Construction versus Environment: Their Reciprocal Impact During Different Stages of Construction and Maintenance

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Abstract

Is it possible to avoid ecological impacts on built environment instead of battling with the consequences? This paper is focused on mutual impact of environment and building from the viewpoint of selecting the appropriate management strategy. In order to create a built environment harmonizing with the natural world, it is important to manage related information in an adequate way. Systematic approach and methods of simulation modelling enable to assess environmental impacts and establish the balanced interactions between: building and environment; construction process and environment; maintenance and environment etc. The damage of buildings and infrastructure caused by disasters has caught the attention of the world. Even in such geographically calm region as Estonia there have been incidents that compel us to pay more attention to the environmental issues while designing and maintaining buildings. One of the aims of European and Asian Infrastructure Advantage (EURASIA) research project is to find out whether and how the prevention of ecological risks enables to minimize such damage.

Keywords: Built environment, reciprocal environmental impact, environmental risks.

1. Introduction

Building is an essential expression of human activity. Since the beginning of the society humans have shaped the environment by creating, changing and removing various structures. The built environment is a multi-faceted concept, including the natural, artificial, cultural, socioeconomic, political etc. components. It can be stated that buildings can not exist without the environment, but natural environment can exist without buildings as it has been for millions of years before the man. Thus natural background is a basis and human activity has to fit delicately into it. In a long run nature impacted by built environment is changing dramatically.

The assessable influence of each building is localized in various parts of environment into considerably smaller spheres of impact, and the impact outside these boundaries can be considered as marginal. We can find both objective and subjective components of impact, with the latter not being any less significant – e.g. in case of building the architectural attractiveness.

The environment with all its components in turn exerts reciprocal impact on the buildings. In the present paper the following questions are discussed:

- the phases of the life span of a building;
- the reciprocal impacts of the building and environment;
- why and how should the reciprocal impacts be identified;
- possibility of foreseeing and preventing harmful impacts.

The aim of the paper is to provide the starting points for future research in the field, enabling to develop the strategy of assessing the impacts at a more detailed level.

2. Reciprocal Impacts of Building and Environment

2.1 Phases of Life Span

It is possible to differentiate between various phases of building activity as: idea generation and specification; data collecting; initial task and drafting; preliminary assessment; design and planning; construction process; maintenance; the phase of depletion of the lifecycle of the building and its demolition; and finally utilization of waste or the spontaneous utilization of the building in the environment. The length of building life span might be very different as it depends on numerous factors, including both, the environment where it is erected and decisions made in the idea generating and planning or maintenance phase. Some buildings have a life span of hundreds and thousands of years in the form of extensions and rebuilding or architectural memorials, another building can complete its cycle already after a few years of its existence due to being erected in a discord with the environment or other human decisions, incidents, accidents etc. There are always numerous buildings in different phases of life span in the same observed area.

2.2 Classification of Reciprocal Impacts

The reciprocal impacts of the building and environment can be identified throughout all the phases of life span, concentrating most from the phase of construction process to the utilization phase as the impact in the design stage of a building is relatively small. On the other hand, the influence of waste dispersed after utilization has been less researched as well as the impact of the expired but un-utilized buildings. Therefore we have to treat the influence of the building and the activity inside it separately. In this paper general aspects and the reciprocal impacts of the building and environment, depending on the life span of the structure are differentiated as:

- the impact of the building on the environment;
- the impact of environment on the building.

The building affects the environment mainly by: placement, time of being located in an environment, the architectural and structural design, building materials used, suitability of the intended use, size and capacity indicators, building technology and intensity of construction, duration of construction period, intensity of usage, preparedness to environmental changes, labour intensity ratio of utilization etc. The harmful impacts and danger factors of the building on the environment include for instance: delays of planning and increase of cost; the logistic load of building, high energy and resource cost, disorders in waste and recycling arrangements, hazardous building materials, unsuitability of architectural decisions, high energy cost at the maintenance stage, leaking of heat, noise level, irresponsibility of energy saving, demolition waste, etc.

