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Measuring the environmental performance of urban regeneration projects using AHP methodology

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Abstract

As the world continues to urbanize, integrated policies to improve the lives of both urban and rural dwellers are needed. It could be claimed that the best way to address such problems in major cities is through sustainable urban regeneration where economical, ecological and social impacts of urbanization are examined and practiced thoroughly. In the literature review, the number of publications and identified key performance indicators are found as insufficient. Also, the key performance indicators identified in publications are insufficient for project-specific performance measurement. Most of them do not include validation and verification of the models. In this study, specific focus is on the environmental performance dimension of sustainable project performance. Thus, this study aims to provide a source for these problems and to systematically measure the environmental performance of urban regeneration projects. It also provides the formulation of the environmental performance measurement model and defines key performance indicators. The data obtained from the literature review and field studies. The proposed AHP model incorporates 9 performance criteria, and 55 related KPIs. After determining the hierarchical structure of KPIs, they are rated using a 7-point Likert scale questionnaire to identify their priority. Next, AHP process have been conducted by participation of 25 experts. Finally, the environmental performance measurement model for urban regeneration projects has been developed. Study results indicate that “Energy” criteria has the highest priority level for determining the environmental performance of urban transformation projects. Consecutively, “Water” criteria comes after followed by “Land Use” and “Ecology”.

Keywords
Environmental sustainability, Urban regeneration, Analytic Hierarchy Process (AHP), Key Performance Indicator (KPI), Construction sector.

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1. Introduction

The construction industry has an important role in national economies by stimulating economic growth in terms of the inputs it uses due to the demand for goods and services produced by directly or indirectly connected subsectors. It contributes to employment and this makes driving force in economic growth (Berk, Biçen, & Seyidova, 2017). Tsolas (2011) stated that financial statements should include a reflection of the construction industry's success.

However, the construction sector is often criticized as having a low level of efficiency due to its unique characteristics. The low level of efficiency is attributed to features such as cost, time-out, poor quality, customer dissatisfaction, and low profitability. Several researchers state that the productivity of the construction industry has declined over the last few decades compared to other economic sectors (Arditi, 1985; Rojas & Aramvareekul, 2003).

It is a known fact that today's construction industry comprises more advanced and larger projects incorporating more complicated systems. Hence, it has become more challenging to reach the goals in terms of time, cost and quality. It can be argued that one of the reasons for not achieving these goals effectively is inconsistency and inefficiency in measuring and managing project performance. In addition to that, increasing competition in the business world calls for additional challenges for the construction industry to measure performance beyond financial and quantitative indicators. (Tekçe, 2010).

Literature research on performance measurement indicates that studies related to performance measurement are generally focused on the project level since construction by nature is a project-based activity (Akkoyun & Dikbas, 2008). Performance Measurement of the Construction sector has been investigated by several researchers in the past. However, the focus of most research tends to be on general projects (Chan & Chan, 2004; Fang, Huang, & Hinze, 2004; Jones & Kaluarachchi, 2008; Lam, Chan, & Chan, 2007; Lin & Shen, 2007; Pillai, Joshi, & Rao, 2002; Sharma, 1995; Yeung, Chan, & Chan, 2008; Yeung, Chan, Chan, & Li, 2007) and construction companies (Chan & Chan, 2004; Fang, Huang, & Hinze, 2004; Jones & Kaluarachchi, 2008; Lam, Chan, & Chan, 2007; Lin & Shen, 2007; Pillai, Joshi, & Rao, 2002; Sharma, 1995; Yeung, Chan, & Chan, 2008; Yeung, Chan, Chan, & Li, 2007) . There are limited studies (Işik & Aladağ, 2017; Kim, 2010; van Twist et al., 2015; Yıldız, 2018) specialized in sustainable performance management of urban regeneration projects.

Current literature suggests that there is no single performance measurement and assessment method used at the project, firm and industry levels in the construction industry.

The future research topics has been suggested such as (1) determining the current applications in the industry and developing non-financial qualitative performance measurement and evaluation methods, (2) developing techniques for the application of performance measurement systems, (3) designing more dynamic and flexible performance measurement systems and solving the problems of transferring the performance measurement models to the administrative models in the field of performance measurement and evaluation (Bassioni, Price, & Hassan, 2004).

Population, production, housing, technical infrastructure systems, education-culture-arts-management organizations that are concentrated in urban centers of the world are constantly growing. At the same time, these cities are experiencing economic, technological, social and cultural transformations together (Topal, 2004). This rapid growth of the cities mostly in developing countries is far ahead of these countries' urban management and planning capacities. Consequently, this situation results in disrupting effects in managing and planning urban growth (Yazar, 2006). Cities are becoming potential centers for many economic, environmental and social problems, such as inequality, unemployment, poverty, inadequate infrastructure, congestion, violence, and diseases (Blowers & Pain, 1999; Jian, De-nong, & Yu-kun, 1999).

With a series of events; rapid urbanization and construction, decreasing green areas, increasing the need for energy consumed in 75% of the big cities, unlimited and unconscious consumption of natural resources, intensive use of fossil-based energy resources and increasing greenhouse gas emissions, which are responsible for cities over 80%, heating problem, ozone layer wear and so on, our world has to face many ecological problems today (Yıldız, 2018).

The need for large housing in this process is met by low-quality, energy-efficient, and earthquake-resistant housing and a significant proportion of slums. As a result, especially in big cities, historical and cultural values as well as green areas were destroyed, both physical and social infrastructures were insufficient.

The world is experiencing an enormous population increase than it has seen in history, and on the other hand, it is becoming urbanized at the same speed. The problems caused by urbanization, which developed in an unplanned way from the beginning, have grown together with more environmental degradation, more unhealthy structures, economic and socially unqualified physical environments that have emerged with the aging of cities (Yıldız, 2018).

The solution to these problems experienced by cities can be evaluated as urban transformation. According to Keleş (1998), an urban transformation has been defined as follows: changing, transforming, improving and revitalizing urban areas that are worn over time for different reasons, sometimes abandoned, unidentified, unqualified and non-standard, following with the socio-economic and physical conditions of the day (Keleş, 1998).

Urban transformation projects can be realized in line with sustainability principles to improve the environmental quality, address the problem of urban degradation, meet various socio-economic needs, strengthen existing social communication networks, improve the inclusion of vulnerable groups and change the negative impacts on the living environment.

Here it is important to determine whether an urban transformation activity is sustainable. Considering that the concept of sustainable urban transformation sometimes overlaps with many concepts such as sustainable structure, sustainable development, and sustainable urban development, it can be said that the world literature is very rich in this sense, but the number of comprehensive studies based on the measurement of sustainable urban transformation is quite limited (Yıldız, 2018).

In the interviews with the experts experienced in urban regeneration projects, It has been stated that there is an urgent need for a structured performance measurement model specifically designated for urban regeneration projects. The model is expected to include key performance indicators determined for widespread use.

