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To cite this article: R Apanavičienė *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **410** 012064

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# Sustainability Assessment of the Building Construction Stage Using Building Sustainability Assessment Schemes (BSAS)

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**Abstract.** Building Sustainability Assessment Schemes (BSAS) are the key instruments to measure, evaluate and implement sustainability goals through all building's life-cycle. The current trend for the establishment of practices resulting to green and sustainable buildings is based on environmental protection aspirations, as well as on rising real estate market demands for improved indoor air quality (IAQ) conditions. The aim of this study was to investigate the impact of the construction stage process on the results of BSAS ratings. Seven administrative buildings rated by BREEAM or LEED, located in Lithuania, were assessed in terms of this study. Five criteria were employed to assess the sustainability of the investigated buildings at the construction phase, including the project management, the responsible purchase of building materials, the use of legal timber materials, the construction waste and the protection against environmental contamination. The selected criteria constitute a significant part of the established sustainability assessment schemes such as BREEAM and LEED. Following the analysis of the actual ratings for the selected categories, weights of the construction stage as well as their impact on the final evaluation results were defined. The findings of this study revealed that the impact of the selected criteria on the final BREEAM scheme rating ranged from 6.98 to 8.57 percent. The impact of the construction stage criteria on LEED system final results ranged from 4.05 to 6.97 percent and in any case demonstrated reduced impact on the final rating result. The study also revealed the contractor's point of view to a building sustainability at the construction stage in Lithuania. The findings of this study may serve as a framework for contractor's organizations intended to improve the construction sustainability of green building projects and this way to increase the overall building sustainability ratings.

## 1. Introduction

For few decades climate change has become increasingly important in the global context [1]. By acknowledging destructive changes in the environment, governments, scientists, entrepreneurs and society consider the new ways of living and doing business with the least impact on nature and the environment.

Buildings construction and operations accounted for 36% of global energy use and 39% of energy related CO<sub>2</sub> emissions in 2017 [2]. The construction industry is the single largest global consumer of resources and raw materials. It consumes about 50% of global steel production and, each year, 3 billion tonnes of raw materials are used to manufacture building products worldwide. It produces an enormous amount of waste [3]. These are significant issues to think over and change the standards for building design, construction and operation that have been established during the past decades.

In many advanced countries norms, laws and standards have been adopted that define the life cycle of a country's buildings from design to demolition. Unfortunately, not all countries are concerned



about the sustainability of buildings, which requires a responsible approach to the environment, awareness of the problem from the public and private sector and a common understanding of society. Only in the last decade significant research has been carried out on this subject, which made it possible to realize the results to be achieved in the area of building sustainability and emphasize the direction to be followed in order to reduce the environmental impact caused by buildings.

Research of scientific articles on the topic has shown quite a big number of studies related to the building sustainability and its evaluation issues carried out all over the world. Many of scientific papers were published within the period of 2016-2018. Authors analyse and compare International sustainability assessment systems such as LEED, BREEAM, Green Star, GBI, Green Mark, BEAM Plus, IGBC and CASBEE [4][5][6]. Similar aspects of green construction are assessed by using different BSAS, however it was a challenge to compare these assessment schemes between each other [7]. The comparison of the assessment areas has revealed that in almost all evaluation systems the highest weights were assigned to the following criteria: use of energy, materials, water, project management, waste management and pollution. This was evident from a mathematical point of view, by analysing weighted criteria of these systems with the highest impact on building certification rating. The approach of CASBEE (Japan) and IGBC (India) was different, since these systems are closely adapted to the environmental problems and peculiarities of construction in these countries [7].

Similarly, local systems based on the needs of the specific country are often compared with the most popular BSAS of LEED and BREEAM [7][8][9]. For example, a scientific study was carried out to identify the key criteria for evaluating green buildings in Estonia [10]. The existing building legislation in Estonia was compared with the practice of BREEAM and LEED certification systems. The best five new buildings that could of qualify for sustainability schemes certification were investigated by comparing their energy consumption, indoor climate, and transport aspects. The results indicated that the existing building regulations in Estonia are not too distant from the evaluation requirements of well-known BSAS, however some aspects, namely building site location and parking issues, are not considered at all.

