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EVALUATION OF CREDIT ACHIEVEMENTS OF LEED-CERTIFIED BUILDINGS

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Nowadays, the concept of green building is no longer an alternative but a necessity. The acceptance of a building as "green" depends on having a certificate. LEED is one of the widely used green building certification systems in Turkey. The main objective of this study is to find out whether there were statistically significant differences between the credit achievements of 105 newly constructed and certified buildings in Turkey, which were certified according to four different levels, and to determine which of these credit achievements are weak. For this purpose, Kruskal-Wallis and Mann-Whitney U tests were performed and the findings were interpreted. Findings revealed that the highest level of achievement of these buildings was in sustainable sites, water efficiency, innovation in design, and regional priority credits, while the lowest level of achievement was in energy and atmosphere, materials and resources, and indoor environmental quality credits. Analyses revealed that the achievements in the energy and atmosphere, materials and resources, and indoor environmental quality credits of green buildings are relatively low when compared to the ones in other credits. There may be several reasons behind these low levels of achievement such as poor green culture, high investment cost of necessary systems, absence of reusable, recycled, and renewable materials. If these problems, most of which are peculiar to developing countries, can be overcome, higher certification levels can be achieved.

Keywords: Sustainability, Green building, Certification systems, New construction.

1 INTRODUCTION

The growth of the world population over the last 60 years has significantly increased the demand for natural resources such as water, energy, etc. As a result of this increase, environmental problems such as global warming, decrease of water quantity and quality, air pollution, and health problems have emerged. Buildings, which were built by using conventional methods, are responsible for nearly 30% of greenhouse gas production, and consuming approximately 60% of electricity and about 15% of drinking water (Castro-Lacouture *et. al.* 2009, Dwaikat and Ali 2016). Consequently, the concept of green building has emerged as a necessity, not an alternative.

Green building can be defined as eco-friendly buildings using natural and non-waste materials, and consuming resources as much as necessary during their lifecycle (Dwaikat and Ali 2016). Green building certification systems based on specific criteria have been developed to assess whether the constructed structures have the green building feature. Some countries use certification systems that they have developed, while some others adopt standard ones. There are various accepted green building certification systems all around the world. Two of the widely

used certification systems are: Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) (Suzer 2015).

Same as many developing countries, the number of green buildings and the demand for them has considerably increased in Turkey over the last decade. LEED is one of the widely used certification systems in Turkey. U.S. Green Building Council (USGBC) announced the Top 10 Countries for LEED, which is a list that highlights countries outside the United States where LEED originated. In this list, China ranked first on the list as the largest market of LEED, with 34.62 million gross square meters (GSM) of certified LEED space. Canada, India, Brazil and the Republic of Korea, Taiwan, Germany, Turkey, Sweden and United Arab Emirates are the other countries in this list, respectively (Sawit 2016).

There are five rating systems listed in LEED: Building Design and Construction (BD+C), Interior Design and Construction (ID+C), Building Operations and Management (O+M), Neighborhood Development (ND), and Homes. BD+C cover the buildings that are newly constructed or going through a major renovation. BD+C apply to the following project types: new construction and major renovation (NC), core and shell development, schools, retail, healthcare, data centers, hospitality, and warehouses and distribution centers. LEED v4 originated in 2013 and LEED v3 2009 was still in effect till October 2016 (USGBC 2009). Therefore, the number of buildings certified according to LEED v4 is very low when compared to the ones according to LEED v3 2009.

The main objective of this study is to find out whether there were statistically significant differences between the credit achievements of newly constructed buildings in Turkey, which were certified according to four different levels, and to determine which of these credit achievements are weak. For this purpose, Kruskal-Wallis and Mann-Whitney U tests were performed and the findings were interpreted.

2 LEED CERTIFICATION SYSTEM FOR NEW CONSTRUCTION

LEED for Building Design and Construction (LEED BD+C) can be used for the core and shell development of any high-rise building, as well as retail, healthcare or hospitality premises, schools, offices, data centers, warehouses and distribution centers. LEED BD+C are designed for new construction and major renovation projects. At least 60% of the project's gross floor area must be completed by the time of certification (Gurgun *et. al.* 2016).

