Sustainable construction success indicators

M Vilnitis¹, VA Lapsa² and A Veinbergs³

¹ PhD Professor, Faculty of Civil Engineering, Riga Technical University, Riga, Latvia
² PhD Leading researcher, Faculty of Civil Engineering, Riga Technical University, Riga, Latvia
³ PhD student, Faculty of Civil Engineering, Riga Technical University, Riga, Latvia

E-mail: martins.vilnitis@rtu.lv

Abstract. The proposed paper examines the success indicators of sustainable construction projects, and its relationship to building codes with specific focus on safety, quality and budget aspects in terms of their implications and impacts prior, during and after construction. Such a research will be very beneficial to the construction industry and the government of all countries in terms of significant money savings and preservation of national wealth and resources through sustainable construction approaches. Consideration of sustainability at the design stage is emphasized. Building safety and the roles of building codes in prevention of structural failures are also covered in the paper together with factors affecting building failures and methods for their prevention in early design phases. Construction process is introduced in the paper from the perspective of modern total quality management. Concepts of quality management, quality control, quality assurance and six sigma and how they relate to building sustainability are discussed with examples. At least the importance of appropriate maintenance of building during expected life time are partly covered in the paper. It was necessary, in an initial stage, to define the key indicators that should be considered in order to assess the main aspects of sustainable construction. This paper intends to present the analysis that was performed in order to select some of quality evaluation indicators.

1. Introduction
Sustainable building is a concept that began its development nearly two decades ago. With sustainable buildings, it is intended to establish building practices that allow minimizing the buildings impacts, build and manage buildings with an adequate balance between environment, society and economy. Several studies have been developed with the goal of understand the reason of these weak implementation. They have concluded that one of the main reasons is because the building stakeholders still consider sustainable practices more expensive [5] [9] [11] [13].

In order to perform a cost-benefit analysis of sustainable construction solutions, it was necessary, in an initial stage, to define the key indicators that should be considered in order to assess the main aspects of sustainable construction. The assessment process could be simplified by using a ready-made wide set of individual sustainability impact indicators for construction products and processes, sensitive to the parameters that determine them to a great extent [24] [2] [16].

2. Safety, Quality and Productivity in Construction
A recent industry survey indicates that there is synergy between lean production and safety management practices in construction [3]. Lean production is based on the Toyota Production System (TPS) to
achieve best quality, lowest cost, shortest lead time, best safety and high morale. Lean production tools include Just-In-Time (delivering right items at right time and amount); autonomation ("jidoka" - never letting defective items go to next station; stopping workers and machines when defects are significant); production leveling (reducing variability and inconsistency); and continuous improvement (there is no best; there is always an opportunity to improve processes). These tools can be applied to improving safety management practices such as management commitment, staffing for safety, planning for safety, safety education/training, worker involvement, evaluation and recognition, subcontractor involvement, and accident investigation. Since the lean approach combines quality with productivity, and it can improve safety, one can conclude that safety, quality and productivity can be collectively improved [18].

The question of how safety is related to productivity often comes up in decisions concerning how much attention and investment must be directed toward safety programs in the construction industry, especially in smaller and mid-sized firms.

Construction projects are expected to simultaneously achieve multiple goals concerning cost, schedule, quality, productivity and safety. These factors are related, while they may be in apparent conflict with each other. Because of pressures on cost, schedule, and productivity, workers may engage in unsafe behavior, believing that this enables them to be more productive. On the other hand, there is strong belief in the industry that no trade off exists between safety and productivity; and in fact they might be synergistic [12][17][23].

There is some evidence to support the notion of safety being negatively correlated with productivity. However, there is stronger support for the opposite; that is, safety and productivity are positively correlated, meaning there would be no loss of productivity due to taking safety measures or executing safety programs in a construction project. On the negative correlation side, there are reports in the safety literature that workers may ignore safety due to productivity concerns. In a recent study, safety audits conducted at 200 residential sites showed 59 % non-compliance, meaning widespread disregard for safety. It was found that this came about as a result of concern over taking time off work to learn new safety measures; fear of cost of compliance; and lack of knowledge (inadequate training). In another study, it was observed that managers believed there was not enough time to work safely and safety practices decreased productivity. Research on the impacts of schedule pressures on safety indeed showed increases in injury rate when such pressures are present. Another research study found that workers cut corners on safety to be more productive for fear of losing their jobs. In a study on roofers, it was observed that productivity dramatically decreased when fall arrest systems were used. Workers lost a lot of time adjusting their lanyards on steep roofs resulting in loss of productivity. In a more balanced study, it was concluded that there was a strong negative correlation between safety and productivity when new safety strategies were implemented; however, the correlation turned positive after some time elapsed in the project.

