



## INTEGRATED QUALITY AND SUSTAINABILITY ASSESSMENT IN CONSTRUCTION: A CONCEPTUAL MODEL

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**Abstract.** In today's world, the definition of quality has been extended to more comprehensive level, which also comprises sustainable performance. The paper systematically builds an integrated model that includes quality as well as sustainable performance of the built environment and accompanying construction processes. This model for the "Integrated Quality and Sustainability Performance Assessment in Construction" presents a three-level arrangement, namely: the structure, process/project, and construction product.

We propose a holistic sustainability assessment methodology based on the authors' previous research work for structures. The strict implementation of quality and environmental management systems in the participating organisations and in the whole construction project guarantees quality and environmental performance at project/process level. On the construction product level, we complement the existing requirement of providing a statement of conformity for each product of the structure with the Environmental Product Declaration (EPD) for all construction products. We use the Life Cycle Assessment (LCA) methodology to obtain the EPDs for specific construction products; in this way, we can evaluate their environmental impacts throughout the life cycle of a product or structure. On the structure level, a model for the integrated sustainability and quality assessment, which was previously proposed by the authors, is employed. Integration of all three levels ensures that the desired plateau of quality and sustainability performance is achieved for structures, processes and products.

In the present version, the model is tailored to the specific features of buildings, and the sustainability aspect is limited to the environmental performance. An investigation of measures required to implement the proposed model into practice shows that clients have a major influence upon the procurement rules. Consequently, the targeted audience of potential users is that of clients procuring buildings.

**Keywords:** construction project, building, construction product, quality, sustainability, QMS, EMS, life cycle assessment, environmental product declaration.

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## 1. Introduction

Today's most widely accepted definition of quality proposed by Crosby (1979) as "conformance to requirements" is also incorporated into the present standard dealing with quality ISO 9001 (2008). However, the concept of quality in construction is rather involved, because it demands the fulfilment of both explicit and implicit requirements/needs, and it needs to be assessed from the viewpoint of the product (structure) or the process (construction project). In addition, one should be aware that quality has a multidisciplinary nature; therefore, different approaches may be required for its analysis and treatment.

1. To assess quality **for the whole structure**, the basic requirements defined already by Vitruvius: "*utilitas, firmitas, venustas*" (function, structure/durability, and aesthetics) (O'Gorman 1998) have to be fulfilled. In addition to these requirements, various stakeholders may have additional ones. Here, it should be kept in mind that a structure is used for a longer period of time, and that there is a great probability that these requirements may be changed over time, especially during the operation and maintenance stage.

Conformance to the specified requirements for the structure is ensured by a) designing the structure in accordance to appropriate rules (EN Eurocodes 2010); b) using construction products (that are permanently built in the structure during the construction process) that conform to the relevant specifications (Council Directive 89/106 1989); and c) proper execution of construction work conforming to relevant standards.

2. Quality has to be considered also from **the construction project** (and associated processes) point of view, where all-conventional construction project goals (i.e. quality, budget and scope) (Fig. 1) (Agenda 21 ... 1999) have to be met, ensuring that the needs of all project participants are fulfilled.

3. Quality assurance of **construction products** has to be dealt with separately by using procedures required by the Council Directive 89/106 (1989) and associated European product standards.

### 1.1. Extending the concept of quality to sustainability performance

In the contemporary world, the awareness of the importance of sustainable development is increasing ever since a global framework for environmental activities was provided first by the so-called Brundtland report (Our common future ... 1987). Consequently, the implementation of principles of sustainable development is today one of the fundamental goals of EU policies. Since 1987, the concept of sustainable development has been extended from purely environmental concerns to also include those related to social and economic issues. Today, these three pillars - environmental, social and economic, are considered to have equal importance.

This is especially valid for the construction sector, where the built environment is its generalized product, and which has large impacts in all three areas of sustainability. Worldwide, estimates indicate that approximately 40% of the total energy consumed, 40% of all the waste produced, and 40% of all virgin raw materials consumed are associated with the construction sector. In today's world, only the total production of petrous materials has larger consumption of water than that of construction (Šelih 2007). In addition, built environment provides infrastructure for humans and substantially contributes to the quality of human life.