Sustainable/green building technologies impact on the greenhouse gas emission reduction represents the other significant research trend. Study on the G-SEED, LEED, BREEAM and CASBEE factors, influencing CO<sub>2</sub> emission revealed, that resources and materials as well as energy savings and renewable energy employment factors leads to the best results of green environment [10]. However, the experts of the United States identified the issues influencing green building technologies adoption, such as increased construction costs and duration, lack of special knowledge and education. The most important drivers for green building technologies are reduced utilities costs, higher rent/sale price, higher indoor air quality, reputation and prestige of the real estate development company [11]. Green building certification requires additional time and financial recourses, which are very much dependent on the experience and qualification of project delivery team. Non-experienced or less experienced in green building construction professionals might encounter difficulties in implementing certification requirements for the building, thus a decision support tool for selecting credits based on project delivery attributes was presented [12].

From the literature review the following scientific problems and the green buildings research directions/trends were identified:

- comparison of buildings international sustainability assessment schemes/systems;
- investigation of buildings sustainability assessment by applying international schemes and local standards;
- application of BSAS to reduce CO<sub>2</sub> emissions;
- main factors that stimulate and hinder the uptake of green building technologies;
- selection of a project team for the development of a green building project.

However, the sustainability of the construction phase is not distinguished separately in any BSAS and is evaluated as aggregate of the different scoring system categories.

## 2. Sustainability criteria for the construction phase

CO<sub>2</sub> emission of green building is up to 30 percent lower and it is assumed that the results achieved during the construction phase make a significant contribution to achieving final sustainability goals. There are several BSAS's developed around the world such as LEED, BREEAM, DGNB, Green Star, GBI, Green Mark, BEAM Plus, IGBC, CASBEE, WELL, etc. Generally, these systems describe sustainable construction and methods of operation in a result reflecting approach. Many of these systems are suited to the region where they were developed, some were adapted to be used internationally: LEED – North America, BREEAM – UK, CASBEE – Japan, IGBC – India, etc. Lithuania's example – Lithuanian Building Sustainability Assessment System (LBSAS) which is based on BREEAM and LEED frameworks and adopted to local standards. System is designed according to international sustainability standards to be applied in local Lithuanian market with more suitable and less expensive way (up to ten times compare to the costs of BREEAM or LEED certification). Nevertheless, BREEAM and LEED are most commonly used BSAS systems in Lithuania so far [13]. This research study examines sustainability criteria for the construction phase of BREEAM and LEED systems as well as real examples of certified buildings.

### 2.1. BREEAM sustainability system

BREEAM has developed assessment systems for all building life cycles (design stage, completed building, in-use and renovation). Since the authors of this study are interested in the construction stage, therefore BREEAM International New Construction 2013 technical manual was analysed [14]. Table 1 shows all categories of BREEAM assessment.

**Table 1.** BREEAM assessment categories [14].

Categories	Weighting (%)	Credits
Land Use and Ecology	10	10
Transport	8	9
Water	6	9
Energy	19	30
Materials	12,5	12
Health and Wellbeing	15	10
Waste	7,5	7
Pollution	10	13
Management	12	22
Innovation	10	10
<b>Total:</b>	<b>110</b>	<b>132</b>

The final BREEAM rating is calculated by multiplying the influence of each category with the percentage of points scored and the final rating of evaluation is based on the sum of the accumulated scores. For example, the maximum number of points available for Management is 22, and 11 points were collected which makes 50 percent. The weight of this category is 0.12 and the rating of the category is  $50\% * 0.12 = 6\%$ . In this way, the ratings of all categories are calculated and the overall final rating is defined. BREEAM certification rating benchmarks are: OUTSTANDING ( $\geq 85\%$ ), EXCELLENT ( $\geq 70\%$ ), VERY GOOD ( $\geq 55\%$ ), GOOD ( $\geq 45\%$ ), PASS ( $\geq 30\%$ ) and UNCLASSIFIED ( $< 30\%$ ) [14]. Costs associated with sustainability and certification of BREEAM system depend on the targeted assessment level and the location of the project being developed. The chosen location may lead to an extra cost of 0.5 to 10 percent for the project to get an Excellent rating [15]. For some buildings that qualify for Outstanding rating, additional costs may be estimated up to 20 percent of project value and it is about 2 percent on average to get a Very Good rating [15].