Environment (as a natural, artificial, cultural and socioeconomic entirety) influences the buildings by the location conditions, duration of stay in the environment, human activity, cultural and socioeconomic and political aspects of the environment. The location conditions and harmony of intended use of building and its parameters are here most vital. Out of natural harmful impacts for example the climatic circumstances not corresponding with the qualities of the building can influence the latter as well as the temperature, rainfall, winds, ground conditions, the groundwater level and its quality, fluctuation of water bodies, tides, seismic activity, harmful gas (radon, methane etc.), UV-radiation etc. Besides the artificial factors of the environment and impacts caused by human activity also other buildings, their insufficient infrastructure or energy supply, water, atmospheric and surface pollution etc. can prove to be detrimental to the observed building. The regarded building can become disharmonious with the cultural and socioeconomic and political components of the environment for example by cultural background, evaluations, convictions, human skills, expectations and needs, economic, social and technical conditions and opportunities, as well as strategic and political decisions and choices of individuals or human groups. Impact chains of various range, complexity and intensity result from the reciprocal impacts of the building and the environment, where the cumulating impacts and indirect reaction can be indirectly noticed (Environmental overview, 2005 [5]).

2.3 Significance of Reciprocal Impacts by Phases of Life Span

The extent and intensity of reciprocal impacts come from the properties of the building and environment. As the environment is a background to the building, we can state broadly that environmental impact on the building is the stronger and more intense, in a bigger disharmony the building has been erected with the surrounding environment. In case some essential environmental aspects of the building have been ignored at design, construction process or in maintenance phase, a contradiction will emerge at a definite moment of life span, exerting negative impact on the building and eventually on human health and welfare. The time of appearance of the harmful factor, its severity, possibility to discard it, cost and expediency will be an issue. In course of assessing the extent of the impact by different factors and stages of life span, the following indicators could be used:

- extent of impact,
- duration of impact;
- intensity of impact,
- significance of impact.

In purpose to create a comprehensive picture of the significance of different impacts of the building and to discover the harmful and aggressive impacts at the initial stage of assessment, the rating system has been suggested in the framework of the present research. In table 1 an example of rating sheet for sample building is presented. The impacts are graded as follows:

- "4" – severe influence;
- "3" – high influence;
- "2" – medium influence;
- "1" – low influence;
- "0" – no influence.

Table 1: Significance of Reciprocal Impacts of Building and Environment by stages of life span

Description of Impacts		Significance of Impact											
		Design Stage			Construction Process			Maintenance			Utilization		
		Extent	Duration	Intensity	Extent	Duration	Intensity	Extent	Duration	Intensity	Extent	Duration	Intensity
a) Impact of the building on the environment													
1.	Labour consumption	1	2	3	3	3	4	3	4	4	2	2	1
2.	Logistic load	1	1	1	3	3	3	4	4	4	2	2	2
3.	Construction waste	0	0	0	3	4	2	1	2	2	0	0	0
4.	Demolition waste	0	0	0	1	2	2	2	2	1	2	3	4
5.	Architectural unsuitability	0	0	0	1	2	2	2	4	4	0	0	0
6.	Structural unsuitability	0	0	0	1	3	2	3	4	4	2	2	2
7.	Waste of maintenance	0	0	0	0	0	0	4	4	4	2	2	2
8.	Energy consumption	1	2	4	3	4	4	3	4	4	2	1	1
b) Impact of environment on the building													
1.	Influence of climate	0	0	0	3	2	4	3	2	4	3	2	1
2.	Temperature fluctuations	1	1	1	3	2	3	3	2	3	1	1	1
3.	Wind force	0	0	0	3	2	4	2	2	4	1	1	1
4.	Ground conditions	0	0	0	4	2	4	1	1	1	2	2	2
5.	Groundwater level	0	0	0	1	1	1	4	4	4	0	0	0
6.	Stability of water bodies	0	0	0	2	2	3	3	3	3	2	2	2
7.	Tides	0	0	0	0	0	0	0	0	0	0	0	0
8.	Seismicity	0	0	0	1	1	1	1	1	1	0	0	0
9.	Harmful gases	0	0	0	1	2	2	3	2	2	0	0	0
10.	Impact of other buildings	3	4	4	3	4	4	3	4	4	3	4	4
11.	Faults of infrastructure	3	4	4	2	3	3	4	4	4	0	0	0
12.	Shortage of energy supply	3	4	4	4	4	4	4	4	4	1	1	1
13.	Environmental pollution	0	0	0	1	1	1	3	3	3	2	2	2