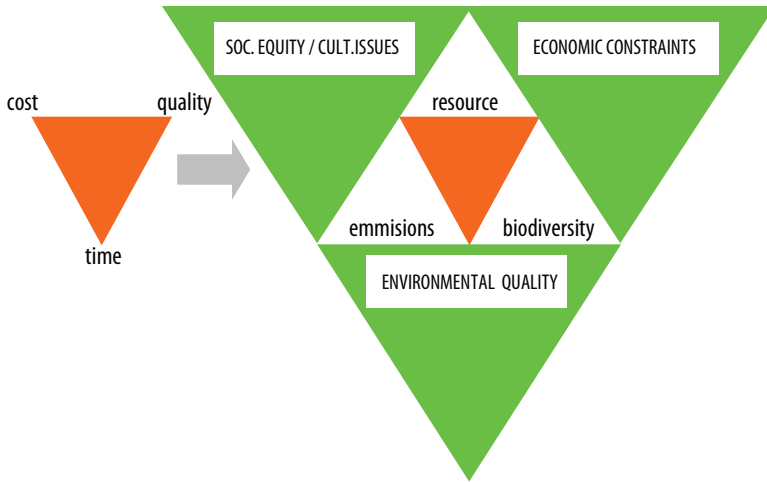


Fig. 1. Extending the conventional construction project goals to the sustainability field (Agenda 21 ... 1999)

The environmental and social effects of the built environment are clearly large. Economics influences construction by demanding for cost efficient buildings and other structures, where cost efficacy is required in construction as well as in the operation and maintenance stages.

In construction, it is apparent that in addition to achieving conformity to the requirements related to the quality of the built environment, sustainable development should be a primary goal; and in this regard, the scope of quality should encompass sustainability. Therefore, a sustainable component needs to complement the goals of the traditional construction project, as presented in Fig. 1 (Agenda 21 ... 1999).

## 1.2. Scope of the paper

Despite the extensive body of research already carried out in this field, there are no explicit guidelines how to conduct sustainability assessment for structures, construction project and various associated processes (taking place in the design and execution stage) and construction products.

Under these circumstances, the two-prone purpose of this paper is: 1) to review the existing standardized procedures currently used to ensure quality of structures, and 2) to extend the concept of quality to the sustainable performance for construction. Due to the complexity of the current definition of sustainability, the scope of this paper is limited to the environmental performance on construction product and construction process level. Therefore, based on the conducted review, we propose an integrated model (**Integrated Quality and Sustainability Performance Assessment in Construction Model**) for the implementation of principles of sustainability performance and quality in construction. The model involves three key levels encountered in construction:

- the structure (building or engineering works, i.e. the final product),
- the project/processes, and
- the construction product.

The sustainability performance receives particular attention on all levels, with special emphasis on the last one - the construction product level.

The simple, yet comprehensive, approach employed in the proposed model will allow the practical implementation of the outstanding environmental issues in the construction field. We designed the model to target predominantly those clients that desire to achieve higher overall environmental performance of the procured buildings. In the field of public procurement, it can also be incorporated in the relevant legislature and accompanying guidelines.

## **2. Quality assessment in construction**

### **2.1. Structure level**

In what concerns the structure, all parties must ensure that quality is satisfied in all stages of its life cycle: inception, design, execution, operation and maintenance, and end-of-life. If the life cycle approach is not used, the structure does not meet the requirements of all stakeholders involved, and consequently the perception, rightly or not, is that structure fails in what quality is concerned (Leonovič, Kaševskaja 2007); under these circumstances, and on an environmental perspective, it is possible the occurrence of burdens, which may shift from one stage to another, when deciding on different options (Braune *et al.* 2007).

Quality of the structure depends first on the successful identification of the requirements provided by various stakeholders: clients, developers, owners, users, tenants, public (represented in various ways, e.g. NGOs), and (finally yet importantly) governmental bodies. In addition, these governmental bodies provide additional requirements and grant permissions for the planned structure at various stages of the construction project, from the conceptual design to the final approval for the structure. The project brief, as the first document where the basic requirements of the client are collected, should be prepared with great care, and it should deal with the planned structure from different perspectives. All stakeholders should receive this document, and they should express clearly and unambiguously the additional requirements and changes that may have. In the pre-tendering stage, the client (or his agent) should ensure the requirements (scope, quality level, timeframe, and costs) are fully understood by the potential tenderers (Hellard 1993).

To ensure conformance to client's requirements, during the design stage, the design documents and drawings have to comply with the project brief at every level (Enshassi *et al.* 2008).