Considering sustainability as a whole with its economic, environmental and social dimensions comprises: (1) improvement inland, (2) improvement in environmental quality, (3) elimination of the problem of urban degradation, (4) meeting socio-economic needs, (5) strengthening existing social communication networks, (6) involving vulnerable groups, and (7) changing the negative effects on the living environment. It has become a very important concept to realize by following sustainability principles (Yıldız, 2018).

To date, many researchers have pointed to problems that cause poor performance in the construction industry. (Uğural, Giritli & Urbański, 2020). These are addressed as the main reasons for lower performance both in the process and the product. The current performance measurement models usually focus on different aspects of performance. However, there are some limitations to these studies:

(1) The number of publications in the literature related to the performance measurement of urban regeneration projects is insufficient (Ali, Al-Sulaihi, & Al-Gahtani, 2013; Cheng, Tsai, & Lai, 2009; Egan, 1998; Jin, Deng, Li, & Skitmore, 2013; Kagioglu, Cooper, & Aoudad, 2001; Latham, 1994; Nudurupati, Arshad, & Turner, 2007; Wang, Lin, & Huang, 2010; Yeung, Chan, & Chan, 2009; Yu, Kim, Jung, & Chin,

2007),

(2) Key performance indicators identified in publications are insufficient for project-specific performance measurement (Aladağ & Işık, 2016; Chan & Lee, 2008; Hemphill, Berry, & McGreal, 2004; Hunt, Lombardi, Rogers, & Jefferson, 2008; Işik & Aladağ, 2017; Michael, Noor, Zardari, & Figueroa, 2013; Shen, Ochoa, Shah, & Zhang, 2011; Yıldız, 2018),

(3) Most of them do not include validation of identified indicators or models (Aladağ & Işık, 2016; Chan & Lee, 2008; Hunt et al., 2008; Işik & Aladağ, 2017; Yıldız, 2018) and most importantly,

(4) Developed models are not tested in suitable projects (Aladağ & Işık, 2016; Chan & Lee, 2008; Hunt et al., 2008; Işik & Aladağ, 2017; Yıldız, 2018).

Besides, another problem to address is that the environmental, economic and social aspects of sustainable performance are not assessed thoroughly. Especially there are difficulties in comparing the urban regeneration projects and producing data for future studies. Although the importance of performance measurement for urban regeneration projects is highlighted in many studies (Aladağ & Işık, 2016; Chan & Lee, 2008; Hemphill, Berry, et al., 2004aa; Hunt et al., 2008; Işik & Aladağ, 2017; Michael et al., 2013; Shen et al., 2011; Yıldız, 2018). A practical and effective sustainable performance measurement model is still needed for urban regeneration projects.

This study is part of larger research that focuses on developing a sustainable performance measurement model for urban regeneration projects by analyzing performance indicators, performance measurement approaches, and conceptual frameworks in the literature. The model intends to provide an opportunity for measuring the overall sustainable performance of urban regeneration projects with a multi-criteria hierarchical approach by the utilization of key performance indicators. The first task is to identify sustainability performance indicators. Another specific task includes determining the importance weights of the components that form the performance measurement model with the Analytic Hierarchy Process (AHP) method.

This study aims to develop and present a specific model to measure the environmental performance of urban regeneration projects. It is important to note that the proposed model focuses on success criteria rather than factors affecting environmental performance.

2. Background

Research on performance measurement in the construction industry has been performed in different approaches. Some of the researchers worked on different levels of construction business (i.e. project, industry, organization). Others investigated frameworks of performance measurement (i.e. European foundation for quality management excellence model (EFQM), Balanced Scorecard (BSC) model, Key performance indicators (KPI) model). Another group worked on research techniques (i.e. Gap analysis, Integrated performance index, Statistical methods, Data envelopment analysis (DEA)) (Table 1).

There is also some research focused on performance measurement of urban regeneration projects. For this study, a thorough search has been conducted on the Web of Science database using keywords. The related period was

Table 1. *Performance Measurement in Construction.*

CRITERIA	SUBCRITERIA	KEY REFERENCES
Levels of performance measurement in construction	Project Level	(Chan & Chan, 2004; Fang, Huang, & Hinze, 2004; Jones & Kaluarachchi, 2008; Lam, Chan, & Chan, 2007; Lin & Shen, 2007; Pillai, Joshi, & Rao, 2002; Sharma, 1995; Yeung, Chan, & Chan, 2008; Yeung, Chan, Chan, & Li, 2007)
	Organizational Level	(Bassioni et al., 2004; Bassioni, Price, & Hassan, 2005; El-Mashaleh, Edward Minchin, & O'Brien, 2006; Horta, Camanho, & Da Costa, 2009; Jin et al., 2013; Kaplan & Norton, 1992; Lin & Shen, 2007; Luu, Kim, Cao, & Park, 2008; Punniyamoorthy & Murali, 2008; Robinson, Carrillo, Anumba, & Al-Ghassani, 2002; Westerveld, 2003; Yu et al., 2007)
	Stakeholder Level	(Ahadzie, Proverbs, & Olomolaiye, 2008a, 2008b; Dainty, Cheng, & Moore, 2003; W. P. Wong & Wong, 2008)
Frameworks of performance measurement in construction	European foundation for quality management excellence model (EFQM)	(Bassioni et al., 2005; Westerveld, 2003)
	Balanced scorecard (BSC) model	(Kagioglu et al., 2001; Kaplan & Norton, 1992; Luu et al., 2008; Robinson, Anumba, Carillo, & Al-Ghassani, 2005; Yu et al., 2007)
	Key performance indicators (KPI) model	(Ahadzie et al., 2008a, 2008b; Chan & Chan, 2004; Dainty et al., 2003; Horta et al., 2009; Lam et al., 2007; Lin & Shen, 2007; Robinson et al., 2002; Yu et al., 2007)
Research techniques for performance measurement in construction	Gap analysis	(Jones & Kaluarachchi, 2008)
	Integrated performance index	(Pillai et al., 2002; Punniyamoorthy & Murali, 2008; Sharma, 1995; Yeung et al., 2007; Yu et al., 2007)
	Statistical methods	(Ahadzie et al., 2008a, 2008b; Fang et al., 2004)
	Data envelopment analysis (DEA)	(El-Mashaleh et al., 2006; Horta et al., 2009; W. P. Wong & Wong, 2008)

chosen to cover the last decade. Table 2 provides brief information about the relative publications.

Related search, reveals a limited study in certain areas:

"A fuzzy AHP model to assess the sustainable performance of the construction industry from urban regeneration perspective" studies with the sustainable performance of the construction industry with the approach of an affected factor of success (Işik & Aladağ, 2017).

"Assessing and Appraising the Effects of Policy for Wicked Issues: Including Unforeseen Achievements in the Evaluation of the District Policy for Deprived Areas in The Netherlands". This study recommends developing property policies enhancing the performance of urban regeneration projects. However, it does not directly provide any insight into the performance measurement of construction projects (van Twist et al., 2015).