14.	Availability of resources	2	3	3	3	2	2	3	2	2	2	2	4
15.	Social discords	0	0	0	1	1	1	4	2	4	1	1	1
16.	Financial limitations	4	4	4	4	4	4	3	4	4	4	4	4
17.	Subjective shortcomings	3	2	4	2	3	2	1	2	1	0	0	0

3. Assessment of Reciprocal Environmental Impacts

3.1 Environmental Impact and Environmental Risk

Environmental impact is usually described as an impact that can accompany human activity and is expressed by changes in natural environment, cultural heritage or assets. According to its common definition environmental risk is a risk where the environment and through that human health, welfare and/or assets are endangered (Morris and Therivel, 2001 [7], Peterson, 2006 [8] and Põder, 2006 [10]. The regular definition of environmental impacts has been focused first of all to the impact proceeding from the building on the environment, leaving the reciprocal influence of the environment on the building as secondary. The definitions contain also no references to the impact division proceeding from the life span of the building.

In purpose to find information regarding the influence of the intended building on the environment and minimize the risks, most countries have adopted a routine to conduct a mandatory preliminary assessment; which can be done within legal framework and legislation, usually called the **assessment of environmental impacts (AEI)**. Focused on the dangers proceeding primarily from the building to the environment, typically the threats proceeding from the environment to the building are handled secondarily and only when it is required by legal instructions. In the present paper the AEI is considered as integral process, including reciprocal (mutual) impact assessment, i.e. assessment of impact exerted by building and *vice versa*, considering the life span of the building. The voluntary assessment of impact for research and knowledge obtaining purposes is also very important besides the legislative due.

3.2 Purpose of AEI (Assessment of Environmental Impact)

In purpose to determine a broader goal of AEI a systematic method should be applied to that. The framework of assessment existing in most countries at a legal level provides good assumptions to it. According to the concept of AEI the assessment is an administrative-regulating measure, characterized by its systematic, reproducible and interdisciplinary nature with a goal to provide the interested parties with competent information of environmental impact of all realistic versions and suggest the optimal solution. Assessment of environmental risk is thereby an activity used to assess the probability and severity of negative impacts proceeding from a source of risk, being exerted to a certain part of environment or by a part of environment to human health or property, as described by Põder, 2006 [10]

In a broader approach of environmental impact and risk assessment it is necessary that impact assessment is meant on one hand map the impacts and their ranges for research purpose (value of knowledge) and on the other hand to help the decision makers, so that all the interested parties might value the results of decisions (practical value). Therefore AEI should have planning and promoting the long term sustainable development by the life span phases of the building as its next essential goal (Peterson, 2006 [8] and Estonian National Strategy of Sustainable Development [6]).

3.3 Method and Procedure of AEI

It is possible to assess the reciprocal impacts and rate actual alternatives by method including the following activities:

- choosing possible alternative versions for AEI;
- identifying the reciprocal environmental impacts of chosen alternative versions;
- ranking the priority sequence of impacts;
- rating the extent, intensity, duration and significance of the impacts by phases of life span as shown in table 1;
- estimating the quantitative values of specific impacts or providing their qualitative assessments;
- analysing the results, selecting actual alternatives of construction and maintenance of the building,
- suggesting on sustainable development, risk level, priorities of impacts etc.