Materials, Waste and Management categories assessed by BREEAM include the criteria associated with the construction stage sustainability assessment [14]. A detailed description of the sustainability criteria associated with construction stage is given in Table 2.

**Table 2.** BREEAM criteria associated with construction stage [14].

No.	Criteria	Credits
1	The principal contractor operates an environmental management system (EMS1) covering their main operations. The EMS must be third party certified to ISO14001/EMAS or an equivalent standard. (Management)	1
2	A sustainability champion is appointed to monitor the project to ensure ongoing compliance with the relevant sustainability performance and process criteria, and therefore BREEAM targets, during the construction, handover and close out work stages (Management)	1
3	Individual is responsible for implementing and maintaining the following considerate construction practices throughout the works stage: Keeping the site clean and tidy, Reducing impacts on the community through community and neighbour engagement, Continuous improvements in safety, Commitments to respect and ensure fair treatment of all workers, Suitable site facilities for operatives and visitors. (Management)	2
4	Monitoring, recording and reporting energy use, water consumption and transport data (where measured) resulting from all on site processes (and dedicated off-site monitoring) throughout the programme (Management)	2
5	Opportunities have been identified, and appropriate measures investigated and implemented, to optimise the more efficient use of materials in building design, procurement, construction, maintenance and end of life. (Materials)	1
6	All timber and timber-based products used on the project are Legally harvested and traded timber (Materials)	1
7	The client or developer has a documented policy and procedure that sets out procurement requirements for all suppliers and trades to adhere to relating to the responsible sourcing of construction products (Materials)	1
8	The available responsible sourcing credits can be awarded where the applicable construction products are responsibly sourced in accordance with the BREEAM methodology (Materials)	3
9	Where appropriate targets for the amount of non-hazardous and hazardous waste produced on site are set in m <sup>3</sup> of waste per 100m <sup>2</sup> or tonnes of waste per 100 m <sup>2</sup> (Waste)	3
10	A significant quantity of non-hazardous construction and demolition waste (where applicable) generated by the project has been diverted from landfill (Waste)	1
11	At least 25% of the high grade aggregate uses (within the development) are provided by secondary or recycled aggregate. This percentage can be measured using either weight or volume (Waste).	1
TOTAL		17

## 2.2. LEED sustainability system

LEED, as well as BREEAM, has schemes for all building life cycles, but for this study LEED Core and Shell v2009 was used only. Categories assessed by LEED are described in Table 3 [16]. LEED system points are awarded for each implemented criterion, scoring points are summarized and total final score is calculated. LEED ratings are: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), Platinum (80 points and above) [16].

**Table 3.** LEED assessment categories [16].

Categories	Weighting (%)	Credits
Sustainable Sites	25,45	28
Water Efficiency	9,09	10
Energy and Atmosphere	33,64	37
Materials and Resources	11,82	13
Indoor Environmental Quality	10,91	12
Regional Priority	3,64	4
Innovation in Design	5,45	6
<b>Total:</b>	100	110

There is a need to look at the additional costs - soft costs and the greening costs of building materials and equipment. Soft costs consist of design, commission, documentation and energy modelling costs. This amounts from 1.5 to 3.1 percent from the total cost of the construction project. The greening costs consist of construction materials and equipment costs can fluctuate greatly, but the overall average is from 5.0 to 8.0 percent [17]. The other research study revealed that seeking LEED certification added 2%–3% to total building costs and less than 2% to the total project cost, depending upon whether the company used an in-house LEED project administrator or outside consultant [18].