In support of positive correlation between safety and productivity, a U.K. study indicated that productivity losses were higher with safety violations than with preventive safety practices. Similar evidence in a different study suggested that safety management is a positive influence on productivity because of declining task performance by the entire crew in case of injuries. According to this study, damaged equipment and materials; time for additional record keeping, accident investigation and training also slow down production. According to Hinze’s [12] distraction theory, workers are more productive when they perceive hazards to be minimal, than working with the perception of being in a high hazard environment. Productivity is compromised when distractions due to hazards turn the worker’s attention to mitigating safety risks. A recent study on manufacturing productivity vs. safety concluded that management should view safety and operating performance measures as being in concert with each other rather than competing entities. There is more scrap, rework and less employee involvement when safety performance is poor. Based on 18 case analyses, a study by Maudgalya, [17] revealed that several organizations realized a payback of their monetary investment in safety initiatives in less than a year. Following the implementation of workplace safety initiatives, organizations observed an average increase of 66% in productivity, 44% in quality, and 71% in cost benefits. The study concluded that as a business case, safety can assist an organization in achieving the long-term benefit of
operational sustainability. Finally, a study by McGraw [18] suggests that contractors are experiencing positive business outcomes from safety programs in terms of shortened schedules, budget/cost savings, increases in project return on investment (ROI), improved reputation, improved market share, and improved project quality.

3. Sustainable Construction Key Indicators

In order to study the sustainable construction it was very important to select the proper indicators. These indicators should include the main building impacts and assess the particular aspects of the socioeconomic context. Generally, building sustainability assessment (BSA) tools evaluate the buildings sustainability level through the aggregation of the building performance in a group of sustainability indicators, such as environmental, social and economic indicators. The first developed BSA tool was BREEAM - Building Research Establishment Environmental Assessment Methodology [6], in 1990. After this, other BSA tools were developed such as: LEED - Leadership in energy and environmental design [15], developed in the United States of America, SBTool – Sustainable Building Tool [12] developed by International Initiative for a Sustainable Built Environment (iiSBE), CASBEE - Comprehensive Assessment System for Building Environmental Efficiency [7] developed in Japan, among many other [20].

In order to define the sustainable building key indicators, four European initiatives have been analysed, the Sustainable Building Challenge 2011 [21] and 2013 [20] key indicators, the Sustainable Building Alliance, the SuPerBuildings [22] and the OPEN HOUSE project [19]. These initiatives are chosen because they are European initiatives that have performed recent work with the goal of define sustainable construction key indicators. The selection of indicators was performed considering the following aspects [4]:

1. All indicators with a subjective assessment were excluded;
2. All indicators whose performance cannot be changed by design options or whose assessment goes beyond the building boundaries were excluded;
3. All indicators whose performance was difficult to translate into economic terms were excluded.

Additionally, it was intended that the key indicators list is broad enough to include the mainly sustainable buildings impacts, but also concise enough in order to make the assessment practicable (see Table 1).

| Table 1. Indicators selected by at least three initiatives [4]. |
| --- |
| **DIMENSION** | **CATEGORIES** | **SELECTED INDICATORS** |
| **ENERGY** | Energy and Emissions | Non-renewable primary energy |
| | | Renewable primary energy |
| | Water | Water consumption |
| **ENVIRONMENT** | Materials and Waste | Materials embodied energy |
| | | Ozone depletion potential |
| | | Acidification potential |
| | | Eutrophication potential |
| | | Photochemical oxidation potential |
| | | Reused and recycled materials |
| | | Responsible sourcing materials |
| | | Waste production |
| **SOCIETY** | Users health and comfort | Indoor air quality |
| | | Lightning |
| | | Thermal comfort |
| | | Acoustic comfort |
| | Process quality | Integrated design project |
| | | Commissioning |
| **ECONOMY** | Economy | Life Cycle Costs |
Through the revision of the results obtained in some European initiatives, developed with the goal of select sustainability key indicators, was possible to observe that despite all the efforts, there are still some differences between the lists of key indicators developed [1] [8] [10].