In most countries environmental impact assessment is regulated by legally set principles. Mutually complemented and reckoned environmental, planning and building laws and codes provide a general framework for AEI. Assessment of environmental impact is generally related to two procedures differing in their content and form as depicted in Peterson, 2006 [8] and Estonian National Strategy on Sustainable Development [6]:

- applying and issuance of activity licences (building permits, waste permits, pollution permits, water-special usage permits) and
- composing and validation of strategic documentation (plans, strategies, projects).

The possibilities of AEI on various levels are illustrated in Figure 1.

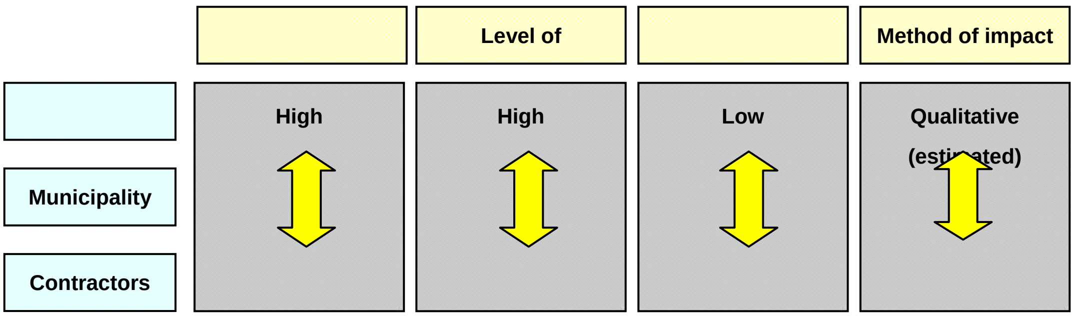

Figure 1: Possibilities of Environmental Impact Assessment on Various Levels

Different countries use different approaches to decide about the need for AEI. For example in Estonia the general conditions of a need for environmental research are provided by legislation as Building Act [7], Act of Environmental Impact Assessment and Environmental Management System [11] and Planning Act [12]. The most significant condition of environmental impact assessment procedure is that it has to be open to public. A special process has been foreseen for disclosure. Disclosure brings forth full preparation of planned activity, its strengths and weaknesses and enables people to track the decisions influencing their living quality. The involvement of the general public improves also the quality of assessment. In order to engage the general public a suitable set of methods excluding information noise and excessive conflicts in accordance with legally set boundaries will be selected.

The assessment of strategic impact should be differentiated from assessment of environmental impact. Environmental risk assessment is a separate measure in addition to regular AEI. Based on current investigation and findings of Peterson, 2006 [8], Põder, 2006 [10] and Veinla, 2006 [13] the present paper provides an outline of basic AEI procedure as shown in Figure 2.

