Ecology of City: Levels and Components

Mindaugas Staniūnas[1*]

[1] *Vilnius Gediminas Technical University, Faculty of Environmental Engineering, Sauletekio ave. 11, LT-10223 Vilnius, Lithuania*

* *corresponding author: mindaugas.staniunas@vgtu.lt*

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Currently, more than half of the world's population live in urban areas and thus cities have become areas of intensive intersections of interests. As a major place for business, living and gathering cities (via citizens) create great pressure on nature; thus, cities can be treated as "battlefields" particularly considering citizens needs and environment. The article discusses current conception of "ecology of a city" at different scales while highlighting the need of a comprehensive approach. A two layer method is proposed, i. e., 1) global and 2) local stages according to which cities can be regarded as: 1) exporters of ecological burden and 2) internal producers of pollution. Although both processes are interrelated and intertwined separate responsible components of each layer are extracted: at a global level the main input from cities comes from energy and waste management sectors while at a local level the key problems are air pollution and noise. The article argues that ecological assessment necessary in urban planning should be done based on aforementioned scheme and calls for the development of it.

Keywords: *Urban ecology, level, component, assessment, impact.*

1. Introduction

Urban ecology is a phenomenon that gets lots of attention nowadays; it attracts developers and investors, politicians and citizens, manufacturers and users, stakeholders and professionals with a different interest. To some extent cities and environment or combination of both can be identified not only as a very common issue but at the same time virtually fashionable. "Urban", "ecology" and their derivatives are the labels often to be stuck on almost everything; for instance, urban clothing, music, environmentally friendly products, eco-driving, eco-districts, sustainability, etc. Urbanization studies constantly increases and although urbanization can be studied from different perspectives (e. g. social, economic) according to a recent research, the major subject categories are environmental sciences, ecology, environmental studies, etc. (Wang et al. 2012).

There are many drivers of the topic, but the key drivers promoting discussions are likely to be only two: 1) the rapid growth of the world population and 2) environmental changes it causes. Increasing population is a recent process that started in 1950, from then on (i. e. within 60 years) the world population more than doubled: the United Nations Populations Fund (UNFPA) reports that there are 7 billion people in the world and other billion is soon expected (UNFPA 2011). Furthermore, the world becomes more and more urban in character and cities are growing almost everywhere: more than half of the world's population lives in cities and in about 35 years additional 25% is expected (UNFPA 2011). This issue is especially vital in developed regions, for instance, in the European Union (EU) 68% of the total population already live in urban areas (Eurostat, 2011). Hence, assuming global trends it can be prognosticated that cities will remain the major places of living and human activities (Pickett et al. 2011).

Human activities inevitably cause disturbances of the environment - unnatural environmental series of changes are other actor that attracts majority of attention. This issue is a double-sided and can be analysed from two perspectives: on the one hand people are responsible for environmental changes (e. g. loss of biodiversity, land degradation) but on the other hand these environmental changes simultaneously affect people life (e. g. floods, UV radiation). World Health Organization (WHO) groups health impacts into three parts: 1) direct (e. g. water shortage, heat waves), 2) "ecosystem-mediated" (e. g. mental health, reduced food yields) and 3) indirect health impacts (e. g. population displacement conflict, inappropriate adaptation and mitigation) (WHO 2012). Having in mind that majority the world's population lives in cities all these procedures are extremely important in urban areas. Furthermore, in essence cities face similar environmental problems such as poor air quality, high levels of traffic and ambient noise, greenhouse gas emissions, generation of waste, etc. (EC 2006).

Basically, cities combine urban, environmental and social issues at the same time and in one place, hence, the concept of sustainability is touched. A complex issue and

numerous attempts to solve it has done unsuspected damage, which is well spotted out by MacGregor-Fors (2011): "synonyms of basic urban ecology terms have been used by researches to describe different environmental conditions, while similar conditions are often describes using diverse terms". As a result there are articles that are devoted solely for reviewing of various environmental indicators (Böhringer and Jochem 2007; Singh et al. 2009). Lastly, more than 20 years passed but sustainable development was not realized anywhere (Millennium Ecosystem Assessment 2005).