"Risk Performance Indexes and Measurement Systems for Mega Construction Projects". This study strives to incorporate risks into cost and schedule performance measurement using 18 indicators, specific to mega construction projects including large urban regeneration programs (Kim, 2010).

Urban regeneration performance assessment frameworks are commonly traced via an indicator-based approach (Audit Commission, 2002; Wong, 2000). According to Hemphill et al. (2004a), indicators are useful to determine the economic statue of regeneration actions, the performance of projects and organizations, and the effectiveness level of collaborating. Also, it is highlighted that the KPIs should contain qualitative and quantitative information about performance.

Table 2. *Performance Measurement of Urban Regeneration Projects.*

Title	Year	Author	Journal	Keywords
A fuzzy AHP model to assess sustainable performance of the construction industry from urban regeneration perspective	2017	(Işik & Aladağ, 2017)	Journal Of Civil Engineering And Management	performance measurement; sustainable performance; urban regeneration; construction industry; multi-criteria decision making; fuzzy logic; Fuzzy Analytic Hierarchy Process (FAHP)
Assessing and Appraising the Effects of Policy for Wicked Issues: Including Unforeseen Achievements in the Evaluation of the District Policy for Deprived Areas in The Netherlands	2015	(van Twist et al., 2015)	International Journal Of Public Administration	complexity; performance evaluation; unforeseen achievements; wicked problems
Risk Performance Indexes And Measurement Systems For Mega Construction Projects	2010	(Kim, 2010)	Journal Of Civil Engineering And Management	risk management; performance measurement; risk performance index; construction industry; mega construction

The determination of sustainable performance indicators is the primary issue to achieve performance measurement. In a recent study by Michael et. al. (2013), a list of sustainability indicators was obtained from thirteen studies and compacted into four dimensions (economic development, social sustainability, environmental conservation, institutional strength. Fifteen postgraduate students were asked to complete the questionnaires and evaluated the indicators for the AHP process. The results of this study indicate that the environmental dimension has more importance than other dimensions. Also, prior indicators are listed as "employment rate", "access to public utilities", "air quality", "enforcement operations". The limitations of this research can be listed as: (1) indicator selection methodology cannot be seen as suitable for every urban regeneration project. Also, it does not include indicators such as compliance with acoustic standards, number of training, issues related to health and safety. Since the major focus of the paper is to provide a systematic approach to sustainability to decision-makers, project performance focus is not properly presented. Finally, there is no contribution from industry experts and the study does not include any verification process using real-life case studies.

Another study proposes a set of affecting factors for socially sustainability projects (Chan & Lee, 2008). The authors focus on the investigation of urban regeneration projects under six critical factors (Satisfaction of Welfare Requirements", "Conservation of Resources & the Surroundings", "Creation of Harmonious Living Environment", "Provisions Facilitating Daily Life Operations", "Form of Development" and "Availability of Open Spaces"). Their research includes a pilot study with contributions from subject matter experts and random people. Some of the limitations of the paper include: (1) major focus on social aspects, no insight on economic and environmental performance, (2) the performance indicators and measurement techniques have not been addressed.

Another study analyzes the decision-making process, assessing sustainable development through evaluation of the indicators (Hunt et al., 2008).

Large scale urban regeneration projects have the potential to be a driving force for the country's economy. Hence, it is quite important to determine the criteria and indicators affecting the performance of these projects to ensure the effective performance of the construction sector in the long term. One of the recent research examined this topic to determine sustainable key performance indicators for construction companies working in urban regeneration projects (Aladağ & Işık, 2016). The authors investigate sustainable project performance under five main topics (i.e. economic, social, environmental, innovation and research & development, and company performance). However, the study is limited only with Turkish construction data and may require additional statistical analyses of KPIs to develop a model.

Hemphill, Berry et al. (2004a) determine four basic performance areas for sustainability in urban regeneration projects as the economic resource use; buildings and land use; transport and mobility, and community benefits. Also, a scoring framework is developed for benchmarking "good" sustainable urban regeneration practice. This study focuses mainly on sustainability and ignores other conventional performance measurement criteria. The authors apply their developed model in their following study (Hemphill, McGreal, & Berry, 2004b).

Hemphill's framework was used at Langstraat's (2006) study and concluded as an efficient methodology to evaluate the sustainable performance of regeneration projects (Langstraat, 2006). According to the results, sustainability and level of success differentiate over urban regeneration projects in Britain. Shen et al. (2011) identified environmental, economic, social and governance factors with a set of 32 indicators namely the International Urban Sustainability Indicators List (IUSIL). In this paper, nine different cities were explored, and indicators were evaluated through these practices to analyze and benchmark the different circumstances and selection of indicators.

This study aims to develop and present a specific model to measure the environmental performance of urban regeneration projects. It is important to note that the proposed model focuses on success criteria rather than factors affecting environmental performance.

To determine the environmental performance criteria and key performance indicators, a literature search on green building rating systems and sustainability models in construction has been conducted. Findings have been updated with contribution from subject matter experts including (1 academician, 2 green building experts, and 2 contractors currently working on urban regeneration projects. The model contents and the hierarchical structure of the model were discussed thoroughly, and data has been gathered for the Analytical Hierarchical Process (AHP). The data were analyzed using the AHP methodology. Major goals of this study included: (1) to guide each group participating in urban regeneration projects and affected by urban regeneration projects, (2) to evaluate environmental performance, which is the most important step of sustainability, (4) to make comparisons between projects with respect to environmental performance aspect, (5) to assist in developing strategic goals and (6) and ultimately to ensure the success of environmentally sustainable projects.

3. Key Performance Indicators

Time, cost and quality, "the iron-triangle" (Atkinson, 1999) is accepted to be the basic performance measurement criteria (Barkley & Saylor, 1994). As a result of the literature study and corresponding workshop, 7 categories (2nd dimension) 28 criteria (3rd dimension) and 135 indicators (4th dimension) of the proposed sustainable project performance measurement model were determined. However, this study focuses on the environmental performance category. This study focuses on