LEED is a point-based certification system. Any project earns LEED points by meeting certain prerequisites and credits. There are seven credit categories for New Construction with LEED v3 2009, which include: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and regional priority. Credits, their prerequisites and points for each credit are presented in Table 1 (USGBC 2009, Uğur and Leblebici 2017).

Table 1. LEED v3 2009 for new construction.

	Credits and Their Prerequisites	Points
	Sustainable Sites (SS)	**26 Possible Points**
Prerequisite 1	Construction Activity Pollution Prevention	Required
	Water Efficiency (WE)	**10 Possible Points**
Prerequisite 1	Water Use Reduction	Required
	Energy and Atmosphere (EA)	**35 Possible Points**
Prerequisite 1	Fundamental Commissioning of Buildings Energy Systems	Required
Prerequisite 2	Minimum Energy Performance	Required
Prerequisite 3	Fundamental Refrigerant Management	Required

Table 1 (Continued). LEED v3 2009 for new construction.

	Credits and Their Prerequisites		Points
	Materials and Resources (MR)		**14 Possible Points**
Prerequisite 1	Storage and Collection of Recyclables		Required
	Indoor Environmental Quality (IEQ)		**15 Possible Points**
Prerequisite 1	Minimum Indoor Air Quality Performance		Required
Prerequisite 2	Environmental Tobacco Smoke (ETS) Control		Required
	Innovation in Design (ID)		**6 Possible Points**
	Regional Priority (RP)		**4 Possible Points**
		Maximum Total Points	**110 Points**

Rating is based on a 110-point system. Total points and range of credits possible points vary depending on the type of building. A building requires at least 40 points for certification in LEED v3 2009. There are four types of certificates; Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), and Platinum (80 and over) (USGBC 2009).

3 CREDIT ACHIEVEMENTS OF LEED-CERTIFIED BUILDINGS IN TURKEY

Since the LEED for New Construction was first published in 1999, it has been assisting practitioners in improving the quality of buildings and reducing their impacts on the environment. LEED's priority criteria are the physical environment, society, transportation, green energy, heat islands, light pollution, water usage, greenhouse gas emissions, materials, waste, indoor air quality, as well as quantity and user comfort. Energy and atmosphere, and sustainable sites credit categories account for 51% of the maximum achievable points in LEED v3 2009 (USGBC 2009).

According to information obtained from the USGBC project website, there are 425 registered projects in Turkey. 240 of them are categorized as New Construction and 219 of them are evaluated according to the LEED v3 2009. Out of these 219 projects, 105 projects received certificate after the evaluation process. The scorecards of these 105 projects were obtained from the USBGC project website.

Average values, standard deviations, and percentage of credit achievements, and the number of projects for each certification level are presented in Table 2.

Table 2. Credit achievements of LEED-NC 2009 certified buildings in Turkey.

Credits and Max. Achievable Points	**Certification Level and Number of Buildings**											
	Certified (8)			***Silver (17)***			***Gold (71)***			***Platinum (9)***		
	Ave.	Std. Dev.	Ach. %	Ave.	Std. Dev.	Ach. %	Ave.	Std. Dev.	Ach. %	Ave.	Std. Dev.	Ach. %
SS (26)	16.63	2.26	63.94	18.41	2.98	70.81	18.87	3.22	72.59	21.00	3.24	80.77
WE (10)	3.75	1.91	37.50	6.71	2.62	67.06	8.13	2.09	81.27	9.56	0.88	95.56
EA (35)	9.00	2.78	25.71	9.65	4.31	27.56	14.61	4.82	41.73	26.56	5.55	75.87
MR (14)	4.00	1.07	28.57	5.29	1.16	37.82	5.70	1.28	40.74	6.22	1.48	44.44
IEQ (15)	4.88	2.10	32.50	6.76	2.19	45.10	8.39	2.27	55.96	11.44	2.35	76.30
ID (6)	2.88	1.25	47.92	4.12	1.05	68.63	5.00	0.99	83.33	5.56	0.53	92.59
RP (4)	2.63	0.74	65.63	2.88	0.93	72.06	3.65	0.56	91.20	3.89	0.33	97.22

The comparison of the percentages of credit achievements of 105 green buildings with respect to different certification levels is shown in Figure 1.