The Council Directive 89/106 (1989), which provides the legal framework for the quality of structures in the European Union, demands the structure meets six essential requirements: 1. Mechanical resistance and stability, 2. Safety in case of fire, 3. Hygiene, health and environment, 4. Safety in use, 5. Protection of noise, and 6. Energy economy and heat retention. These requirements are applicable throughout the life cycle of the structure, design, construction, operation and maintenance as well as demolition. The directive states the requirements are met when a) construction products that are built in the structure comply with the relevant European product standards, and b) appropriate procedures are used in the design and execution stage.

Design of structures must comply with the series of Eurocode standards (EN Eurocodes 2010); therefore, appropriate standards of these series must be used for different loads and structural materials.

Once the construction starts, quality of the structure is ensured by following the structure specifications and accompanying documentation. Full adherence to national standards for the execution of structures is required at the execution stage. At the European level, quality of execution for reinforced concrete and steel structures is ensured by complying with the European standards EN 13670 (2009) and EN 1090-1, 2 (2008), respectively. Rules for the execution of other types of structures (composite, timber, masonry) are dealt with by relevant Eurocodes.

In addition to following the above mentioned design rules, quality of the design process and execution in most European countries is assured by specifying the requirements for the qualifications of the design and construction site engineer. These requirements refer predominantly to the education (level and field of study), years of experience and full membership of the Engineers' Chamber of Slovenia.

## **2.2. The project / process level**

In order to create a structure or a construction product, the intervening parties execute a large number of processes converting the inputs into outputs; the different organizations and the project itself carry these processes (Schieg 2009). In both cases, they need to be specified and monitored if the desired level of quality of the output (outcome) is to be achieved. Both organizations and projects need to establish quality management systems (QMS) that ensure that the specifications are reached. Standardized requirements for these systems are collected in standards ISO 9001 (2008) and ISO 10006 (2003) for organizations and projects, respectively.

## **2.3. Construction product level**

According to the Council Directive 89/106 (1989), the essential requirements of the structure are met, if construction products that are permanently built in the structure comply with the relevant European product standards. Most of these standards are harmonized, which means that they were adopted by CEN (Comité Européen de Normalisation), following mandate issued by the EC and after consultation with member states. Compliance with standard specifications provides a first assurance of conformity with the essential requirements for the structure. The standards are adopted by CEN first and, subsequently, by the national standardization bodies in member states. CPD provides rules for the attestation of conformity of construction products. The attestation of conformity of a product is dependent on:

- a) the manufacturer having a factory production control system to ensure that production conforms with the relevant technical specifications; or
- b) for particular products indicated in the relevant technical specifications, in addition to a factory production control system, an approved certification body being involved in assessment and surveillance of the production control or of the product itself.

The selection of the attestation of conformity procedure for a given product or family of products is specified by the European Commission. It depends upon:

- a) the importance of the part played by the product with respect to the essential requirements, in particular those relating to health and safety;

- b) the nature of the product;
- c) the effect of the variability of the product's characteristics on its serviceability; and
- d) the susceptibility to defects in the product manufacture.

The manufacturer's declaration of conformity or the certificate of conformity entitles the manufacturer to affix the corresponding CE Marking on the product itself, on a label attached to it, on its packaging or on the accompanying commercial documents.

### 3. Formulation of the Integrated Quality and Sustainability Performance Assessment in Construction Model

Based on the conducted research, we propose a conceptual model that extends well-established quality assurance procedures to the field of sustainable performance. The model is structured in the same way as the comprehensive quality assessment model presented in the previous section, i.e. the concept of quality is integrated with sustainability performance on three levels: structure, process and construction product level. When the model is implemented, all goals of a sustainable construction project depicted in Fig. 1 can be achieved. At the present stage, the model is limited to buildings. However, we should note the model could be easily extended to include other construction works (e.g. infrastructure).

The LCA (Life Cycle Assessment) method will be used on both product and structure level in the proposed model; consequently, the basic features of this methodology will be presented in what follows.

#### 3.1. Life cycle assessment (LCA)

Environmental performance of products, structures and processes can be assessed by using LCA methodology that allows assessment of environmental impacts of the product/structure/process under consideration throughout its life cycle (extraction of raw materials, production, use and disposal). Figure 2 schematically presents the life cycle of a structure.