Two main categories were identified as related to sustainability of construction stage by LEED: Materials and resources and Indoor air quality. The main criteria assessed by LEED in the construction stage are listed in Table 4.

**Table 4.** LEED criteria associated with construction stage [16]

No.	Criteria (Category)	Points
1	Divert at least 50% of the total construction and demolition material; diverted materials must include at least three material streams (Materials and resources)	2
2	Use salvaged, refurbished or reused materials such that the sum of these materials constitutes at least 5%, based on cost, of the total value of materials on the project. (Materials and resources)	1
3	Use materials, including furniture and furnishings, with recycled content such that the sum of postconsumer recycled content plus 1/2 of the pre-consumer content constitutes at least 10% or 20%, based on cost, of the total value of the materials in the project. (Materials and resources)	2
4	Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within a specified distance of the project site for a minimum of 10% or 20%, based on cost, of the total materials value. All building materials or products have been extracted, harvested or recovered, as well as manufactured within a 500-mile (800 kilometre) radius of the project site. (Materials and resources)	2
5	When using new wood-based products and materials, use a minimum of 50% that are certified in accordance with the Forest Stewardship Council's principles and criteria. (Materials and resources)	1
6	To promote the well-being of construction workers and building occupants by minimizing indoor air quality problems associated with construction and renovation. (Indoor air quality)	1
<b>TOTAL</b>		<b>9</b>

The research of construction stage sustainability impact on the final ratings of BREEAM and LEED certified buildings is presented in the next section.

### 3. Research on construction stage sustainability of BREEAM and LEED certified buildings

#### 3.1. Research Data

By the end of 2018 there were 49 buildings certified by BREEAM, 10 buildings by LEED and 1 building by LPTVS [18]. BREEAM In-use and LEED Building operations and maintenance are the most popular schemes that have been applied in Lithuania, however these schemes do not evaluate construction process. Buildings that have been assessed by BREEAM New construction and LEED New Construction are significantly less in numbers. This part of the study examines construction stage of all administrative buildings that have been assessed by BREEAM and LEED in Lithuania by the beginning of 2019. All the criteria that is associated with construction stage have been investigated by using the earlier mentioned technical manuals and presented in the previous section.

In order to examine the situation about construction stage sustainability in Lithuania the projects that have been assessed by BREEAM International New Construction (Business centre „Saltoniskiu 7,1“, Business centre „Quadrum East“, Business centre „Narbuto 5“) and LEED 2009 for Core and Shell schemes (Business centre „3 burės“, Business centre „Technopolis Ozas Delta A“, Business centre „UNIQ“, Business centre „Penta“) were selected. All of the projects are office buildings, built in capital Vilnius within the period of 2013-2018. Systemized data and achieved assessment scores of BREEAM International New Construction and LEED Core and Shell certified projects are presented in Table 5 [19][20].

**Table 5.** Projects Assessed by BREEAM New Construction and LEED Core and Shell.

Project	Area, m <sup>2</sup>	Year	Sustainability system and scheme	assessment	Final score
Business centre A	15 000	2018	BREEAM International New Construction	73.09%	Excellent
Business centre B	17 000	2016	BREEAM International New Construction	58.20%	Very Good
Business centre C	5 088	2017	BREEAM International New Construction	62.59%	Very Good
Business centre D	29 233	2019	LEED Core and Shell	88/110	PLATINUM
Business centre E	22 500	2013	LEED Core and Shell	66/110	GOLD
Business centre F	10 363	2015	LEED Core and Shell	86/110	PLATINUM
Business centre G	15 204	2017	LEED Core and Shell	74/110	GOLD

The results of the construction stage sustainability criteria of BREEAM New Construction scheme assessed projects are presented in Table 6. It is worth mentioning that environmental monitoring, monitoring of designation, environmental management, the use of legal wood and a small amount of construction waste were the most common targets of Lithuanian construction contractors. The efficient use of materials, responsible purchase of building materials and the use of recycled materials were between the most rarely applied. For the most part, this depends on the client's aspirations and project peculiarities, but there is a noticeable difference in time frame when the project was carried out and evaluation was achieved.