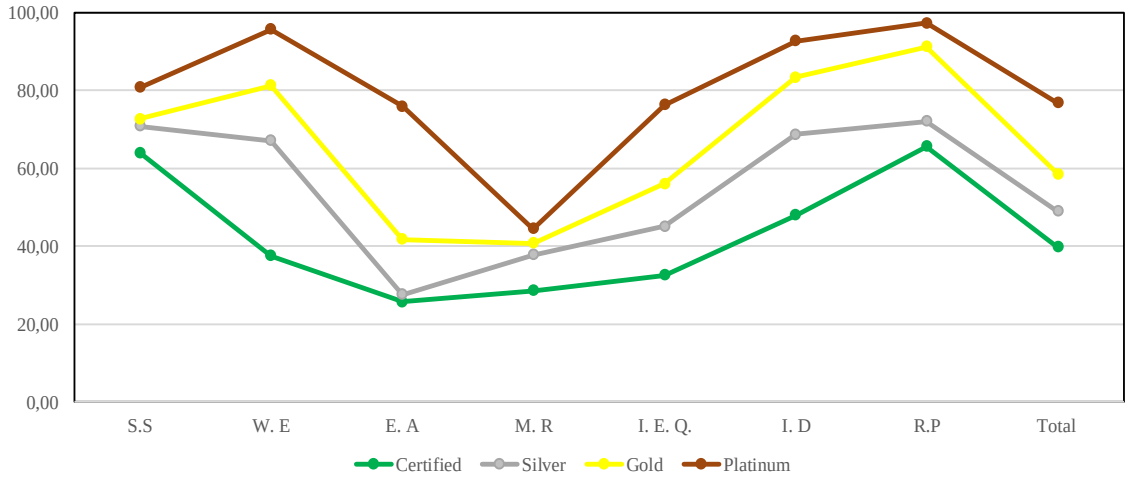

Figure 1. Comparison of percentages of credit achievements of LEED-NC 2009 certified buildings.

According to Figure 1, it can be interpreted that while the percentages of achievements in materials and resource (M.R) credit are very close in all certification levels, the percentages of achievements in energy and atmosphere (E.A) and indoor environmental quality (I.E.Q) credits in platinum certified buildings are very high when compared to the ones in other certification levels.

Another aim of this study is to find out whether there were statistically significant differences between the credit achievements of newly constructed buildings in Turkey, which were certified according to four different levels. For this purpose, Kruskal-Wallis test was conducted via the StatTools v 7.5 software. Kruskal-Wallis is a technique, which is used to test the significance of differences between averages of three or more groups in non-normal distribution groups (Choudhry and Iqbal 2012). The *p* values obtained from the Kruskal-Wallis test are presented in Table 3. If the *p* values are less than 0.05, it indicates that there is a statistically significant difference in credit achievements of buildings certified according to different certification levels at 95% significance level.

Table 3. Kruskal-Wallis test *p* values of credits.

Credits	Kruskal-Wallis Test *p* Value
Sustainable Sites	**0.0314***
Water Efficiency	**0.0000***
Energy and Atmosphere	**0.0000***
Material and Resources	**0.0036***
Indoor Environmental Quality	**0.0000***
Innovation in Design	**0.0000***
Regional Priority	**0.0000***

* Statistically significant at 95%.