Table 3. *Environmental Performance Components.*

1st DIMENSION	2nd DIMENSION	KEY REFERENCES	3rd DIMENSION	KEY REFERENCES	4th DIMENSION	KEY REFERENCES
OVERALL SUSTAINABLE PERFORMANCE	ENVIRONMENTAL PERFORMANCE (EP)	(Aladağ & Işık, 2016; Chan, Scott, & Lam, 2002; Chan & Tam, 2000; Hemphill, Berry et al., 2004a; Lin & Shen, 2007; Maclaren, 1996; Rankin, Fayek, Meade, Haas, & Manseau, 2008; Tekçe, 2010; Wong, 2000; Yang, Yeung, Chan, Chiang, & Chan, 2010)	Ecological (EP1)	(Aladağ & Işık, 2016; ISI, 2012)	(EP1-1) Level of protection or restoration of habitat	(Couch & Dennemann, 2000; Council, 2013; ISI, 2012)
					(EP1-2) Total carbon emissions	(Council, 2013; Hemphill, Berry, et al., 2004a)
					(EP1-3) Ecological footprint	(Council, 2013; Wackernagel & Rees, 1996)
			Design (EP2)	Aladağ & Işık, 2016; ISI, 2012)	(EP2-1) Level of esthetic design	(Aladağ & Işık, 2016)
					(EP2-2) Level of landscape design	(Aladağ & Işık, 2016)
					(EP2-3) Level of integrated design policies	
			Land Use (EP3)	(Aladağ & Işık, 2016; Babcicky, 2013; Carbonaro & D' Arcy, 1993; Cullingworth & Nadin, 2006; DTI (Deparment of Trade and Industry), 1998; DETR, 1998c, 1998b, 1998d, 1998a, 1998e; Hemphill, McGreal, et al., 2004b; ISI, 2012; Johnston, 1998; Ravetz, 1996; Saisana, 2014)	(EP3-1) Level of effective site selection	(Aladağ & Işık, 2016; Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a)
					(EP3-2) Preservation level of high value landscapes and its features	(Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a)
					(EP3-3) Level of access to public transportation and public facilities	(Couch & Dennemann, 2000; Council, 2013; Hemphill, Berry, et al., 2004a)
					(EP3-4) Alternative transportation opportunities	(Couch & Dennemann, 2000; Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a)
					(EP3-5) Level of compact development	(Council, 2013)
					(EP3-6) Provision of open spaces	(Council, 2013; Hemphill, Berry, et al., 2004a)
					(EP3-7) Level of regularization of population density/urban development	(Aladağ & Işık, 2016; Council, 2013)
					(EP3-8) Number of housing stock	(Aladağ & Işık, 2016; Council, 2013; Hemphill, Berry, et al., 2004a)
					(EP3-9) Level of increase in existing reconstruction rights	(Hemphill, Berry, et al., 2004a)
					(EP3-10) Number of storm water management measures	(Council, 2013)
					(EP3-11) Land pollution reduction	(Couch & Dennemann, 2000; Council, 2013; ISI, 2012)
					(EP3-12) Level of accessibility	(Couch & Dennemann, 2000)
			Waste Management (EP4)	(Aladağ & Işık, 2016; Constructing Exellence, 2019; Cha, Kim, & Han, 2009)	(EP4-1) Design for minimum waste	(Aladağ & Işık, 2016; Babcicky, 2013; Couch & Dennemann, 2000; Council, 2013; Hemphill, Berry, et al., 2004a; Robertson, 1997; Saisana, 2014)
					(EP4-2) Provision of construction waste management plan	(Council, 2013)
					(EP4-3) Ratio of recycled/reused waste	(Couch & Dennemann, 2000; Council, 2013)
					(EP4-4) Identification and reuse of unwanted by-products/discarded materials	(ISI, 2012)
					(EP4-5) Storage and collection of recyclables	(Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a; Robertson, 1997)
					(EP4-6) Ratio of recycled or salvaged material	
			Energy (EP5)	(Aladağ & Işık, 2016; Constructing Exellence, 2019; Taisei AR, 2005)	(EP5-1) Building energy performance certificate level (EPC)	(Council, 2013)
					(EP5-2) Provision of building energy model	(Aladağ & Işık, 2016; Council, 2013)
					(EP5-3) Building energy efficiency level (Performance or prescripted)	(Council, 2013; Hemphill, Berry, et al., 2004a)
					(EP5-4) Utilization level of renewable energy	(Couch & Dennemann, 2000; Council, 2013)
					(EP5-5) Level of measurement and verification system applied	(Council, 2013)
					(EP5-6) Application level of building commissioning	(Council, 2013)
					(EP5-7) Provision of greenpower	(Babcicky, 2013; Council, 2013; Saisana, 2014)
					(EP5-8) Reduction level the net embodied energy	(Council, 2013; ISI, 2012; Sundell et al., 2011)
			Water (EP6)	(Aladağ & Işık, 2016; Babcicky, 2013; Constructing Exellence, 2019; ISI, 2012; Saisana, 2014)	(EP6-1) Level of reduction of water pollution (Negative impact on water)	(Couch & Dennemann, 2000; Council, 2013; ISI, 2012)
					(EP6-2) Total water use reduction	(Council, 2013; Robertson, 1997)
					(EP6-3) Provision of water efficient landscaping	(Council, 2013; ISI, 2012)
					(EP6-4) Number of innovative waste water technologies applied	Council, 2013; ISI, 2012)
			Use of Material (EP7)	(Aladağ & Işık, 2016; Hee Sung Cha & Kim, 2011; Hemphill, Berry, et al., 2004a)	(EP7-1) Quantity of environmentally preferable materials used	(Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a)
					(EP7-2) Regional material usage level	(Council, 2013)
					(EP7-3) Material reuse level	(Council, 2013; ISI, 2012; Hemphill, Berry, et al., 2004a)
					(EP7-4) Level of building life cycle impact reduction	(Council, 2013)
					(EP7-5) Number of materials with EPDs	(Council, 2013; ISI, 2012)
			Indoor Environment Quality (EP8)	(Aladağ & Işık, 2016; Hemphill, Berry, et al., 2004a; Lin & Shen, 2007)	(EP8-1) Indoor air quality level	(Babcicky, 2013; Council, 2013; Saisana, 2014)
					(EP8-2) Application of indoor air quality strategies	(Council, 2013)
					(EP8-3) Low emissioning materials used	(Babcicky, 2013; Council, 2013; Saisana, 2014)
					(EP8-4) Provision of construction IAQ plan	(Council, 2013)
					(EP8-5) Compliance level with daylight design requirement	(Council, 2013)
					(EP8-6) Compliance level with lighting design standard	(Council, 2013)
					(EP8-7) The chemical and pollutant source control level	(Council, 2013)
					(EP8-8) Building acoustic standards/requirements compliance level	(Council, 2013)
					(EP8-9) Noise pollution reduction level	(Couch & Dennemann, 2000; C.-J. Yu & Kang, 2011)
					(EP8-10) Air pollution prevention level	(Aladağ & Işık, 2016)
			Compliance with Regulations (EP9)	(Aladağ & Işık, 2016; Kaplan & Norton, 2000; McCabe, 2001; Neely, Adams, & Kennerley, 2002)	(EP9-1) Level of compliance with property rights	(Aladağ & Işık, 2016)
					(EP9-2) Number of reported environmental issues/disputes	(Kaplan & Norton, 2000; McCabe, 2001)
					(EP9-3) Level of compliance with legal requirements	(Neely et al., 2002)
					(EP9-4) Number of actions to improve sustainable performance	ISI, 2012

the environmental performance category. Success criteria for environmental performance have been determined and analyzed using the AHP process (Table 3).