Table 7 presents the real data collected from projects certified by LEED Sustainability Assessment System. It shows the great differences between four LEED-rated buildings. Mostly, the aim was to manage the quality of the building materials produced in the region and the quality of the indoor work. The criteria of certified wood and reused materials were between the least common ones. Although all business centres were built recently, a better performance at the construction stage was achieved only in the last years.

**Table 6.** Results of BREEAM-rated buildings construction stage results.

Criteria	BREEAM benchmark score	Business centre A	Business centre B	Business centre C
Environmental management	1	1	1	1
Construction stage Sustainability Champion	1	1	1	1
Considerate construction	2	2	1	1
Monitoring of construction site impacts	2	2	2	2
Efficient use of materials	1	0	0	0
Legally harvested and traded timber	1	1	1	1
Sustainable procurement plan	1	1	1	0
Responsible sourcing of construction products	3	0	0	0
Construction waste reduction	2	2	2	2
Diversion of resources from landfill	1	1	1	1
Recycled aggregates	1	0	0	0
Construction stage sustainability	13.81%	8.57%	8.02%	6.98%
Achieved result of the construction stage sustainability	100%	62.06%	58.07%	50.54%

**Table 7.** Results of LEED-rated buildings construction stage results.

Criteria	Maximum score	Business centre D	Business centre E	Business centre F	Business centre G
Construction Waste Management	2	1	0	2	2
Materials Reuse	1	0	0	0	0
Recycled Content	2	2	0	1	0
Regional Materials	2	2	2	2	0
Certified Wood	1	0	0	0	0
Construction Indoor Air Quality Management	1	1	1	1	1
Total construction stage sustainability points	9	6	3	6	3
Achieved result of the construction stage sustainability	100%	66.60%	33.30%	66.60%	33.30%

When assessing the sustainability of the projects at the construction stage, the general trend can be observed - the more recent the project, the better the result. This shows that market trends require increasingly higher certificate ratings. The more green building projects were developed by the real estate companies, the higher level of competition was achieved and the better the sustainability ratings were granted.



### 3.2 Results and Discussions

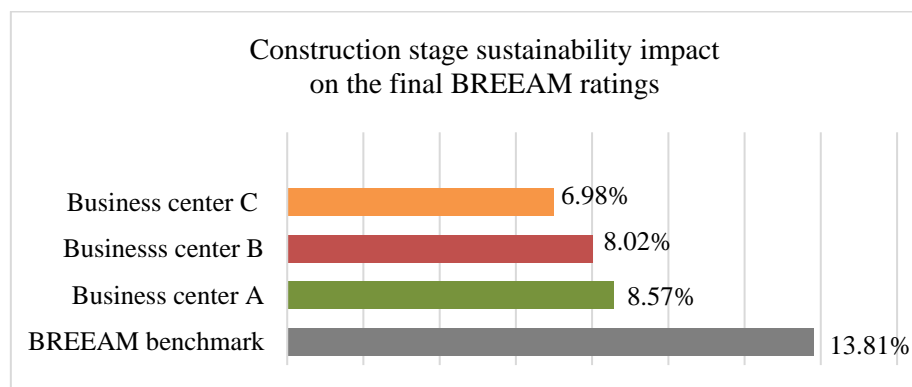
The main aim was to determine whether the sustainability assessments of the construction phase could have influenced the final certification ratings.

Data in Table 8 reflect the sustainability results achieved in the construction stage by each project and the estimated construction stage importance to the result of each project.

**Table 8.** Construction stage sustainability evaluation of BREEAM certified projects.

Construction stage sustainability	BREEAM benchmark score	Business centre A	Business centre B	Business centre C
Construction stage sustainability impact on the final score	13.81%	8.57%	8.02%	6.98%
Final rating score	100% Outstanding	73.09% Excellent	58.20% Very Good	62.59% Very Good
Hypothetic score without construction stage sustainability impact	86.19% Outstanding	64.52% Very Good	50.18% Good	55.61% Very Good

Figure 1 shows that the results achieved at the construction stage had an influence of 6.98% - 8.57%. Two out of three analysed projects would have received lower ratings than they had been rated if sustainability criteria were not reached during the construction phase, i.e. Very Good instead of Excellent, Good instead of Very Good. That means goals of construction stage could have been decisive in terms of the final result if they wouldn't have been achieved at all.