4. Proposed Methodology of Quality Evaluation

The topicality of the problem in the world is confirmed by Directive 2014/24/EU of the European Parliament and of the Council in Article 49 in which the “best” proportion of price and quality is named as the main criterion of the award of contract. In order to clarify, it is recommended to claim a “smaller” proportion, i.e., a cheaper offer for higher quality. However, the word “quality” remains comprehensive, abstract, non-weighted by one number and therefore a too freely usable concept here, as well, which will lead to unfair competition and sustainable disregard of construction principles.

Economic profitability – economic efficiency or benefit gained by a customer, may be mentioned as the second criterion. In order to assess the economic efficiency correctly, not only costs should be taken into account, but also the following factors:
1. Contract performance terms;
2. Operating costs;
3. The quality of construction works;
4. Aesthetic characteristics;
5. Functional specification;
6. Environmental compliance;
7. Technical advantages;
8. The availability of spare parts;
9. Security of supply process;
10. Other contract-related factors.

The aim of this research is to show that it is completely enough with the price lists available in the market, quality documents of materials, specifications of construction details, tariff rates of construction workers, time norms and cost estimates, to calculate the economic efficiency of materials, construction and the whole building by a single and calculated efficiency price of the unit of measurement. However, in order to determine this, it is not enough with only the use of market units of measurement, but the standardized efficiency (which is also quality) units of measurement of both; the material and construction must definitely be used in the calculations. The offered quality assessment methodology contains the following components:
1. Quality concept assumed as the materials, structures, as well as all construction utility functions (strength, load bearing capacity, heat resistance, frost resistance and many others) indicators that client are looking for and willing to pay for them.
2. Each utility function has its own specific normative measurement, which may differ from the units used in the market.
3. Utility functions could be found in the project, both as materials and structures specifications as well as all the building life time parameters.
4. The price for each component of the utility function could be calculated dividing the construction materials or structures market price to the utility normative measurement specified in the Technical project. With similar approach can evaluate the usefulness of the project as a whole. In that case as the utility function should be chosen expected building life time, specified in the contract or project, less than operating expenses during building life time.
5. As the criteria of competitiveness for certain project or building could be set the utility function for the all components usefulness or the total price for all project usefulness.
6. Utility functions evaluation, comparison of prices and how to achieve designed quality for the lowest price (optimum choice) will be the responsibility of designer and this prove his competitiveness.

The offered methodology does not consider such competitiveness criteria as guarantee scope (the time may be considered), all compulsory or other types of insurance, however, it is also a cost which may be easily added to the calculated quality price. An example of the practical application of the offered
quality assessment methodology – a thermal house construction and technology is included in the next chapter.

5. Experimental Results and Discussion
This practical example shows another positive effect of the application of the offered methodology – minimization of the building costs and the social effect obtained from it. By applying the offered methodology it is possible to build a low energy consumption house in a much cheaper way than from traditional construction and technologies.

Let us deal with the price dependence of concrete efficiency – its compression strength on the compression strength classes as the first which is clearly shown graphically (see Figure 1).

![Figure 1. Concrete market price (1) and a price of its strength (2) depending on the concrete class.](image)

Upon increasing concrete strength, its market price of 1m³ may certainly grow. But what is the economic efficiency of 1m³ of concrete? No one gains any benefit from the fact that the supporting construction occupies a large capacity in the building and is heavy. It means that the market unit of measurement 1m³ may not be an efficient unit of measurement of concrete.

By investigating the curve it may be established that with the increase of concrete strength, the price of its construction efficiency function, compression strength, rapidly decreases. It may also be seen that upon exceeding the concrete strength of 45 MPa, this relation seemingly becomes stable. However, the technical and economic benefit to be gained behind this border is easily explained – it is the further decrease of concrete consumption, own weight and load of the construction on the lower constructions. A similar relation may be observed when evaluating the efficiency of another building construction material, steel. Its market unit of measurement is tons, from which no one gains any benefit. With the increasing strength of steel, the market price of 1t certainly increases, as well, while the price of efficiency unit of strength measurement [€/t·MPa] falls. Steel with high strength is used as cold-rolled, light thin walls and rational profiles.

Other building properties standardizing the quality of building material may be evaluated in the same way by cost, for example, chemical resistance or frost resistance: the cost of one cycle of frost resistance? The efficiency criterion of heat insulation materials will certainly be their heat resistance \(1/\lambda\) by the unit of measurement mK/W.
The economic efficiency price of the roof covering efficiency may be evaluated similarly by dividing its market price €/m² by the efficiency criterion – service life in years. Then, upon choosing the material with this price [€/m²-years] a customer and designer will see that the most expensive material in the market will be the cheapest one in the long term.