The article aims to describe "ecology of a city" from an urban planner's perspective: an urbanist is one of the key persons that are responsible for urban development, hence, future of a city. However, the article aims to consider solely about "ecology of a city" and thus firstly it seeks to analyse what is a difference between sustainability in general and its ecological "ingredient". Secondly, it tries to sort city's ecology in accordance with impact it has on the environment. Finally, an aggregated scheme for understanding of city's ecology is proposed.

2. Sustainability vs. Ecology

Already has been mentioned that sustainable development has not been realized anywhere (Millennium Ecosystem Assessment, 2005) logically one can assume that the same situation occurs with all its compounds, i. e. economy, society and ecology and thus that means that there is no possible solution. A model that works in practice does not exist so it is impossible to find it. However, the question is not unresolvable – the solution does exist because of crucial difference between sustainability in general and its compounds separately.

Such statement requires further explanation and a comprehensive context. Speaking about sustainability in general and its constantly failing implementation in practice, one can hypothesize that it occurs due to the nature of a process, i. e. its flexibility. That means that sustainability is not a fixed and final result, which once reached will last forever. Regularly new issues and problems arise echoing a normal-life set of series of actions (e. g. environmental conditions, human needs, political systems, etc.) which continually develops. That is to say that what was right and important yesterday may not be valid and essential today. Furthermore, in a real world dynamics of processes are strengthened and accelerated by large sustainability's concept and thus the problems that arise cannot be answered right away. For instance, if emission (pollution) of greenhouse gases were stabilized today, concentration of carbon dioxide (CO_2) in the atmosphere (it is crucial for global environmental changes) would stabilize only after 100-300 years and a sea level rise due to melting of glaciers would last for thousand years (Aresta 2010; IPCC, 2007a). The same lagging is common to other sustainability components, for example, if in Libya investments in education, drinking water infrastructure, etc. were made after changes in politics everything has to be started over again.

Therefore, in practice a delay is an integral part of sustainable development; it is a constant process occurring continuously over a period of time and thus perpetual alterations have to be done (Fig. 1 upper curve). And exactly at this point, i. e. the action of correcting something, sustainability in general is different from its separate elements. It is extremely well noticeable if environmental issue is considered. Cogitating about environment specialists highlight irreversibility, i. e. in the real world an absolute environmental limit exists, which once crossed leads into changes that cannot be undone or altered. For instance, currently such situation occurs with some plant/animal species that are put on the edge of extinction. A finite result is essentially different from dynamical and flexible process of sustainability: when the limit is reached any contra-actions become meaningless and negotiations are already impossible (Fig. 1 lower curve). This fact is neatly presented by Albert Arnold Gore (a former Vice President of the United States and Democratic Party presidential candidate; Nobel Peace Prize Laureate in 2007) in a documentary "An Inconvenient Truth". The scene (77 minute) shows scales that balances two different things: on the one side there are gold bars and on the other side – the entire planet. At that very moment A. Gore ponders that such weighting is a false choice for two reasons from which the first is – "if we don't have a planet…" Hence, the major aim considering ecological compound of sustainability is not to "lose", i. e. do not over abuse the planet and do not exceed the critical level. This task remains within any field of actions and urban planning is not an exception, it is a subcomponent of a larger global ecology.

The meaning of the word "ecology" was significantly modified since its introduction in the XIX century: it changed from an exceptionally biological science to a much broader field incorporating other areas of natural and non-natural sciences (Wittig 2009) and thus currently four different meanings of the term can be recognised (Haila and Levins 1992).

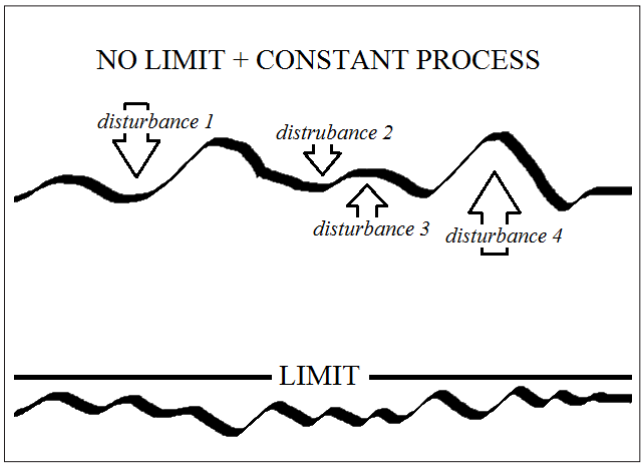

Fig. 1. *Sustainability vs. ecology*

The concept "urban ecology" is a compound of two terms and as a result it is a complex concept that has different dimensions. In essence urban ecology is an applied science (Niemelä, Kotze and Yli-Pelkonen 2009) and this branch of ecology can be used on two different levels depending on the standpoint (Alberti et al. 2003; Wittig 2009,