According to Table 3, the Kruskal-Wallis test *p* values are less than 0.05 for each credit. This means that the credit achievements of buildings certified according to four certification levels are statistically significant different at 95% significance level. Having conducted the Kruskal-Wallis test, the Mann-Whitney U test was performed in order to determine whether there is a statistically significant difference in credit achievements of buildings certified according two different certification levels. The Mann-Whitney U test is a non-parametric technique used to test the

significance of differences between two independent group averages in non-normal distribution groups (Chan *et. al.* 2011). If the *p* values are less than 0.05, it indicates that there is a statistically significant difference in credit achievements of buildings certified according to two certification levels at 95% significance level. The *p* values obtained from the Mann-Whitney U test are presented in Table 4.

Table 4. Mann-Whitney U test *p* values of credits.

Credits	Certification Level	Mann-Whitney U Test *p* Values			
		Certified	Silver	Gold	Platinum
Sustainable Sites (SS)	Certified	-	0.2028	**0.0169***	**0.0111***
	Silver		-	0.4823	0.0978
	Gold			-	0.1128
	Platinum				-
Water Efficiency (WE)	Certified	-	**0.0083***	**0.0000***	**0.0000***
	Silver		-	**0.0326***	**0.0047***
	Gold			-	**0.0448***
	Platinum				-
Energy and Atmosphere (EA)	Certified	-	0.9068	**0.0008***	**0.0000***
	Silver		-	**0.0003***	**0.0000***
	Gold			-	**0.0000***
	Platinum				-
Materials and Resources (MR)	Certified	-	**0.0174***	**0.0009***	**0.0055***
	Silver		-	0.2171	0.1471
	Gold			-	0.3684
	Platinum				-
Indoor Environmental Quality (IEQ)	Certified	-	0.0598	**0.0008***	**0.0003***
	Silver			**0.0109***	**0.0006***
	Gold				**0.0015***
	Platinum				-
Innovation in Design (ID)	Certified	-	**0.0308***	**0.0002***	**0.0003***
	Silver		-	**0.0029***	**0.0015***
	Gold			-	0.1254
	Platinum				-
Regional Priority (RP)	Certified	-	0.5526	**0.0000***	**0.0006***
	Silver		-	**0.0004***	**0.0050***
	Gold			-	0.2133
	Platinum				-

* Statistically significant at 95%.

4 FINDINGS AND CONCLUSION

According to the analysis results, the following findings can be highlighted:

- In the sustainable sites credit, the average achievement of the certified buildings remained significantly lower than the gold and platinum buildings, and there is a statistically significant difference between them. However, the average achievement of certified buildings is at the same level of silver buildings, and there is no statistically significant difference between them. Silver, gold and platinum buildings have the same average level of achievement and there is no statistically significant difference among them.
- In the water efficiency credit, the average achievements of all certification levels vary greatly. For this reason, there is a statistically significant difference among all certification levels.

- In energy and atmosphere and indoor environmental quality credits, the average achievement of certified buildings and silver buildings are at the same level, and there is no statistically significant difference between them. There is a considerable difference among the average achievements of the other certification levels, and there is a statistically significant difference among them.
- In materials and resources credit, the average achievement of certified buildings is considerably lower than those of silver, gold and platinum buildings, and there is a statistically significant difference between them. Silver, gold and platinum buildings have the same average level of achievement and there is no statistically significant difference among them.
- In the innovation in design credit, the average achievements of platinum and gold buildings are at the same level, and there is no statistically significant difference between them. There is a considerable difference among the average achievements of the other certification levels, and there is a statistically significant difference among them.
- In the regional priority credit, the average achievements of platinum and gold buildings, and certified and silver buildings are respectively at the same level, and there is no statistically significant difference within each pair.

The analyses revealed that the achievements in the energy and atmosphere, materials and resources, and indoor environmental quality credits of green buildings are relatively low when compared to the ones in other credits. There may be several reasons behind these low levels of achievements. First, the green culture is not very mature. Second, the initial investment cost of necessary systems (e.g., HVAC systems) is very high. Third, renewable energy sources are very limited. And fourth, manufacturing of reusable, recycled, and renewable materials is very limited and most of them are imported, which in turn increases the purchasing cost and brings about logistics problems. In future studies, these reasons can be discussed in more details.

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