By applying the offered methodology the building construction itself may also be evaluated. It will be the load carrying capacity price for the supporting constructions – for columns €/kN, beams €/kNm, while for plates €/kN m². The application of the methodology is comparatively simple because load carrying capacity may be found in both the design, and in the specifications of built-up constructions, while the prices are indicated in the price lists of the supplier or manufacturers of materials.

It may easily be seen that the efficiency function of the separating constructions – external walls and their elements, windows, is their heat resistance RT= 1/U with the unit of measurement m²K/W. It should have monolith construction included in the design, while market prices should be indicated in the cost estimate together with all construction costs. The heat resistance (or its opposite unit W/m²K) for built-up constructions, panels, windows may be found in the specifications or in the manufacturer’s certifications, but a competent customer or designer may choose its market price appropriate to a minimum and guaranteed efficiency price.

For economically efficient optimum selection of building materials a scheme should be used which is clearly shown in the table (see Table 2). Different external wall materials are included here for comparison – those which include both functions at the same time – load carrying capacity + heat insulation, as well as specialized ones – provided for only load carrying, or to be used only for heat insulation of the building with the highest values of both these efficiency functions (strength and heat resistance).

**Table 2.** Market prices of construction building materials and their efficiency prices, according to RTU, Construction Technology department survey.

| Material                      | Density kg/m³ | Price €/m³ | Heat resistance 1/λ K·m/W | Price of heat resistance € W/m² K | Compressive strength MPa | Price of compressive strength €/m³ MPa |
|--------------------------------|---------------|------------|---------------------------|----------------------------------|--------------------------|----------------------------------------|
| Concrete C35/45                | 2400          | 84,00      | 0,49                      | 144,90                           | 45,00*                   | 1,87                                   |
| Ceramic blocks                 | 650           | 113,00     | 5,65                      | 20,00                            | 12,5                     | 9,04                                   |
| AAC blocks                     | 400           | 67,00      | 9,10                      | 7,36                             | 3,00                     | 22,33                                  |
| Wooden structure (pine)        | 600           | 165,00     | 8,20                      | 20,1                             | 8,5 16,0                 | 19,4 103                               |
| Foam polystyrene (EPS60)      | 15            | 57,23      | 30,30                     | 1,89                             | 0,060**                  | 953,8                                  |

As it is seen, the highest concrete compression strength class found in the construction market is 45 MPa (150 x 150x 150 mm for cubes*), but it has the least heat resistance. On the other hand, polystyrene foam EPS 60 has the highest heat resistance and it is 30.3 m.K/W, but its compression strength (at 10% of deformation**) is insignificant – only 0.06 MPa. However, unlike mineral wool, it is completely sufficient in the technological sense for the remaining heat insulation formwork. Upon comparing the prices of efficiency functions of both these specialized building materials with the efficiency prices of traditional materials, it may be seen that the cost indicators of both efficiency functions – strength and heat resistance of both, that ceramics, aerated concrete blocks and wood are more expensive. It may be easy to make a conclusion on the basis of these numbers that it is not profitable technically nor economically to try to combine implementation of both aforementioned efficiency functions in one external wall material, because both will be too expensive as a result. It is also obvious that it is most profitable in the technical and economic sense to make a separating construction from two separate and high-specialized materials – so that the load carrying material performs its function with the lowest strength price, as well as with the least consumption and mass, while the heat insulation material should
be chosen with the minimum (necessary only for assembly) durability and minimum heat resistance $1/\lambda$ price.

How does such a division of efficiency functions of building materials, together with the cost minimization of these functions, determine the building properties of the construction and how will the improvement of its efficiency functions affect construction costs? We will deal with the building of the external wall construction of thermal houses as an example of the offered evaluation methodology of the efficiency factors (see Figure 2 and Figure 3).

Figure 2. An external wall construction of a thermal house in the remaining formwork. 1- concreted columns, 2- heat insulation formwork, 3- hard internal finish, 4- external finish of the wall, 5- heat insulation window classes.

Figure 3. Concreting of the external wall of a thermal house.