Pickett et al. 2011). The first – natural science level – describes ecosystems in cities in terms of biophysical, ecological, etc. processes, i. e. area of biology that is concerned with cities. The second one – political and urban planning level – describes issues of urban design programmes, planning the environmental amenities of cities for people and mitigation of negative environmental impacts of cities.

Strictly speaking the main object of urban ecology is urban ecosystems, which are densely populated and has a high degree of built structures and infrastructure, thus it does not incorporate the remote areas affected by energy and material transformations generated in urban core (Pickett *et al*., 2011; Wittig, 2009). Ecological scholars (Alberti *et al.* 2003, Grimm et al. 2000, McDonnell *et al*. 2009) have been highlighting the shortcomings of traditional (narrow) conception of urban ecology for some time already: basically, current studies analyses how urban territories alter natural environment, what influence these territories have on particular species (animals, birds, plants, etc.) or compare urban ecosystems with suburban. In other words, it means that humans (i. e. citizens) a priori are treated as "something" that hovers somewhere above, is exceptional, not typical, single and having minimal contact. This conception is very narrow-minded because reality is clearly different: in fact, the cities are mostly affected by citizens but not somebody else (e. g. birds, frogs, trees, etc.). Ecologists even call the cities "a human dominated ecosystem" (Vitousek et al. 1997). Therefore, in a broader sense urban ecology includes less densely populated areas (for instance, sparsely settled villages) and integrates various areas of science, political decisions and planning that improve living conditions but simultaneously alter environment (Alberti et al. 2003, Wittig 2009, Pickett et al. 2011). And although from traditional standpoint the boundaries of urban ecosystems are often set by administrative units in practice many occurring processes extend beyond these boundaries: they affect other areas directly as well as remotely (Alberti et al. 2003, Pickett *et al*. 2011). Hence, if artificial limitation on issue is not the aim, then urban ecology (or ecology of cities) has to be evaluated comprehensively, in a full context, dealing with all aspects and especially paying attention to citizens – a propulsive element of the system.

Following the above mentioned logic it seems useful to take glance at the most important ecological problems at a global scale. Probably in a global ecological context it will become clear what is "input" of cities and what is important for cities. That will present compounds of the broader understanding, when cities are treated as 1) an outer, external player as well as discusses about 2) what and how affects city's "inner" ecology, i. e. what is substantial for a city not globally but locally, within its boundary. It is important to highlight that the paper aims at urban planning issues but not at biology field.

3. "Inner" and "Outer" Ecology

Identification of the world's worst ecological issue is not very hard; however, with one exception. Even the worst and obvious problems can be criticized and diminished depending on one's point of view, that is to say that everything is relative. Therefore, a double-checking practice was used in this article and a statement was assessed two times: firstly, it is checked if the statement is endorsed by the experts in general and, secondly, it is checked if there are any facts that validate it. If the majority of experts agree upon the phenomenon and there are facts proving the accuracy – then it is believed that the phenomenon is correct. Such an assessment is not officially binding, but author believes it is the most proper one.

Hence, the world's greatest ecological problem (in general it is acknowledged and facts exist) is global climate change, frequently described as a threat to humanity's future (IPCC, 2007b, McMichael et al. 2003, UNEP, UNICEF, WHO, 2002, Parry, 2007). In general, climate change itself is not dangerous: it is resonant turn of events that is so much important, for instance, temperature extremes, droughts, floods, etc. and in recent decades majority of problems are caused by global warming. Global warming or to be more precise increasing concentration of greenhouse gases is caused by many anthropogenic activities, e. g. industrial processes or farming. Various activities are responsible for different gases; however, in the world as well as in the European Union the biggest share of emission belongs to carbon dioxide and methane. In 2004 carbon dioxide amounted up to 77% and methane – 14% of the world's total greenhouse gas emission; in 2009 in the EU (EU-27) 80% of emission belonged to carbon dioxide and 9% to methane (Barker et al. 2007, UNFCC, 2009). At a global scale from 1970 until 2004 (only in 34 years) emission of carbon dioxide and methane increased by 80% and 40% respectively (Barker et al. 2007).