The participants are selected with a network selection method. According to Aladağ & Işık (2017), there is no specific number of participants required for AHP. In this study, selected participants included 9 architects, 7 civil engineers, 5 mechanical engineers, 1 urban planner, 1 technician, 1 landscape architect, and 1 geomatic engineer. The participants were selected to cover almost all processes of urban regeneration projects and the construction sector.

Most of the participants (36 %) had less than five years' experience and 20 % had 5 to 10 years' experience. participants with 10-15, 15-20, and 20-25 years of experience form 12 % of total participants. Finally, the participants with more than 25 years of experience make up 8 %of the total participants. In the overall assessment, most of the participants had some level of experience in urban regeneration and construction. Besides, 2 of the participants contributed to the academy. The participants were interviewed individually and queried about the key performance indicators identified within the scope of the study. Each key performance indicator is scored from 1 to 7. These data were added to the model by using weightings and normalizing them.

Next, the participants were asked to determine the criteria of environmental performance through pair-wise comparisons. Corresponding results were defined as the group decision. Geometric Means were used to forming the group decision matrix.

4. Methodology

In this study, the success indicators of environmental performance, one of the most important components of the proposed Sustainable Performance Measurement Model for Urban Regeneration Projects, were determined using the AHP method. With this analysis, it gives information about which criteria and/or key success indicators are more significant for companies, managers, employers, etc., i.e. stakeholders who want to measure project performance from an environmental perspective. In this way, experts can determine the issues they need to focus on more clearly and develop their future strategies according to their importance.

The managerial and performance measurement problems are often complex and addressing them generally requires expert opinion and analytical thinking. Besides, the fact that these problems have both qualitatively and quantitatively measurable components requires a methodology such as AHP to be used for addressing these types of multi-criteria evaluation systems (Işik & Aladağ, 2017).

The advantages of AHP include:

• AHP allows objective / subjective considerations to be included in the decision-making process systematically using qualitative/quantitative information.

• AHP provides an easy-to-implement decision-making methodology that allows decision-makers to accurately determine their preferences for their goals.

• AHP allows the research problem to be handled through a logical hierarchy. With a structure/process that simplifies complex problems, it facilitates decision-makers' understanding of the definition and elements of the decision problem.

• It allows measuring the degree of consistency in decision maker's judgements.

The AHP, allows decision-makers to handle expert judgment, experience, and acceptance (Tekçe, 2010).

AHP includes four steps:

1) The first stage of AHP is the formation of the decision hierarchy. After dividing the problem into small pieces, the system determines the importance of the two elements compared. This is important for concept formation in human perception, classification of samples and logical reasoning.

2) The second stage is the development of comparison matrixes. Pairwise comparisons are designed to establish decision criteria and priority distributions of alternatives. Eventually, the elements in the hierarchy are compared in pairs to determine their relative importance to the element in the upper level (Saaty, 1980, 1994).

It is stated that if the number of options to be evaluated exceeds the so-called magic number of nine, there will be a considerable risk for the decision-maker to be overwhelmed (Brownlow & Watson, 1987; Forman, 1990). However, in the hierarchical model developed during this study, the pairwise comparison matrix has been selected among the criteria of the environmental performance dimension with a dimension of 9x9, which is compliant with the referenced limits.

The application of group decisions in AHP decision-making could be based on two different approaches (Aczél & Saaty, 1983; Ramanathan & Ganesh, 1994; Saaty, 1980). The first approach recommends reaching to a consensus on the issue through discussion by members of the group or engaging a facilitator who will fulfill the task of drawing a conciliation from the members' judgments. The second approach is to combine every pair-wise (Tekçe, 2010) judgment through mathematical formulation, usually via geometric means. Assessments by each expert should be translated into a single weight of significance for each factor. The geometric mean method is accepted as the most popular methodology for combining expert judgment (Aull-Hyde, Erdogan, & Duke, 2006). Another benefit of using the geometric mean method is that it reduces the effect of extremely low or extremely high values that cause controversy in the arithmetic mean method (Taleai & Mansourian, 2008). In this study, we preferred combining every pair-wise judgment through geometric means.

3) After the "pairwise comparisons matrix" is developed; each environmental performance criterion has priority vectors indicating the severity of the criteria. Linear algebra techniques are used to construct priority vectors. Different techniques can be used for the development of priority vectors for ease of implementation, provided that it complies with the methodology of AHP (Lipovetsky, 2009). The two most common prioritization procedures of

AHP are the eigenvector method (EM) and the line geometric mean method. Both methods achieve the same relative importance vector values (Escobar & Moreno-Jimenéz, 2007). In this study, the eigenvector method was used.

Finding the eigenvector:

In a pair-wise comparison matrix or group decision matrix, each column element is summed, and each element is divided into this sum to obtain a normalized group decision matrix (Aw). In this matrix, the sum of the columns is equal to 1.

In the normalized group decision matrix (Aw), the arithmetic mean of the elements in each row is obtained to the relative importance (priority) vector (Wi). The sum of the elements in this vector is equal to 1. The elements in the group decision matrix are multiplied by the relative priority vector to generate the weighted total vector (D). Each element of this vector (D) is used for measuring the consistency of the eigenvector (E) by dividing the corresponding element in the relative importance vector (Wi).

4) At the last stage, it is necessary to calculate the consistency ratio for each comparison matrix to determine whether the decision-maker behaves consistently when comparing the factors (Dağdeviren, Diyar, & Mustafa, 2004). The consistency ratio (CR) obtained from the product of the pairwise comparisons matrix and the significance distribution vector must be less than 0.10 (10%).

In this study, AHP has not been applied to select between multiple choices or decisions, but as a part of the methodology to determine the importance weights of a group of factors.

Firstly, background research is conducted as Literature Review. After this step the dimensions, criteria and key performance indicators are determined. Secondly, field studies were started. At this stage, key performance indicators were scored using the 7-point Likert scale. Then the AHP process was started. 9 performance criteria were evaluated using pair-wise comparison matrices. As the output of this stage, the importance weights of the performances criteria and key performance indicators were determined.

In the last stage, the results of the field studies were analyzed, and the consistency of the group decision matrix was determined. The output of this phase was the sustainable environmental performance measurement model, which included performance criteria and KPIs with significant weighting.

5. Analyses

This section presents the application steps of AHP and corresponding analysis results. The general steps of AHP and their application in this study are presented as follows.

Step 1. Model construction and problem structuring: Proposed key performance indicators of the environmental performance which is one of the main performance dimensions of sustainable project performance for urban regeneration projects, the determined based on a literature study were discussed through a pilot survey. Finally, 55 KPIs were determined to measure the success of environmental performance. An AHP model structure that includes criteria and sub-criteria (i.e. KPI's of the environmental performance of an urban regeneration project) has been configured. In this context, the formed AHP model structure is shown in Figure 1.