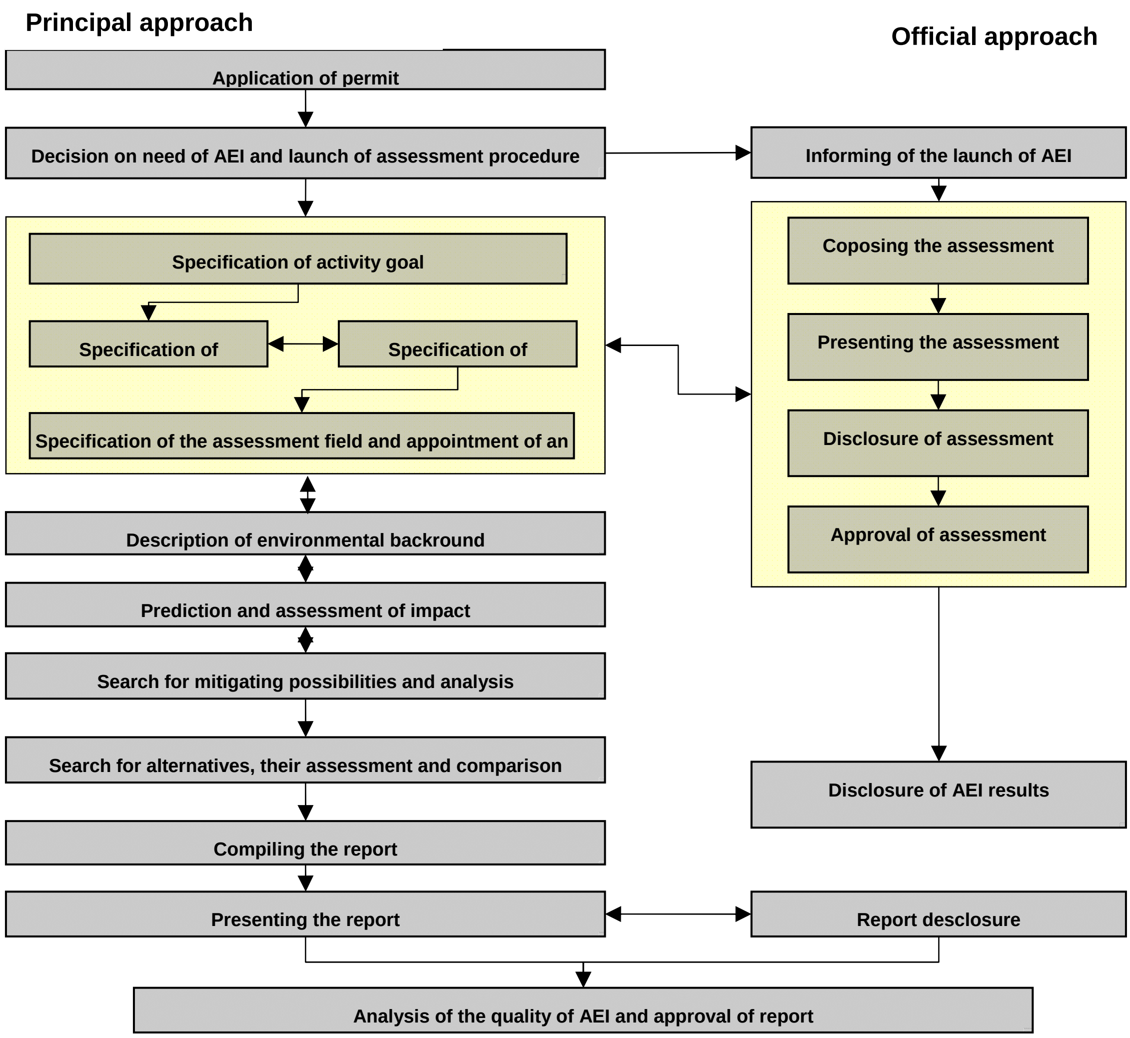

Figure 2: Procedure of Assessment of Environmental Impact (AEI)

3.4 Assessment of Indirect Impact

In the process of AEI one should always consider that besides the direct reciprocal impact the assumed indirect impact has to be specified also. The indirect impact of activity is formed by relational reason-result chains between different parts of environment. They can be manifested far from the immediate locality. The indirect impact can develop as a consequence of direct influences in the long run and it could hardly be predicted during the regular AEI. Impact chain is one of the resources to determine the indirect and cumulative impact. The whole environmental impact is completely specified when all the impact spheres, presumable direct impacts and chains leading to indirect impacts and according results have been ascertained. The field of impact can often be found only at the end of AEI when modelling regarding the distribution of pollutants, water regime alteration, range of changes in socioeconomic environment etc. have been made. The description of environmental background will be taken as the base point of simulation modelling and its parameters will provide an overview on the condition of the influenced object (environment or building) before the beginning of the process. Different environmental aspects and parameters will be described by appointing relevant indicators for the assessment process.

In order to determine the parameters special studies, environmental audit or expertise will be carried out or they will be derived from preliminary analogue projects or case studies. In principle the environmental impact can be assessed both as a by qualitative expert assessment or by mathematic quantitative simulation. The selection of prediction method depends on technical possibilities and nature of impact. The goal and the object will be specified during the simulation process. For modelling a sample model of ecosystem or building will be prepared, where the boundaries of the system, system elements and reciprocal relations of the elements, external factors and exchange processes with the other systems will be specified.