**Figure 1.** Construction stage sustainability impact on the final BREEAM ratings.

Lower than expected certified assessment could be potentially crucial to developers. It could mean lower property and lease prices, slower ROI, lower project brand value in already very competitive markets where sustainability systems are applied. Major contractor has to show compliance and deliver expected results to the client. On the other hand, developer must identify very clear goals about the criteria and principles of sustainable construction implementation during the project delivery. All these features must be included in the contract. Contractor has to evaluate the increased expenses of project management, waste management and materials while bidding for the project. In general, companies working on green building project for the first time usually over-estimate their abilities which can lead to losses on the project. Developer is advised to hire contractors with green building

experience which is capable to deliver expected results on time and ensure fluent progress of the project.

The next step is to compare the results of buildings evaluated in Lithuania with foreign experience. Sweden, France and Belgium are the countries with the widest application of BREEAM system [21]. In the statistics only the scores of main categories are provided. Because BREEAM criteria of the construction stage sustainability stand within the categories of project management, building materials and pollution, the results are compared within the average statistical scores of these categories.

It is seen from the Table 9 that Lithuania's achievements in this area looks quite good compared to the selected countries, however there were only three projects analysed in this research study. The foreign countries' statistical data was based on the analysis of 1660 buildings in France, 668 in Sweden, and 359 in Belgium [21]. Since the data for these countries is considered as statistically proved, the results of the presented Lithuanian green buildings can be seen as a recent trend only.

**Table 9.** Construction stage sustainability results by BREEAM.

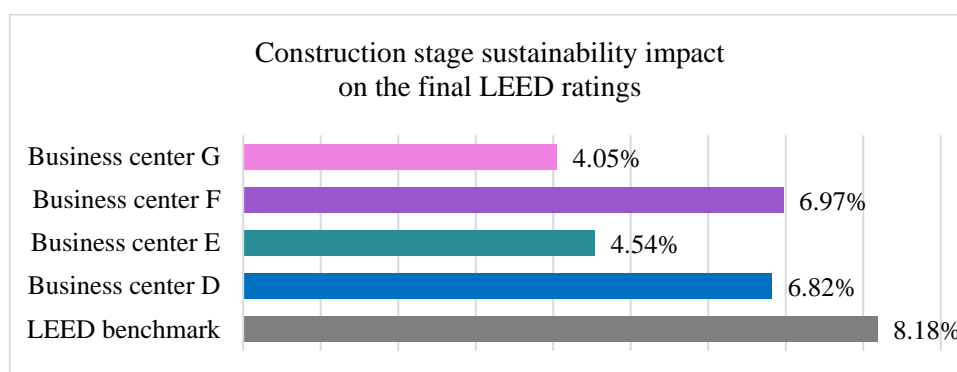
Country	France	Sweden	Belgium	Lithuania
Construction stage sustainability results	51.46%	25.80%	57.22%	56.89%

When LEED results are compiled into the final table, it can be seen that the results achieved at the construction stage had a 4.05% - 6.97% influence, which is not a significant number (Table 10). None of the objects under consideration would have received a lower rating because of the sustainability of the construction stage than it had already received. This is due to the relatively small impact of construction stage sustainability (8.18%) in LEED system (Figure 2).