The economic and technical indices of the external wall construction of the thermal house are divided here in two parts (see Table 3). The first part – from p.1.1. to p.1.8., shows that upon making an optimum division of the efficiency functions in the external wall construction together with their cost minimization (Column 5) by comparing with constructions made of traditional materials with both combined efficiency functions (Column 3 and 4) is obtained by a building company. These are considerably decreased construction costs. The second part (p.2.1 – p. 2.4) shows what else is obtained by a customer apart from the cheapest price within the long-term process of the use of the building. The thermal external wall heat resistance is 8.27 m².K/W, which far exceeds the minimum 5.555... m².K/W required in the Latvian Construction Standard LBN 002-15, is also the cheapest. Upon a customer’s wish, there are no difficulties to increase the heat resistance of thermal walls even more by the offered
technology. Besides, the 1m² weight of the external wall is considerably less, which allows to make the constructions with smaller volume and mass, as well as cheaper respectively.

### Table 3. Technical – economical comparison of outside wall.

| Indicators of the economical and technical benefits for outside wall | Unit of measurement | Type of outside wall                                                                 |
|-------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------|
|                                                                   |                      | Ceramic blocks, 40 cm $\lambda=0,177$ W/m·K                  | AAC blocks, 40 cm $\lambda=0,11$ W/m·K | Expanded polystyrene blocks 40 cm as formwork filled with concrete core |
| 1. Economical indicators                                           | €/m²                 | 34,49                                                                               | 36,18                                    | 31,00                                                |
| 1.1 Materials (with VAT)                                           |                      | 14,74                                                                               | 11,37                                    | 5,14                                                 |
| 1.2 Labour costs                                                  | €/m²                 | 3,48                                                                                | 2,68                                     | 1,21                                                 |
| 1.3 Social security taxes 23,59 %                                 | €/m²                 | 1,47                                                                                | 1,14                                     | 0,51                                                 |
| 1.4. Mechanisms and hand tools                                    | €/m²                 | 2,76                                                                                | 2,89                                     | 3,03                                                 |
| 1.5 Transport costs                                               | €/m²                 | 5,69                                                                                | 5,13                                     | 4,09                                                 |
| 1.6 Contractor profit                                             | €/m²                 | 13,15                                                                               | 11,84                                    | 9,45                                                 |
| 1.7 VAT 21%                                                       | €/m²                 | 75,79                                                                               | 71,23                                    | 54,43                                                |

| Indicators of the economical and technical benefits for outside wall | Unit of measurement | Type of outside wall                                                                 |
|-------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------|
|                                                                   |                      | Ceramic blocks, 40 cm $\lambda=0,177$ W/m·K                  | AAC blocks, 40 cm $\lambda=0,11$ W/m·K | Expanded polystyrene blocks 40 cm as formwork filled with concrete core |
| 2. Technical indicators                                           |                      | 360,00                                                                              | 160,00                                   | 78,00                                                |
| 2.1. Weight                                                       | kg/m²                | 2,26                                                                                | 3,810                                    | 8,27                                                 |
| 2.2. Price of heat resistance                                     | €/m²                 | 33,54                                                                               | 18,70                                    | 6,58                                                 |
| 2.3. Heat loses for heating season                                | €/kWh/m²             | 43,12                                                                               | 25,57                                    | 11,78                                                |
|                                                                  | €/m²                 | 3,04                                                                                | 1,81                                     | 0,83                                                 |

The offered methodology may also be easily applied for profitability assessment of the whole building, for example, by dividing its price (or construction costs) with the service life indicated in the design. Such an assessment might not match the efficiency assessment of particular constructions in terms of cost, because one covering panel may serve (carry load) a much longer than the life of the building. On the other hand, if the service life of the building is determined, some of its maintenance indicators may be used as a competitiveness criterion, for example, the forecast heating costs in the unit of time. Upon multiplying them with the service life of the building, the costs of the determined efficiency, in this example heating costs, are obtained within the entire service life of the building. They will certainly be important only to the customer, but they must determine the cooperation of both, designer and builder, upon developing a sustainable building product. The assessment methodology of the offered efficiency functions may also be used concurrently – for materials, construction and for the whole building.

### 6. Conclusions

The work presented in the paper selects a set of indicators that will be used in the cost-benefit analysis to sustainable construction. Due to the goal of the work, some specificities were applied in the selection of indicators. However, when selecting a set of indicators to assess sustainability, it is important to...
analyse the most significant buildings impacts and the socio-cultural context. As the result, we could make several statements:

1. All the most important sustainability criteria can be measured by money, either evaluating materials and structures or construction in general.
2. Construction costs of the Building could be reduced by maximization of sustainable construction criteria, and the minimization of their costs. In such a way, we could increase economic benefits which are important for client as well as for construction companies.
3. Using proposed methodology of quality evaluation as a result the low energy buildings could be built cheaper, from economic life time prospective, than average (traditional) buildings.