The above mentioned information should help reflecting upon the raised question: "what is "input" of cities"? In general, it is clear that an answer must be connected with greenhouse gas emission particularly its management (decline). In other words it should answer how cities can mitigate its input to global warming. However, if practical implementation is a target then it is required to know who, where and why generates emission.

Although the Intergovernmental Panel on Climate Change (IPCC) indicates a few sectors that are extremely responsible for greenhouse gas emission, for instance, energy, industrial processes or waste management, a unique global understanding does not exist: various international organizations give slightly different descriptions. Basically, the difference lies in aggregation process because various operations can be counted in several sectors, for example, transport can be assigned to energy sector but on the other hand taking into account today's importance and intensity of the sector it can be treated individually. However, in accordance with the reports of the most influential international organizations (e. g. IPCC, OECD, UN), the most responsible sector contributing to global greenhouse gas emission is energy sector. The same situation is in the EU where energy sector is responsible for 80% of the total greenhouse gas emission, further goes agriculture (10%), industrial processes (7%), waste management (3%) and solvents (UNFCCC, 2009).

Therefore, "outer" ecology of a city is nothing more but greenhouse gas emission, which is generated in order to fulfil city's energy demand and thus the objective of "outer"

ecology is city's energy management. Carbon dioxide plus methane are two gases that make 89% of the total EU emission; hence, management of these gases must get the biggest attention.

Tracing that the major polluter in cities is energy sector is not very hard – statistical information shows a strong gap between energy and other sectors. A recorded gap has other advantage: being so big it clearly indicates the key problem; nevertheless, it is hard to indicate other (second, third, etc.) responsible activities. It is to say that further top-bottom approach will not give clear and unambiguous results: difference between emissions wanes, sectorial dependency fades, etc. However, seeking for solutions applicable to practice a common concept and unified action plan are required. It must be highlighted that speaking about ecological simulation of cities such unanimous indicators have not existed for a very long time. Slightly more than a decade ago in 1999 the EU started an international project – the European Common Indicators initiative – which focused on helping local authorities monitor environmental sustainability of its urban environment (Tarzia 2003). Such practical aim required moderate number of indicators and thus only the key ones were selected. The final set consists of merely 10 indicators, which in principle are applicable to any city of the Union. Last but not least important is the fact that initiative tried to involve as much participants as possible starting from experts, governmental, EU and national institutions and finishing with public. The Organisation for Economic Co-operation and Development (OECD) also supports the idea of minimizing the number of indicators and gives a felicitous explanation: a shorter list with basic indicators is easier understandable for public and thus ensures a clear and tight cooperation between local authority and citizens (OECD 2008). Actually, "easier understandable" means literally "understandable" because in most cases people simply do not know about city's future, they are unable to read the information.

The above mentioned list consists of the following indicators: 1) citizen satisfaction with the local community, 2) local contribution to global climatic change, 3) local mobility and passenger transportation, 4) availability of local public open areas and services, 5) quality of local ambient air, 6) children's journey's to and from school, 7) sustainable management of the local authority and local business, 8) noise pollution, 9) sustainable land use and 10) products promoting sustainability (EC, 2012). The aim of the initiative was vast, cumulative and touching sustainability issue as a whole; hence, not all indicators are concerned with ecology. Exceptional relations with climate change has only one indicator (i. e. the second: local contribution to global climatic change) and it validates the earlier discussed logical sequence. A special methodology was developed for indicators and thus following the description of the second indicator 4 key stones can be selected. They will benefit to the further development of city's ecology.