When the elements and relations of the system are determined, the next stage in creating the model includes the description of relations by mathematical equations, proceeding from the law of conservation and balance of systems. The simulation model consists from mutually related sub modules where the motion of critical process is defined. The solutions will be found as analytical or numerical answers, for example by appointing the network of calculation points to the system under investigation. The calculation ratios are used to characterize the intensity and run of the researched processes, using the approximate relations describing the processes. The values of model ratios will be required at calibration where the calculation results will coincide with the measurements. Calibration has to cover ignorance, revealing the limitation of the theoretical principles of the model.

4. Planning Strategy of Sustainable Development

4.1 AEI as a Method for Planning Sustainable Development

Following the AEI it is important to estimate the quality of completed assessment by checking if the evaluation of impacts met all the set terms. After picking up the reciprocal environmental impacts identified as a calculation model the next step will be to consider the mentioned impacts in every possible way at planning the activity in sustainable development. The respective activity in its initial stage is called spatial planning. According to Estonian National Strategy on Sustainable Development [6] and Development Plan of Estonian Country Life [4], the spatial planning is a long term planning of three-dimensional development, co-ordinating and integrating development plans of different fields, considering the tendencies and needs of the economic, social, cultural and natural environment. The goal of sustainable development can be defined also as understanding that our present actions would not endanger the welfare of posterity. Sustainable development is not a goal in itself, but a measure to balance the activity of mankind with its surroundings in a longer run (Sustainable Development Program of Estonian Fund of Nature: [12]).

The arrangement of strategic impacts in the framework of general planning is an essential starting-point of planning the strategy of sustainable development. The goal of preliminary and general planning is to determine the main tendencies and conditions of the territorial development of the area, prepare the underlying basis for detailed planning to set the land use and building terms. Assessment of strategic impacts creates thereby assumptions for the best application of the most vital environmental factor – the suitable location already in the general planning stage when the likely locations of buildings of specific purpose will be specified. Based on general plans it is possible to proceed to a more detailed level in the stage of detailed plans and to the resulting issuance of building and activity permits, by constituting the required conditions for sustainable development.

4.2 Management Strategy for Prediction of Harmful Impacts

The transition from general to the individual (more detailed) and considering the impacts of every activity should be an integral part of the management strategy in the course of assembling a general plan. Management strategy includes the developed systematic activities proceeding from a national policy covering the stages of from general to detailed plans, followed by building permit issuance and concluding with deliberate methods at construction, maintenance and utilization of the building in harmony with environmental sustainability. AEI must always precede the planning in accordance with the degree of detail. Building site management should be conducted according to the impacts of various phases of life span; considering the traffic scheme, infrastructure and engineering supplies. Various alternative versions from the viewpoint of the most suitable environmental solution should be reckoned over when selecting the architectural and structural design.

The natural factor of the environment is one of the strongest and most valid factors besides the artificial, social and economic components. The natural component of the environment deserves separate regard, as in spite of hidden agents the impact might be unpredicted and destructive, posing a direct hazard to a man as well as to the nature itself. In order to avoid the harmful effects exerted by natural environment the impacts must be gradually mapped, considering the functional and constructive alternatives of the building and searching for mitigating possibilities already before the planning of the structure or in the course of construction process. The dangers related to existing structures can be minimized to a certain extent by identifying potential impacts in various stages of life span and planning according protection measures. In case of the most vital aspect ─ the unsuitable location of the building, it must be considered that there might not be so many options at human residential areas to accommodate the desired building.