Step 2. Construct pairwise matrices of the components: the experts were asked to make pairwise comparisons between determined criteria above. However, due to the large number of KPIs, pairwise comparisons between them were too complex to be applicable. Hence, they were rated using a 7-point Likert scale. Afterward, the average weights of the KPIs are normalized and included in the model.

$$a_{w11} = \frac{a_{11}}{\sum_{i=1}^{m} a_{i1}} \qquad (1)$$

In comparisons between items at a particular hierarchical level, an item in row i is not always compared to an item in column j. In the corresponding terminology, aij is an indication of how much (or less) element i is more important than j. In AHP, preferences are assumed to have reciprocity (3). For example, if i-th is x times more im-

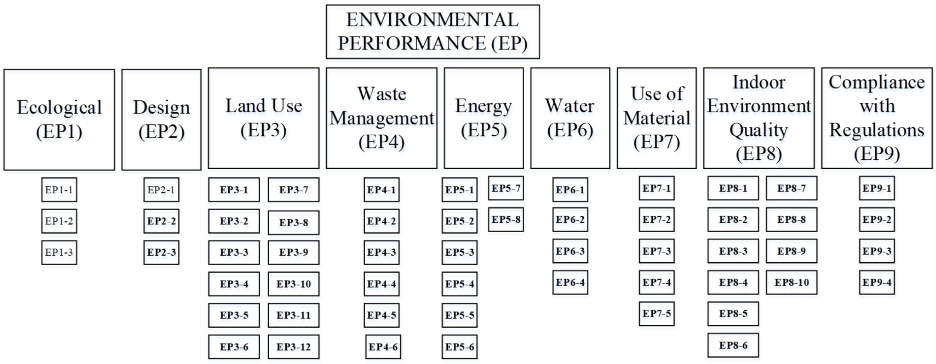

Figure 1. *AHP structure of Environmental Performance for Urban Regeneration Project.*

portant than j-th (aij = x), then it is automatically assumed that j-th is as important as 1 / x as i-th (aji = 1 / x). An appropriate assessment scale should be introduced to enable the participants of the AHP study to accurately measure all parts of the characteristics of the elements to be analyzed. In this study, the AHP scale is presented from 1 to 9. A detailed interpretation of the assessment scale is given in Table 4.

Different feedback from the expert panel indicates the views of a group. To consolidate the assessments of the experts for each pairwise comparison, the most common geometric mean method was used to combine pair-wise judgments. Thus, pair-wise comparison matrices reflecting the group decision were generated for the next step in the AHP algorithm process. Saaty (2005) proposed the consolidation of the opinions of different participants by using the weighted geometric mean method to obtain a single opinion from these different views. The X dataset, X = (x1, x2,…, xn), n represents the feedback of the participant, and the W dataset, W = (w1, w2,…, wn), represents the consolidated assessment to express the importance weights of these participants. The weighted geometric mean of the evaluations was calculated as indicated in (1) (Saaty, 2005):

$$\bar{x} = \left(\prod_{i=1}^{n} x_i^{w_i} \right)^{1/\sum_{i=1}^{n} w_i} \qquad (2)$$

In Table 5, the formula (2) is used to calculate the importance weights of 3rd level performance criteria.

Step 3. Finding Priority and Eigen Vector: as previously mentioned, the normalized group decision matrix (Aw), the relative importance (priority) vector (Wi), the weighted total vector (D) were obtained. Each element of this vector (D) is used for measuring the consistency of the Eigenvector E (Table 6-7).

Step 4. Checking consistency: Through face-to-face interviews with experts, consistency of the pair-wise comparison matrices generated was checked. In this way, it was evaluated whether the process of comparison of criteria was consistent. If any inconsis-

Table 4. *Evaluation Scale Used in Pairwise Comparisons (Cabała, 2010).*

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong Importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Interval Values

Table 5. *Group Decision Matrix.*

	GROUP DECISION MATRIX								
	EP1	EP2	EP3	EP4	EP5	EP6	EP7	EP8	EP9
EP1	1,00	2,45	0,85	0,81	0,46	0,59	1,31	1,37	3,07
EP2	0,41	1,00	0,39	0,51	0,26	0,36	0,88	0,60	1,10
EP3	1,18	2,56	1,00	1,23	0,44	0,70	2,12	1,38	2,38
EP4	1,24	1,96	0,81	1,00	0,39	0,46	1,83	0,85	2,85
EP5	2,19	3,83	2,27	2,57	1,00	2,14	3,70	2,74	3,92
EP6	1,70	2,78	1,43	2,17	0,47	1,00	2,93	1,85	3,57
EP7	0,76	1,14	0,47	0,55	0,27	0,34	1,00	0,59	1,65
EP8	0,73	1,66	0,72	1,17	0,36	0,54	1,70	1,00	2,77
EP9	0,33	0,91	0,42	0,35	0,26	0,28	0,61	0,36	1,00
SUM	9,54	18,29	8,36	10,37	3,90	6,41	16,08	10,75	22,31

Table 6. *Normalized Group Decision Matrix and Relative Importance (Priority) Vector (Wi).*

	NORMALIZED GROUP DECISION MATRIX									RELATIVE IMPORTANCE (PRIORITY) VECTOR (Wi)
	EP1	EP2	EP3	EP4	EP5	EP6	EP7	EP8	EP9	
EP1	0,10	0,13	0,10	0,08	0,12	0,09	0,08	0,13	0,14	0,11
EP2	0,04	0,05	0,05	0,05	0,07	0,06	0,05	0,06	0,05	0,05
EP3	0,12	0,14	0,12	0,12	0,11	0,11	0,13	0,13	0,11	0,12
EP4	0,13	0,11	0,10	0,10	0,10	0,07	0,11	0,08	0,13	0,10
EP5	0,23	0,21	0,27	0,25	0,26	0,33	0,23	0,25	0,18	0,25
EP6	0,18	0,15	0,17	0,21	0,12	0,16	0,18	0,17	0,16	0,17
EP7	0,08	0,06	0,06	0,05	0,07	0,05	0,06	0,05	0,07	0,06
EP8	0,08	0,09	0,09	0,11	0,09	0,08	0,11	0,09	0,12	0,10
EP9	0,03	0,05	0,05	0,03	0,07	0,04	0,04	0,03	0,04	0,04
SUM	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 7. *Weighted Total Vector (D) and Eigen Vector (E).*

WEIGHTED TOTAL VECTOR (D)	EIGEN VEKTOR (E)
0,98	9,08
0,48	9,11
1,11	9,12
0,93	9,09
2,25	9,16
1,53	9,15
0,57	9,10
0,88	9,11
0,40	9,07
LAMDA MAX	9,11

Table 8. *Consistency Index and Consistency Ratio.*

CONSISTENCY INDEX	RANDOM INDEX	CONSISTENCYCONSISTENCY RATIO (CI/RI)	<0,10 (<%10)
0,0138	1,45	0,0095	OK

tencies were detected, decision-makers were asked to reconsider their pairwise comparisons.