First and one of the most important tasks is determining a city's "input", contribution to global climatic changes. In this particular case we speak about identification of further (going after energy sector) elements that remained unclear before. The methodology confirms that many sectors are responsible for greenhouse gas emission; however "the energy sector, together with the waste management sector, represent the main focus for action by the local authority" (EC 2012), i. e. it is affirmed that considering ecology of city there are only two – the energy and the waste management – sectors that are really important. The waste management sector is responsible for 3% of the total emission but even 3/4 of the gases come from landfills (UNFCCC, 2009) and thus this is a sector, which is much easier and cheaper to manage than, for instance, industrial processes. Moreover, it is worth noting that implementing Kyoto's flexible mechanisms the most common ones are related to these two sectors: the lion's share of projects (about 67%) are in energy industries while the second place (about 14%) is taken by waste handling and disposal (UNFCCC 2012).

Secondly, the methodology quite explicitly discloses the energy sector, i. e. analyses its elements. The energy sector is particularly different if compared to the waste management sector because it consists of many parts (e. g. energy generation and demand in industry, households, transportation, etc.) and thus to determine these single elements would be a time consuming procedure. Furthermore, a threat exist that in such case integrity will be lost and it would be very unfavourable for urban planning procedures. Upholding entirety of the concept the methodology suggests disaggregation of the energy sector based on consumption analysis; hence, there are 4 parts: 1) residential, 2) commercial, 3) industrial and 4) transportation.

Thirdly, if cities are being analysed in a context of global ecological issues one crucial fact becomes evident: any city occupies a limited plot of land, i. e. it has administrative boundaries; ecological problems behave totally differently as they do not "know" boundaries. Therefore, the methodology proposes substitution of geographical/ administrative limitations with responsibility and thus two new phrases arise: "debt emissions" and "credit emissions". For instance, a city consumes energy for street lighting and although the energy comes from a power plant that is far away from the city this emissions should be assigned to the city. It is its demand and requirement that is to say its "debt emissions". The model works vice versa, for example, if a big city has waste incineration plant it can "import" wastes from other cities and gain "credits". The final assessment should involve three stages: 1) emission that is generated within geographical/administrative boundary plus 2) "debt emissions" and minus 3) "credit emission".

Lastly, the question about values arises. In general, when referring to boundaries absolute values are being used; however, the methodology stresses the importance of comparative values. Normally lots of actions and procedures that occur in a city are not manageable with common urban planning tools, for instance, wind turbines contribute to the use of renewables, but they can be erected only on sites that favour adequate wind. Hence, the methodology proposes to use absolute and comparative values simultaneously and additionally monitor alteration of emissions.

Further discussing about city's ecological framework it is useful to remember a question that was raised at the outset, i. e. what is important for cities and why cities

are important? In essence the question consists of two elements: inner and outer impact. The above mentioned indicator supplements the main "culprit" (i. e. the energy sector) with the waste sector and explains the second part of the question enough comprehensively. That means that in cities these two sectors are mainly responsible for global warming or to be more precise not the sectors themselves but the emissions. The phrase "enough comprehensively" means that speaking about ecological issues at global scale extremely precise result is not necessary (and probably not possible) and proper management of only two sectors could help achieving good results. However, the first part of a question is still not answered, i. e. what is important for cities, for their inner life and processes?

There is a huge difference between "inner" and "outer" city life: things important in a city can be completely non-essential at a global scale and vice versa. To illustrate such independence two examples are discussed. For instance, a main street of a city with 100000 citizens runs through living districts. Due to constant and intensive traffic flow people that live near that street are exposed to a high level of noise and have poor air quality. That means that living conditions in these districts are dangerous and habitants suffer from disturbances. However, at a global scale greenhouse gas emission from a traffic fleet of 100000 cars (a car for each inhabitant) is statistically insignificant. As already has been mentioned this model works on contrary too. For example, due to global warming droughts become more frequent in Africa and thus it becomes harder to get an access to drinking water, water shortage occurs. Meanwhile a huge problem in Africa (locally) this issue is physically not perceptible for citizens of industrialized countries and thus is not important for most of them. Citizens of the USA or the EU can simply open water tap whenever they need water or worse – to buy a bottle of water.

It can be stated that each city has individual character and its processes are somewhat unique. Nevertheless, if practical implementation is the aim then a common understanding and action plan are the necessary conditions. Hence, the major problems of cities inner processes have to be identified and grouped. The European Common Indicators initiative has two indicators that could have relations with ecology, but this time with "inner" ecology. These indicators are the fifth and eighth: quality of local ambient air and noise pollution.