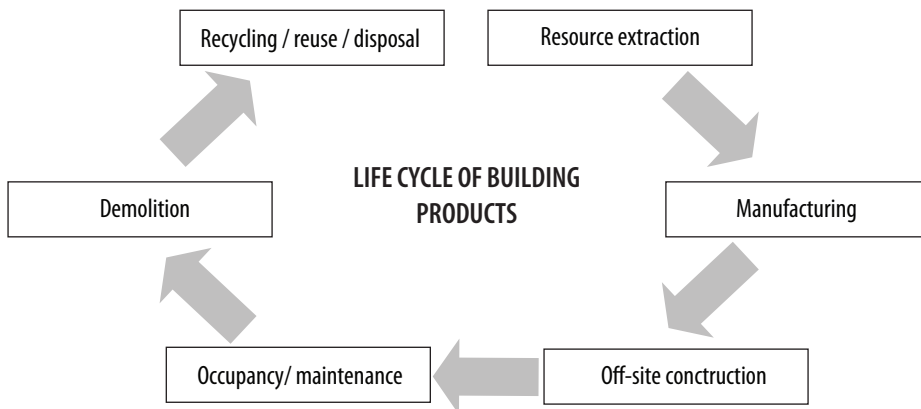


Fig. 2. Life cycle in construction (LCA Models and Tools 2010)

Life Cycle Assessment is an objective procedure to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and material usage and environmental releases, to assess the impact of those energy and material uses and releases on the environment, and to identify and implement opportunities yielding environmental improvements. The environmental impacts considered can be global such as greenhouse gases, regional, such as acid rain, or local, such as smog formation (Osman, Ries 2006).

In the production of consumer goods, the interested parties have increasingly used the method as a tool to assess and decide among alternative technologies or products; however, it has not been widely used to analyse construction products and building production and use. Only recently, an increasing body of literature has dealt with this area, e.g. (Asif *et al.* 2007; Bilec *et al.* 2010; Blengini, Di Carlo 2010; Blom *et al.* 2010; Chowdhury *et al.* 2010; Jönsson *et al.* 1998; Josa *et al.* 2004; Koroneos, Dompros 2007; Medineckiene *et al.* 2010; Nixon *et al.* 2004; Ortiz *et al.* 2010; Sobotka, Rolak 2009; Schmidt *et al.* 2004; Schuurmans 2002; Treloar *et al.* 2004), as revealed by an extensive literature search.

### 3.1.1. Methodology

Life Cycle Assessment methodology became standardized with the introduction of the international standards ISO 14040 (1997), ISO 14041 (1998), ISO 14042 (2000) and ISO 14043 (2000). The standard analysis contains the following steps:

- Goal and scope definition; where boundaries of the system under consideration are identified;
- Life Cycle Inventory (LCI) and inventory analysis; this includes modelling the product system, data collection, as well as description and verification of data;

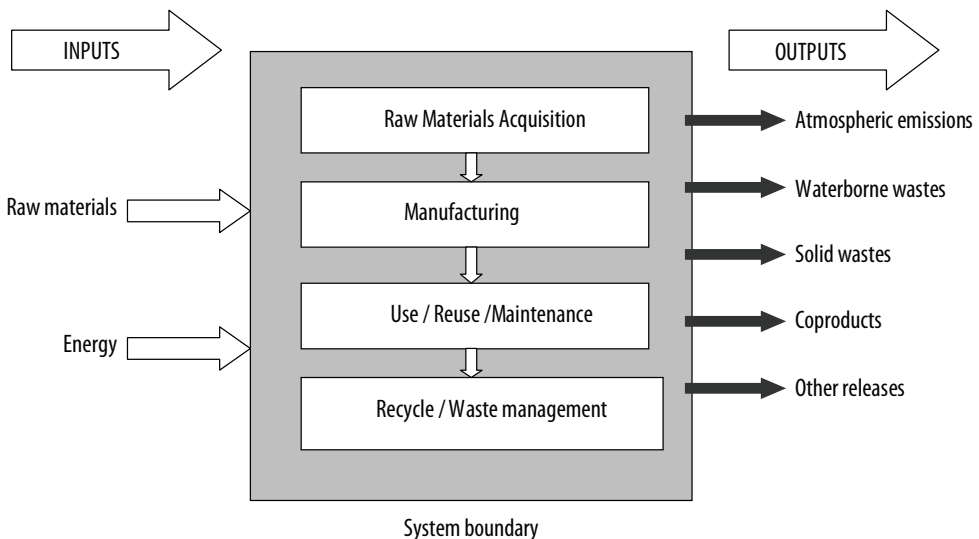


Fig. 3. Typical measured inputs and outputs of LCA (Life Cycle Assessment 2010)

- Impact assessment; where impact potentials are calculated on the basis of LCI, and
- Interpretation of results;
- LCI involves tracking of all flows in and out of the system – raw resources or materials, energy by type, water, emissions to air, water and land by specific substance (Fig. 3).