**Table 10.** Construction stage sustainability evaluation of LEED certified projects.

Construction stage sustainability criteria	Maximum score	Business centre D	Business centre E	Business centre F	Business centre G
<b>Total construction stage sustainability points</b>	9	6	3	6	3
<b>Achieved result of Construction stage sustainability</b>	100%	66.60%	33.30%	66.60%	33.30%
<b>Construction stage sustainability impact on the final score</b>	8.18%	6.82%	4.54%	6.97%	4.05%
<b>Final LEED score</b>	110/110 Platinum	88/110 Platinum	66/110 Gold	86/110 Platinum	74/110 Gold
<b>Hypothetic score without construction stage sustainability impact</b>	101/110 Platinum	82/110 Platinum	63/110 Gold	80/110 Platinum	71/110 Gold

Globally, LEED is the most widely used in countries such as the US, China, Turkey and Brazil [22]. In the US there were 3694 LEED-rated buildings, in China 172, and in Turkey 86 buildings were analysed [22]. Since in the statistical scores of the categories were provided only, the construction stage related ones were considered: Building materials, Indoor air quality and Waste management. Compared results of Lithuania and the selected foreign countries are presented in Table 11.



**Figure 2.** Construction stage sustainability impact on the final LEED ratings.

**Table 11.** Construction stage sustainability results by LEED.

Country	USA	China	Turkey	Brazil	Lithuania
Construction stage sustainability results	78.60%	93.00%	89.30%	89.60%	50.00%

The results achieved in Lithuania are lower compared to foreign countries, which apply LEED system widely. However, with a small sample of data, the meaningful conclusions about the achievement of these criteria in Lithuania cannot be drawn.

#### 4. Conclusions

Green Building construction is one of the most promising ways for reducing the greenhouse gas emission within the created built environment. In Lithuania the construction of the certified sustainable buildings has been started only during the last decade, however the number of green buildings is recently growing fast. There are correspondingly more projects developed with higher assessment scores of sustainability in the recent years in Lithuania. This situation increases the competition between green buildings: buildings with lower ratings are no longer as attractive as projects with superior ratings. It encourages real estate developers to achieve enhanced results and thus create more high quality, sustainable and environmentally friendly buildings.

Literature analysis revealed that many authors of scientific articles compare BREEAM, LEED and other systems as well as their practical applications, analyse CO<sub>2</sub> emission reduction due to adoption of building sustainability assessment schemes, and examine problems and factors that hinder the uptake of sustainable building technologies. However, no studies have been carried out to assess the sustainability of the construction phase.

In order to examine the peculiarities of the sustainability assessment of the construction phase, the technical guides for selected BREEAM International New Construction and LEED Core and Shell schemes were analysed. However, the assessment criteria for the construction phase are not distinguished into a separate category and are assessed as an integral part of the general score. The following categories which include criteria evaluating the sustainability of construction stage were identified: Land use, Transport, Water, Energy, Building materials, Health and indoor environment, Waste, Pollution and Innovation.

7 administrative buildings located in Lithuania rated by BREEAM and LEED were selected for investigation of construction stage sustainability. Assessment of selected buildings in all categories were analysed and weights of construction phase criteria were estimated as well as their impact on the final evaluation result. Calculations have shown that the impact of the construction phase criteria on

the final result of the BREEAM system ranges from 6.98 to 8.57 percent. Since the evaluation step is 10 percent, it have resulted a higher level of the final evaluation. In the LEED system, the total weight of the construction phase criteria ranges from 4.05 to 6.97 percent and in all cases it has not demonstrated a significant impact on the final result because of the of the insignificant achievements of these projects.

The building's sustainability goals in Lithuania are being implemented and the sustainability of the construction phase has a significant impact on the final certification assessment (BREEAM case). Construction phase of sustainable buildings in Lithuania is usually aimed at responsible construction practices, purchase of building materials produced in the region, and management of construction waste. Reused construction materials and the purchase of materials from sustainable building materials producers are the rarest implemented goals. The client's responsibility is to select sustainability goals and set up the requirements for architects, designers, contractors and other participants. At the same time all project participants are obliged to fully implement the criteria of the selected sustainability scheme. It might be considered that the sustainability of a building construction stage is related to the specific solutions of the selected building contractor. The contractors usually have to be aware of the additional costs for green building construction.

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### Acknowledgments

The authors gratefully acknowledge the representatives of JSC “Vesta Consulting” for shearing their knowledge, information and experience.