References
[1] Alwaer H and Clements-Croome D J, 2010 Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings Building and Environment 45(4): 799-807
[2] Alyami S H and Rezgui Y 2012 Sustainable building assessment tool development approach Sustainable Cities and Society 5(0): 52-62
[3] Antillon E I, Alarcón L F, Hollowell M R and Molenaar K R 2012 A Research synthesis on the interface between lean construction and safety management Proc. Construction Research Congress ASCE West Lafayette
[4] Araújo C, Bragança L, Almeida M 2013 Sustainable Construction Key Indicators Building Sustainability Assessment Tools 505-512
[5] Bragança L et al 2010 Building Sustainability Assessment Sustainability 2(7): 2010-2023
[6] BREEAM 2012 BREEAM - Building Research and Consultancy’s Environmental Assessment Method, Retrieved 27-12-2012, 2012, from http://www.breeam.org.
[7] CASBEE 2012 CASBEE - Comprehensive Assessment System for Building Environmental Efficiency, Retrieved 27-12-2012, 2012, from http://www.ibec.or.jp/CASBEE/english/overviewE.htm.
[8] Chen Y et al 2010 Sustainable performance criteria for construction method selection in concrete buildings Automation in Construction 19(2): 235-244
[9] Cole R J 1999 Building environmental assessment methods: clarifying intentions Building Research & Information 27(4-5): 230-246
[10] Ding G K C 2008 Sustainable construction - The role of environmental assessment tools Journal of Environmental Management 86(3): 451-464
[11] Freyd A-C 2012 Annual Report 2012 - Sustainable Building Alliance, Sustainable Building Alliance
[12] Hinze J 1996 The distraction theory of accident causation Proc., Int. Conf. On Implementation of Safety and Health on Constr. Sites, CIB Working Commission W99: Safety and Health on Construction Sites, L. M. Alvez Diaz and R. J. Coble, eds., Balkema, Rotterdam, The Netherlands, 357–384
[13] Huovila P 2012 Sustainability and performance assessment and benchmarking of buildings - Final report, Finland, VTT Technical Research Centre of Finland
[14] iiSBE 2012 SBTool 2012, Retrieved 21-01-2013, 2012, from http://iisbe.org/sbtool-2012
[15] LEED 2013 LEED - in Energy & Environmental Design, Retrieved 27-12-2012, 2012, from http://www.leedonline.com
[16] Mateus R and L Bragança 2011 Sustainability assessment and rating of buildings: Developing the methodology SBToolPT-H Building and Environment 46(10): 1962-1971
[17] Maudgalya T, Genaidy A and Shell R 2008 Productivity—Quality—Costs—Safety: A sustained approach to competitive advantage—A systematic review of the National Safety Council’s case studies in safety and productivity Hum. Factors Ergon. Manuf. Serv. Ind. 18 (2 ), 152–179
[18] McGraw Hill Construction 2013 Safety management in the construction industry: Identifying risks and reducing accidents to improve site productivity and project ROI SmartMarket report
[19] OPEN HOUSE 2010 OPEN HOUSE - Seven Framework Programme Home Page, Retrieved 06/06/2013, 2013, from http://www.openhouse-fp7.eu/
[20] SB Conferences 2013 Sustainable Building 2013-2014 Conferences Series - SB Challenge, Retrieved 06/06/2013, 2013, from http://sbconferences.org/concursos/
[21] SBChallenge11 2011 Sustainable Building Challeng 2011, Retrieved 06/06/2013, 2013, from http://sbchallenge.iisbe.org/
[22] SuPerBuildings, 2012 SuPerBuildings - Sustainability and Performance Assessment and Benchmarking of Buildings, Retrieved 08/06/2013, 2013, from http://cic.vtt.fi/superbuildings/
[23] Veltri A, Pagell M, Behm M and Das A 2007 A data-based evaluation of the relationship between occupational safety and operating performance J. of Safety, Health and Env. Research, Vol.4. No.1
[24] Zavrl M Š et al 2010 D1.3. Definition of indicators, sustainability performance levels and procedures to evaluate them, OPEN HOUSE