For this process, the eigenvector E matching the maximum eigenvalue λmax of the group decision matrix Aw is calculated with the formula (1) (Cabała, 2010).

After determination of the λmax, the consistency index (CI) was calculated as follows:

$CI=\lambda max-n/n-1$, where n is the matrix size.

Next, the consistency ratio was calculated using the Consistency Index (CI) and Random Index (RI) to check the consistency of the judgments. The Consistency Ratio of the study is 0.0095, where any value below 0.10 is acceptable. Therefore, the result indicates that expert judgments are consistent (Table 8).

Finally, the priorities of the proposed AHP structure of the general environmental performance components are presented in Table 9.

6. Discussion

The general significance weights identified in the AHP model can be discussed as follows:

Overall assessment of the results: As mentioned earlier, many dimensions are for measuring sustainable project performance of urban regeneration projects. These include; Financial Performance, Time Performance, Quality Performance, Health and Safety Performance, Stakeholder Satisfaction, Innovation, and Environmental Performance. In a recent study by Aladağ & Işık (2017), environmental and social performance rather than cost, time and quality were determined as the most important components in determining overall performance.

As a part of a larger research on Sustainable Project performance Measurement for the Urban Regeneration Project, this study mainly focuses on measuring environmental performance. The importance of environmental performance in determining overall sustainable performance compared to other performance measurement dimensions is the subject of a more comprehensive study. Besides, the importance of performance measurement criteria and KPIs in determining overall project performance will differ.

According to the developed AHP model, the "Energy" criterion has the highest importance in determining the environmental performance of urban regeneration projects. "Water" criterion is the second most important criterion. "Land use, Ecology, and Waste Management," criteria have almost similar importance and are listed as the third, fourth and fifth in determining environmental performance, respectively. Finally, the criteria "Indoor Environment Quality, Use of Material, Design, Compliance with Regulations" are found to be the least important cri-

Table 9. *The Priorities of the Criteria and Indicator of Environmental Performance.*

A*	Performance Criteria	B*	C*	Key Perfromance Indicators
0,1081	Ecological	0,0187	0,002	Level of protection or restoration of habitat
		0,0192	0,0021	Total carbon emissions
		0,018	0,002	Ecological footprint
0,0529	Design	0,017	0,0009	Level of aesthetic design
		0,0172	0,0009	Level of landscape design
		0,0178	0,0009	Level of integrated design policies
0,1213	Land Use	0,0199	0,0024	Level of effective site selection
		0,0189	0,0023	Preservation level of high value landscapes and its features
		0,0201	0,0024	Level of access to public transportation and public facilities
		0,0193	0,0023	Alternative transportation opportunities
		0,0174	0,0021	Level of compact development
		0,0177	0,0021	Provision of open spaces
		0,018	0,0022	Level of regularization of population density/urban development
		0,0169	0,002	Number of housing stock
		0,0177	0,0021	Level of increase in existing reconstruction rights
		0,0178	0,0022	Number of storm water management measures
		0,0196	0,0024	Land pollution reduction
		0,0196	0,0024	Level of accessibility
0,1025	Waste Management	0,0193	0,002	Design for minimum waste
		0,0179	0,0018	Provision of construction waste management plan
		0,018	0,0018	Ratio of recycled/reused waste
		0,0174	0,0018	Identification and reuse of unwanted by-products/discarded materials
		0,0184	0,0019	Storage and collection of recyclables
		0,0179	0,0018	Ratio of recycled or salvaged material
0,2456	Energy	0,0197	0,0048	Building energy performance certificate level (EPC)
		0,0187	0,0046	Provision of building energy model
		0,0191	0,0047	Building energy efficiency level (Performance or prescripted)
		0,0175	0,0043	Utilization level of renewable energy
		0,0165	0,0041	Level of measurement and verification system applied
		0,0172	0,0042	Application level of building commissioning
		0,0174	0,0043	Provision of green power
		0,0184	0,0045	Reduction level the net embodied energy
0,1668	Water	0,0192	0,0032	Level of reduction of water pollution (Negative impact on water)
		0,0201	0,0033	Total water use reduction
		0,0188	0,0031	Provision of water efficient landscaping
		0,0179	0,003	Number of innovative waste water technologies applied
0,0628	Use of Material	0,0183	0,0011	Quantity of environmentally preferable materials used
		0,0178	0,0011	Regional material usage level
		0,0175	0,0011	Material reuse level
		0,0179	0,0011	Level of building life cycle impact reduction
		0,0164	0,001	Number of materials with EPDs
0,0964	Indoor Environment Quality	0,0197	0,0019	Indoor air quality level
		0,0177	0,0017	Application of indoor air quality strategies
		0,0178	0,0017	Low emissionining materials used
		0,0177	0,0017	Provision of construction IAQ plan
		0,0182	0,0018	Compliance level with daylight design requirement
		0,0175	0,0017	Compliance level with lighting design standard
		0,0188	0,0018	The chemical and pollutant source control level
		0,017	0,0016	Building acoustic standards/requirements compliance level
		0,0178	0,0017	Noise pollution reduction level
		0,0194	0,0019	Air pollution prevention level
0,0437	Compliance with Regulations	0,0178	0,0008	Level of compliance with property rights
		0,0172	0,0007	Number of reported environmental issues/disputes
		0,0177	0,0008	Level of compliance with legal requirements
		0,0178	0,0008	Number of actions to improve sustainable performance

A: The importance of criteria in measuring environmental performance
B: Normalized Priorities of the KPIs
C: The importance of key performance indicators in measuring environmental performance (A*B)

teria for determining environmental performance, remaining below 10% in the evaluation.

When evaluating KPIs, their importance in measuring environmental performance was evaluated on a scale of 1-7 and the normalized significance of each KPI was determined by a weighted average. Then, these were multiplied by the weighting of each criterion they are under in the hierarchical system, to get the overall weight for each KPI to determine the environmental performance of the project.

The evaluation for each criterion has been listed below in the order of importance:

Evaluation of Energy criterion: 8

KPI's were specified under the Energy criterion. Among these, the "Building energy performance certificate level (EPC)" indicator has the highest rating (0.0048). "Building energy efficiency level" comes second (0.0046). "The provision of building energy model" (0.0046) and "Reduction level in the net embodied energy" to share the third and fourth place (0.0045) levels, respectively. The weightings of other KPIs are listed in Table 9.

Evaluation of Water criterion: "Total water use reduction" indicator has the highest importance (0.0033). It is followed by the "Level of reduction of water pollution" indicator (0.0032). "Provision of water-efficient landscaping" indicator (0.0031) and "Number of innovative wastewater technologies applied" (0.0030). The results indicate that "the number of innovative water-based solutions" is accepted as an insufficient indicator of success in environmental performance.