### 3.1.2. Selection of functional unit

A functional unit should carry out the assessment. This unit should describe the function of the product or process under scrutiny. Its careful selection will improve the accuracy of the comparative study and usefulness of the results. A simple example of a well-chosen functional unit would be the selection per unit area of insulating material with a defined thermal insulation capacity. If two insulation materials are compared in terms of their environmental impact, and if material A has larger insulation capacity than that of material B, then the functional units for these two materials must have different thicknesses.

In construction, the functional unit is defined with respect to the goals of the analysis at structure or product level.

### 3.2. Structure level

As already discussed, quality of the structure is ensured by identification of user's needs, selection of appropriate construction products, and appropriate design and execution.

According to the Agenda 21 (1999), the strategies for sustainable construction should be compatible with the climate, the culture, building traditions, the level of industrial development and the nature of the building stock. Therefore, we can evaluate structure sustainability based only on the local conditions, which require specific national criteria.

During the last decade, several international groups developed methodologies for the holistic assessment of the building sustainability. Although developed in specific countries, they are internationally recognized. The most important are LEED (Leadership in Energy and Environmental Design) (Humbert *et al.* 2007), BREEAM (Building Research Establishment Environmental Assessment Method) (2010), DGNB ("German Sustainable Building Certificate" certificate) (2009) or LENSE (Label for environmental, social and economic buildings) (Kornadt, Wallasch 2008). These methodologies take into account factors like the energy and CO<sub>2</sub> emissions, resource consumption, indoor environmental quality, health and comfort, life cycle costs (LCC), transport, sustainable materials use and many other sustainability issues (Erlandsson, Borg 2003). Some of the above methods are also customized for different building types, in particular for apartment buildings. Methodologies used to assess the sustainability on the level of residential areas, e.g. (Tupenaite *et al.* 2010; Viteikiene, Zavadskas 2007; Zavadskas *et al.* 2008), can be encountered as well. Research has been carried out also in the field of engineering works, such as roads or bridges (e.g. Chester, Horvath 2010; Kendall *et al.* 2008; Koo *et al.* 2009; Zavadskas *et al.* 2008) and various structural elements (e.g. Turskis *et al.* 2009) although in lesser extent.

Both quality and sustainability aspects that include the perception of the architects, engineers, owners and users (tenants) are included in a robust, easy-to-use model for multi-apartment buildings proposed by Šijanec-Zavrl *et al.* (2009). For buildings, the integrated



model proposed in this work draws extensively from the methodology advanced in the above-mentioned work. Quality and sustainability indicators in this model are based on:

- 1) technical and functional aspects related to quality,
- 2) environmental aspects associated with energy usage,
- 3) built in materials, and
- 4) use of other resources.

The following impact areas are taken into the account: building architecture, urbanism, building structure, materials, building physics, HVAC systems, and electric installation. For each impact area, a list of evaluation elements is identified. Criteria and associated indicators are determined on the element level, taking into the account the most suitable form of the proposed indicators (single vs. several indicators; measurable vs. descriptive indicators). Appropriate weights are assigned to the individual criteria. The selection of weights should reflect the national context of the building sustainability. In order to determine the appropriate weights, polls that include various groups of stakeholders (among others, clients, municipalities, maintenance managers, tenants, potential buyers) are to be employed. In the final stage, the indicators are aggregated to the level of the three key pillars of sustainability. Detailed description of the model is beyond the scope of this paper and can be found in Šijanec-Zavrl *et al.* (2009).

### 3.3. Project/process level

Construction project is a unique endeavour that consists of a large number of activities, carried out by a large number of participants. The final goal of this project is a functioning structure, completed and handed over in due time. The design and consulting offices, contractors, subcontractor and suppliers of construction products and services ensure the quality of their products and services by implementing quality management systems (QMS) into their organizations. The standard ISO 9001 (2008) specifies the requirements for these systems.

At the level of construction project, the model first proposes the environmental aspects, as shown in Figure 1, be included in the traditional construction project goals. The model also encompasses a project quality management system, in addition to quality management systems of participating organizations.