Quality of ambient air as well as global warming is determined by particular hazardous pollutants, but in this case the consequences are extremely well visible at a local level, e. g. asthma, decline of working capability, heart diseases, etc. It is investigated that the main pollutants of ambient air in European cities are mainly linked with combustion processes in 1) mobility, 2) heating systems and 3) industries (European Commission, 2012). The methodology of the fifth indicator indicates 7 major pollutants, which are following: 1) sulphur dioxide, 2) nitrogen dioxide, 3) carbon monoxide, 4) volatile organic compounds, 5) particulate matter, 6) ozone and 7) lead.

Noise pollution as well as quality of ambient air is directly related to human health. Furthermore, it is a local problem that occurs only in particular places. The eighth indicator describes noise pollution as unwanted or harmful sound created by human activities; sound can be generated from traffic (i. e. road, rail, air) and from sites of industrial activity (European Commission, 2012). It is interesting to note that here we see the same mixture of energy and industry activities, the key difference is that here local impact is more severe.

4. Results and Discussion

The results are expressed graphically in Fig. 2. An important moment is a direction of arrows: it indicates direction of city's ecological impact, which can be outer (arrow points up) or inner (arrows point in). Capital letters indicate components of city's ecology: 1) greenhouse gases, 2) quality of ambient air and 3) noise pollution.

The main shortcoming of a model is limited "inner" ecology because it basically regards only citizens welfare and ignores the rest, i. e. flora and fauna. However, the principle idea of the model is a critical threshold or limit and thus it allows some losses, but only some. In this particular case "some" means that these losses are not crucial to the specific population and do not cause irreversible changes. Therefore, exceeding of the critical level is not allowed.

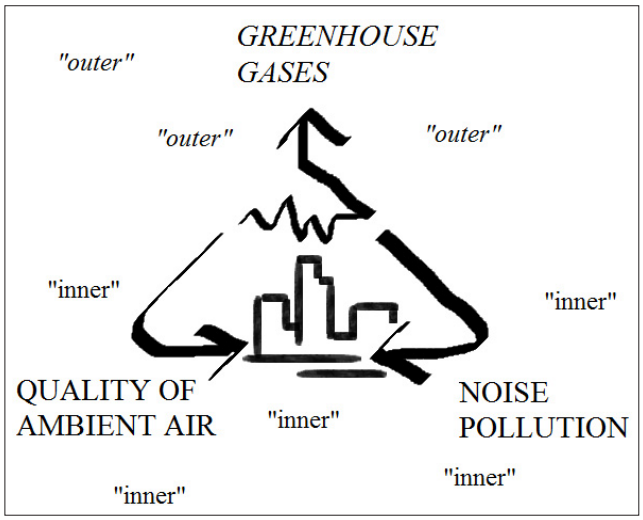

Fig. 2. *Ecology of city*

5. Conclusions

Although ecology of city is a very common phrase nowadays it yet lacks unification and thus to develop a city's development plan that would consider ecological aspect is a tricky question. Ecological element is one of the sustainability's compounds but it is in essence different: it has limits while sustainability is a dynamic process. Taking into account the major environmental problems and international initiatives it has been proposed to set only two stages of city's ecology. The results are expressed graphically in Fig. 2 and differ according to the impact they have on the surroundings. If the impact is oriented outwards then it is regarded as city's "outer" ecology otherwise it is "inner" ecology (i. e. it has impact within administrative boundaries). "Outer" ecology is concerned with emissions

of greenhouse gases, basically, from energy and waste management sectors and "inner" ecology is related with two components: ambient air and noise pollution.

The above mentioned levels and components form a framework for city's ecology according to which ecological assessment so necessary in urban planning should be done. However, this job still requires further elaboration. (I. Gurauskiene, 2006, Eco-design methodology for electrical and electronic equipment industry).

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Mindaugas STANIŪNAS – assistant at Vilnius Gediminas Technical University, Faculty of Environmental Engineering.
Main research area: urban planning and ecology.
Address: Vilnius Gediminas Technical University, Faculty of Environmental Engineering, Sauletekio ave. 11, LT-10223 Vilnius, Lithuania.
Tel.: +370 5 274 4719
E-mail: *mindaugas.staniunas@vgtu.lt*