Evaluation of Land Use Criterion: Several indicators have been used to measure the performance of this criterion. "Level of effective site selection" and "Level of access to public transportation and public facilities" have the highest importance level (0.0024). "Land pollution reduction" and "Level of accessibility indicators" are of equal importance (0.0024). "The alternative transportation opportunities" indicator has a significant weight of 0.0023, which supports the importance of transportation in realizing the success of land use. The weightings of other KPIs are listed in Table 9.

Evaluation of Ecology Criterion: Terminology used in sustainability studies usually associates the environmental dimension of Ecology. However, this study concludes that environmental sustainability includes a wide spectrum of criteria. According to the analysis conducted in this study, Ecology is rated as the 5th important criteria when measuring environmental performance. Under these criteria, "Total carbon emissions" has the highest weight (0.0021). "The level of protection or restoration of the habitat "also has the secondary highest weight (0.0020) and "Ecological footprint" follows them (0.0020).

Evaluation of Waste Management Criterion: "Design for minimum waste "is of utmost importance (0.0020). This indicates that the design process, i.e. planning before construction starts, is very important. "The storage and collection of the recyclables" were found to be of secondary importance (0.0019). Although "the reuse rate of wastes" is a measurable indicator, it has third-degree importance in determining the success of waste management (0.0018). "Provision of construction waste management plan" and "The ratio of recycled or salvaged materials are equally important. The results indicate that waste reuse is perceived as more important than Recyclable Content. "Identification and reuse of unwanted by-products / discarded materials" are ranked the least significant indicator.

Evaluation of Indoor Environment Quality Criteria: Indoor quality is measured with a total of 10 KPIs. There is a major focus on air quality, acoustics, and lighting. Additionally, "The provision of an indoor air quality plan" and "The control levels of some pollutants" are assessed. Here, the results indicate that "Indoor air quality level" and "Air pollution prevention level" were found to be the most important KPI's (0.0019). They are followed by "Chemical and pollutant source control level" and "Compliance level with daylight design requirement" (0.0018). "Compliance level with lighting design standard" and "Building acoustic standards/requirements compliance level" are found to be the least important KPI's. The weightings of other KPIs are listed in Table 9.

Evaluation of Use of Material Criterion: The Use of Material criterion ranks 7th in measuring environmental performance with a weight of 0.063 significance. All five indicators identified for the evaluation of the use of material have almost the same importance (0.0011). The detail weightings of other KPIs are listed in Table 9.

Evaluation of Design Criteria: Although most of the participants are architects, the design criterion is at the end of the importance of ranking. The main reason for this outcome could be the indirect effect of design on environmental performance. This resulted in the selection of qualitative KPIs for design. Under this criterion, "The level of integrated design policies" was more found to be more important than "Landscape design" and "Aesthetic design" (0.0009).

Evaluation of Compliance with Regulations Criterion: Compliance with environmental performance laws and regulations was found to be the least important criterion by the participants. This criterion has a weight of 0.044 in measuring environmental performance and determining success. "Level of compliance with property rights" has the highest importance, while "The number of actions to increase sustainable performance" is second. "The level of compliance with environmental legal obligations" and "The number of reported environmental issues and disputes" are ranked as third and fourth. The last place for "Compliance with legal obligations" criterion indicates that although it is important to comply with Legal requirements, it is not perceived as an indication of success in environmental performance. The weightings of the KPIs are listed in Table 9.

7. Conclusion

Historically, the construction sector has often been a target for criticism for its low performance and efficiency issues and its impact on the environment. Urban regeneration projects are considered as important drivers of construction industry, due to their wide scope, a large budget and social, economic and ecological effects on urban life. In this context, this study is a part of a larger research, focusing on developing a model for measuring the environmental performance of urban regeneration projects.

Urban transformation projects are considered as the driving force in the construction industry and economies of the countries (Aladağ & Işık, 2016). Standardization in these projects can be achieved by increasing efficiency and performance measurement studies to be carried out on a larger scale. Each country and / or city can develop its own performance measurement model and apply it in urban transformation projects. Therefore, the findings obtained from this study shall be used to measure the environmental performance, which is developed for the sensitive nature of urban transformation and is one of the most important steps of sustainability.

This study intends to address the problem of measuring the level of impact of urban regeneration projects on the environment and provides a model for the analysis of performance. It is strongly believed that the wide adoption of a sustainable performance measurement model for urban regeneration projects shall address rising concerns about the environmental impacts of construction all over the world. This study is also expected to help to improve the level of quality in construction sector. Determination of environmental performance KPI's for urban regeneration project will provide a tool for decision-makers to monitor and assess their achievements not only financially but also from an environmental perspective, An AHP model, defining the priorities between environmental performance criteria and determining the weights for the Key Performance Indicators has been developed under this study.

The study results indicate that "Energy" Criteria has the highest priority level for determining the environmental performance of urban regeneration projects.

Top KPI's under Energy Criteria include; Building Energy Performance Certificate Rating (EPC), energy efficiency level, provision of an energy model and reduction in the net embodied energy.

Consecutively, "Water" criteria is the second. Most selective KPI's under water is listed as; total water use reduction, level of reduction in water pollution, water efficient land scaping and number of innovative wastewater technologies applied.

"Land Use" is the third important criterion to determine the environmental performance of urban regeneration projects. Some of the KPIs listed under land use, including access to alternative transportation, provision of open spaces, level of compact development and land pollution reduction are especially important for highlighting the added value by the project in the environment, as well as in the quality of life.

"Ecology", a term which is usually used in the same context with the environment, has been rated as the fourth important criterion in this study. It is followed by "Waste Management", which could be expected to have a higher priority when measuring the environmental performance of urban regeneration projects. The importance of Waste Management when measuring the environmental performance of urban regeneration projects could be the subject of other research. Other criteria; including Indoor Environmental Quality, Material Use, Design and Compliance with Regulations have importance levels less than 10% and are considered as criteria with less priority when measuring the environmental performance of urban regeneration projects as a result of this study.

The results indicate that project stakeholders for urban regeneration projects prioritize criteria with direct effects on environment such as Energy, Water, Land use and Ecology as prevailing measures of environmental performance. Also, most of the KPI's under these criteria are quantitative, which is a good indication of the tendency of technical staff to rely on measurable results for project performance. Some of the criteria listed under Green Building and Construction Rating systems (e.g. LEED, BREEAM, Envision) as critical success factors such as Design, Indoor Environmental Quality, and material used did not get higher scores from participants of this study. This may be due to the low level of awareness in construction professionals about green building rating systems in urban regeneration. This is another area for additional research.

The model developed in this study can be used as a baseline for future researches and may be improved in the context of alternative project types, stakeholders and/or organizations. In addition to this study, a larger model including other performance criteria and related KPI's for measuring the sustainable performance of urban regeneration project shall be developed as the extended version of this study. The extended model shall be tested by the experts, to determine its usability, practicality, and feasibility for measuring the sustainable performance of urban regeneration projects.

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