The environmental management systems (EMS) supplement the quality management systems existing in participating organizations; the EMS should be based on documented environmental policy and they should contain the following elements:

- goals, methods and timeline for meeting environmental requirements and voluntary undertakings;
- procedures for maintaining appropriate documentation relating to its goals;
- a defined structure for responsibilities for each task, together with availability of adequate resources;
- corrective and preventive actions and emergency procedures;
- an employee training plan;
- a plan for periodic auditing of the company's performance (i.e. how well the goals are achieved); these quantitative results allow the planning of continuous improvement actions.

Environmental management systems in a particular organization can follow the requirements set in ISO 14001:2004; in this case, the proposed model can easily integrate the quality and environmental systems.

The proposed model envisages the establishment of a project environmental management system, fully compatible with the quality management system of the project. Similar to the project QMS, the environmental management system of the project is interconnected with the different EMS of the participating organizations. In this case, the environmental impacts of the processes executed during the construction project are fully monitored and controlled.

### 3.4. Product level

As already discussed, formal requirements of compliance to the relevant EN, standards assure quality of construction products. Recent developments in the EU show that the main strategy to evaluate and improve environmental performance of products, including construction products, are Environmental Product Declarations (EPDs) (Braune *et al.* 2007), that provide quantified environmental data based on LCA methodology for the product under consideration. EPD schemes have been developed in order to provide credible information on the environmental impact of products. Standards ISO 14024:1999; ISO 14021:1999; ISO 14025:2006 define standard procedures related to EPDs.

In construction, the most appropriate type of EPD is type III label that communicates product specific results from a LCA (carried out according to the series of standard ISO 14040:1997; ISO 14041:1998; ISO 14042:2000; ISO 14043:2000) in a formalized and comparable way. In this way, the client, contractor or another buyer can decide on the most sustainable product.

Some EPD schemes are covering more than one product group, and some have been developed for one sector only. In construction, several EU countries, e.g. Denmark, Germany, Netherlands, Norway, Sweden and UK) have already established the EPD national schemes.

For construction products, the proposed **Integrated Quality and Sustainability Performance Assessment in Construction Model** is integrating conformance of quality report and environmental performance declaration (in conformance with standard ISO 14025:2006) into a single document that is at disposal to the buyer at the time of purchase. This is in line with the recent proposition at the EC level to introduce the 7th Essential Requirement, Sustainable use of natural resources for the construction works (Ilomaki 2009).

Fig. 4 shows a schematic representation of the three levels and associate elements of the proposed model.

BUILDING LEVEL	Integrated quality & sustainability assessment
PROCESS/PROJECT LEVEL	Established QMS & EMS (project & organization level)
CONSTRUCTION PRODUCT LEVEL	Statement of conformity & EPD

Fig. 4. Levels and elements of the proposed conceptual model

#### 4. Discussion

The requirements for sustainable development have generated additional needs in the field of sustainability of the built environment. For this reason, we propose a model that integrates assessment of quality and environmental performance of a building on three levels (structure, process / project, and product). The successful implementation in practice of the proposed conceptual model requires the support of various actions.

Procurement rules (of both public and private clients) should include the outcomes of the model's assessment (for the structure) as inputs required in the selection of the design solution. At the structure level, the use of the model for sustainability assessment as proposed by Šijanec-Zavrl *et al.* (2009), or a similar one, should be encouraged by the authorities and promoted in public (i.e. among potential buyers) as a competitive advantage.

The final goal is using the proposed model as a part of the required procedures in the so-called green procurement. Public procurement of construction works, goods and services in the EU strongly encourages green procurement. Recent studies, however, have found out that the uptake of the green public procurement (GPP) is relatively low, mainly because of:

- Limited established environmental criteria for products and services – where these do exist, there are often insufficient mechanisms, such as databases, to publicize them.
- Insufficient information on the cost of products over their life cycle and the relatively high first costs of environmentally friendly products and services.
- Low awareness of the benefits of environmentally friendly products and services.
- Uncertainty about legal possibilities to include environmental criteria in tender documents.
- Lack of political support and resulting limited resources for implementing and promoting GPP; improved training is necessary.
- Lack of a coordinated exchange of best practices and information between regions and local authorities (FAQ on EC ... 2010).

