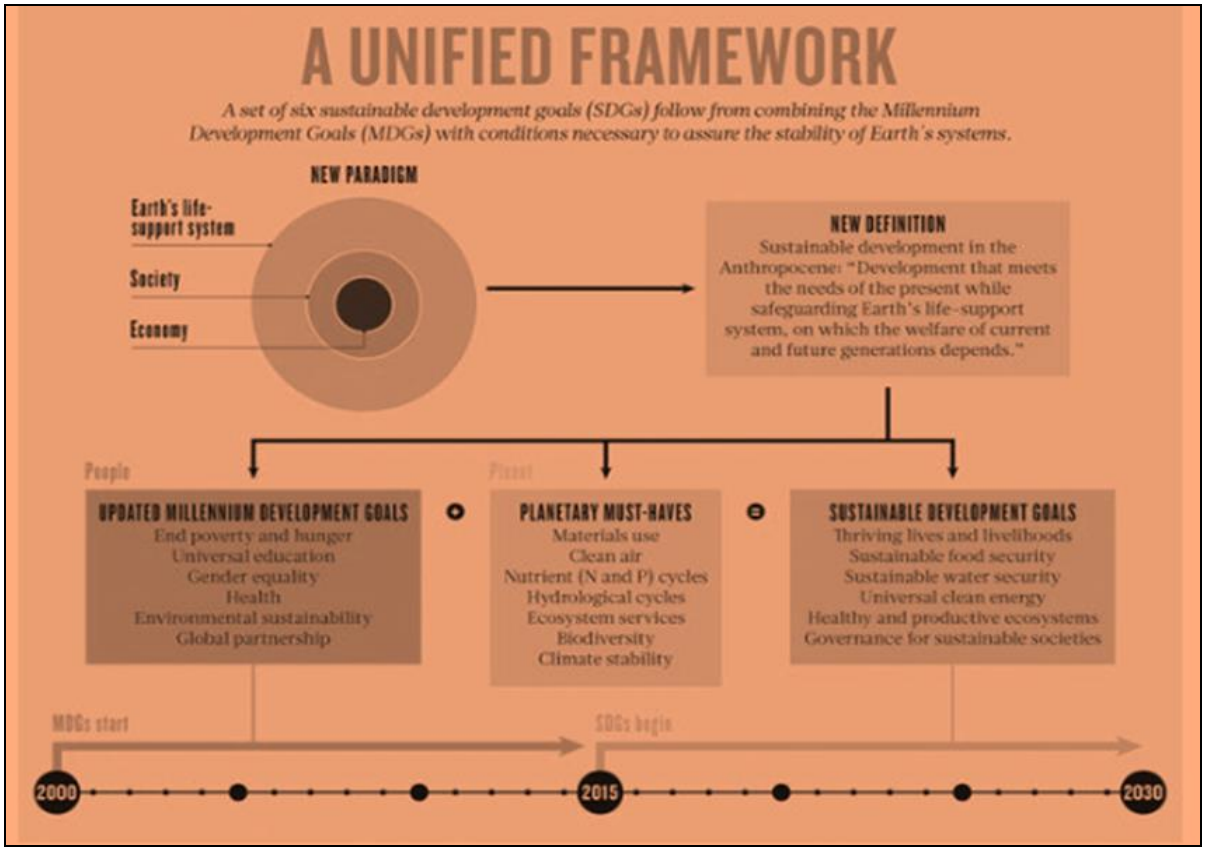

Fig 2: New Defined Sustainable Development Goals (Griggs *et al*., 2013).

An excerpt of the six sustainable development goals was made in order to explain the most relevant ones for this study. The goals presented were SDG 4, SDG 5 and SDG 6. SDG 4: Universal clean energy to have access to universal clean energy that minimizes local pollution and health impacts and mitigates global warming. The extension of this goal is to ensure at least a 50% probability of staying within 2˚ C warming, and aim for global greenhouse gas emissions to peak in 2015-2020. The goal also aims to decrease emissions by 3-5% per year until 2030 and to fall by 50-80% by 2050 (Griggs *et al*., 2013). SDG 5: Healthy and productive ecosystems. This goal combines the MDG environmental targets with the 2030 projections of the Aichi targets which are adopted by the Convention on Biological Diversity and it's about sustaining biodiversity and ecosystem services through better management, measurement, valuation, conservation and restoration. More specifically, the rate of extinction should not exceed ten times the natural background rate and at least 70% of species in any ecosystem and 70% of forests should be retained. To safeguard areas for biodiversity, fisheries and ecosystem services of marine and aquatic ecosystems (Griggs *et al*., 2013).

SDG 6: Governance for sustainable development goals the aim of this goal is to transform governance and institutions at all levels to address the other five sustainable development goals. The goal is based on MDG partnerships and incorporate environmental and social targets into global trade, investment and finance. The goal implies to eliminate subsidies on fossil fuels and policies that support unsustainable agricultural and fisheries practices by 2020. The product prices should take into account environmental and social impacts. National systems for monitoring, reporting and verification must be established for sustainable development goals and to open access to information and to secure decision making processes at all levels (Griggs *et al*., 2013).

Planetary Boundaries

There is growing evidence and real-world changes which convincingly show that humanity is driving global environmental changes. This is sometimes referred to as a new geological epoch called the Anthropocene (Griggs *et al*., 2013). Even though Earth has undergone many periods of significant environmental change, the environment of the planet has been unusually stable for the last 10 000 years (Rockström *et al*., 2009). This period of stability is known to geologists as the Holocene, and is the state under which ideal conditions apply for human civilizations to arise, develop and thrive. During this period, environmental change occurred naturally and the Earth's regulatory capacity preserved the conditions that enabled human development. Since the Industrial Revolution, the new era called the Anthropocene has arisen, in which human actions have become the main driving force of global environmental change. It is threatening the stability of the Earth by pushing the Earth system outside the stable environmental state of the Holocene with detrimental or even catastrophic consequences for large parts of the world. The rapidly growing reliance on fossil fuels and industrialized forms of agriculture have today reached a level that could damage the desirable Holocene state of the Earth. To meet the challenges of keeping the Earth in the desirable Holocene state, Rockström *et al*. (2009) proposed a framework based on "planetary boundaries" which defines a safe operating space for humanity with respect to the Earth system. These boundaries are associated with the planet's biophysical subsystems or processes. There were nine processes or subsystems found and each process has a threshold which can be defined as a critical value for one or more control variables, such as carbon dioxide concentration. Planetary boundaries are values for the control variables which are either at a "safe" distance from thresholds for those processes with evidence of threshold behavior, or at dangerous level for processes with no evidence for threshold. These results are uncertain since the true position of many thresholds is difficult to determine.

Conclusion

Strong leadership, a clear objective that is realistic given the budget, in combination with private and public participation and awareness all seems to be components to reach success. An easy-to-follow, descriptive framework may facilitate the process for planning, implementing and evaluating a city project but a close collaboration is essential to reach maximum potential.

Finally an effective economic resource use where decisions are made through the application of synergies, long-term perspective in mind and clear compromises so that conflict of interest is avoided are all parts of reaching ecological, economic and social sustainability in urban development.

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