Natural impacts can be divided into general and local ones. The strongest general impacts are the climate, temperature, precipitation, winds, seismic activity and level of water bodies and its fluctuation etc. The local and weaker impacts are the impact of groundwater, ground conditions, harmful gases etc. Neglect of general impacts can cause large scale, fatal results to humans; in case of local impacts the effect will be more localized. For example the analysis of major natural disasters occurring in the past years all over the world (hurricanes, earthquakes, tsunamis, floods) and their destructive impact has revealed that often there has been insufficient knowledge in the planning of the buildings as probability of endangering hazard or destructive impact of cumulating events was not considered. According to Atwater et al, 2005 [1] it might be possible to forecast both ─ the most devastating disaster of the new millennium ─ the tsunami of South-East Asia in 2005 and the hurricane Katrina, that destroyed New Orleans. These resulted in thousands of victims and a very big economic and environmental damage by dangerous substances proceeding from buildings and ruins. One conclusion of the analysis of the disasters stated that even relatively realistic danger visions obtained by the time spent on predicting the impacts and fiscal means were unable to make the general public react beforehand in a sufficiently active manner with the present management system, economic model and level of responsibility due to traditions, decision making habits, political demands and support of the law between the short term (aggressive, planned to increase progressively) and long term (stable, sustainable) developmental strategy. The key words are versatile awareness of the participants in a decision making mechanism and willingness, resourcefulness and adequacy at searching the mitigating measures, fiscal policy reckoning with priorities and juridical framework sets guaranteeing the certainty of decision making.

As example from Estonia the establishment of buildings on the shore of coastal areas during the real estate boom of 2005-2006 can be brought; which is not negative in itself if all the reciprocal impacts would be considered. The environment influences the buildings located at shore areas mainly by stable water level, probable tides due to gales and wind, as well as the structure and stability of ground. Seismic activity and impact of precipitation have thereby been relatively small. Yet there are developmental areas in Estonia, where short term business interests hold a priority at development and where the dwelling houses and the infrastructure supporting them are established literally to shallow marshland, to the same height with the sea level. The rise of sea level that occurred in Pärnu, Estonia during the January storms in 2005, resulting in major water damage to buildings and facilities located even within a kilometre from the coastal area, let alone the damage to the property and indirect damage to nature, testifies of the insufficiency of danger prevention measures. According to Soomere, 2005 [11] the tsunami caused by earthquake will be also in future improbable in Estonia, but there might be a rise of water level again due to atmospheric phenomena. Therefore building to coastal areas is always an activity of enhanced risk level, that should be preceded already in the planning stage by a versatile analysis of strategic impacts to specify the suitability of building areas at coastal and shore areas and conduct the preliminary assessment of the adequacy of possible mitigation measures. When building to coastal areas one should particularly reckon with relevant foundation, increasing the water and wind resistance of structures, volume-spatial project solutions considering also the probable rise of water level, architecturally used water and wind resistant building materials and improved technologies, as well as the resistance of infrastructure and communications to the impacts of water and wind. The respective research requires more support and recognition, which enables to use derived knowledge already in the design and construction stage of the buildings. This demand nationally regulated policy and increased awareness of decision makers, but also programs and training at the local authority level.

5. Conclusions

The present paper provides a basic overview on the stages of the building life span, reciprocal impacts of the environment and building, their distribution in lifecycle stages, identification of impacts and structure of procedures.

It is important to acknowledge that the environmental impacts can be foreseen already on the planning stage of the building. The following gaps in common assessment of environmental impacts are revealed on the basis of current study:

- as a rule environmental impact assessment involves only the phase of construction process and maintenance, while design and utilization phase of construction life span are almost ignored;
- while impact of the building is usually accepted the reciprocal impact of environment is considered to be insignificant;
- the peculiarity of reciprocal environmental impacts by different phases of life span has not earned deserving attention.

In purpose to continue this research besides fulfilling the gaps mentioned above a list of the reciprocal environmental impacts should be established and a simulation model reflecting the dependences of the sets of reciprocal impacts created.

Knowing the direct and indirect impacts and impact chains it is possible to plan the built environment fitting into nature so that in each planning and building stage reciprocal discords will be minimized. Thereby it has become evident that only increasing the awareness of the general public and decision makers and creating the system of nationally recognized rules, balanced management methods and financing policy, can lead to a result where environmental impacts will be considered at planning stage in purpose to ensure a sustainable development.

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