Nevertheless, use of GPP procedures is slowly increasing in the public procurement of buildings. In this field, it should be first emphasized that green procurement of structures can be carried out only if the project brief includes requirements addressing environmental performance of the whole structure, associated processes and products. For buildings, one should be aware that the legislative requirements for the total energy consumption are becoming increasingly more severe with time. Therefore, in the near future, the energy demand and total environmental effects of the building in the operation and maintenance stage will be relatively low when compared to the initial environmental effects of the whole building. Consequently, emphasis will be placed on the influence upon environment created by the production of construction products and on-site construction processes.

Green procurement, if it contains also the requirements regarding the EMSs, can also improve the environmental performance of processes and construction project as a whole. Public procurement directive (Directive 2004/18/EC, 2004) enables adding non-price criteria into the process of contractor selection. Existence of the EMS facilitates their adoption as a criterion in the (public or private) procurement process.

On the construction product level, the clients and contractors have to be stimulated to identify and select a set of construction products that constitute the structure with the minimum total environmental impact. This set is only feasible if integrated documents (consisting of product declarations of conformity and EPDs, as proposed in this model) for all built-in products, and data on environmental releases for all construction processes taking place during execution are available. The project EMS will provide for the relevant data for the processes.

Using EPDs allows to add up the LCI/LCA based information in the whole supply chain, from single product to the whole building (final product), that is based on a large number of materials, semi-manufactured products and products.

## 5. Conclusions

Due to the complexity of the construction project, introducing sustainability assessment into construction practice presents even a bigger challenge as in manufacturing. Each stakeholder, client, designer, contractor and the user, interpret sustainability within a different context and level. The whole construction supply chain can therefore profit from a model that provides systematic guidance on different fields and levels to be tackled. Integration of quality and sustainability performance assessment into a single model, as proposed in this paper, can lead to a more sustainable as well as cost efficient management of the construction project while meeting all project goals. It can therefore serve as a useful tool for the main targeted audience, the construction clients. The successful implementation of the model requires various measures on all specified levels (construction products, processes/project, and building).

The green procurement is receiving high priority today, and the proposed model can constitute an important part of green procurement schemes, for both public and private clients. In addition, national policies on sustainable development should promote the legislation and accompanying measures that enable full implementation of the integrated quality and sustainability assessment in construction.

The developed model is in its present stage limited to buildings; however, there is no particular difficulty in extending it to other construction works. In this case, the major difference arises on the structure level, where we propose that a full standard LCA be performed for the case under consideration instead of the sustainability assessment methodology suggested in this work.

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## INTEGRUOTAS KOKYBĖS IR TVARUMO VERTINIMAS STATYBOJE. KONCEPCINIS MODELIS

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**Santrauka.** Šiandieniam pasaulyje kokybės apibrėžimas yra išplėstas, ir dabar jis apima tvarumą. Straipsnyje aprašomas integruoto modelio kūrimas, apimantis tiek produkcijos kokybę, tiek aplinkos ir statybos procesų tvarumą. Šis integruotas kokybės ir tvarumo statyboje įvertinimo modelis sudarytas iš trijų pakopų: konstrukcijų, proceso/projekto ir statybos produkto. Siūloma holistinė tvarumo vertinimo metodika, pagrįsta ankstesniais autorių tyrimais. Griežtas kokybės ir aplinkos vadybos sistemų reikalavimų laikymasis statybos metu garantuoja kokybę ir aplinkosaugą projekto/proceso lygmeniu. Statybos produkto atitiktį užtikrina aplinkosauginė gaminių deklaravimo (AGD) sistema, taikoma visoms statybos medžiagoms ir gaminiams. Taikant gyvavimo ciklo įvertinimo (GCĮ) metodiką, galima įvertinti konkrečių statybos produktų poveikį aplinkai visą jų gyvavimo laikotarpį. Tvarumą konstrukcijų lygmeniu užtikrina autorių anksčiau sukurtas integruotas vertinimo modelis. Integracija visais trimis lygmenimis užtikrina,

kad kokybę ir tvarumą įkūnija projektavimas, gamyba ir galutinis produktas. Šios versijos modelis pritaikytas tik tam tikroms pastatų savybėms vertinti, o tvarumo aspektas yra tik aplinkosauginis. Pasiūlyto modelio diegimo praktikoje tyrimas atskleidė, kad potencialūs sistemos vartotojai yra pastatų užsakovai.

**Reikšminiai žodžiai:** statybos projektas, pastatas, statybos produktas, kokybė, tvarumas, KVS, AVS, gyvavimo ciklo vertinimas, aplinkosauginė produkto deklaracija.

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