A USER-CENTERED APPROACH TO GREEN EXISTING BUILDINGS: BILKENT UNIVERSITY LIBRARY AS A CASE STUDY

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İhsan Doğramacı Bilkent University

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REYYAN SENA OKUTAN

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July 2016

I certify that I have read this thesis and have found that is fully adequate, in scope and in quaility, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

Assist. Prof. Dr. Yasemin Afacan
Supervisor

I certify that I have read this thesis and have found that is fully adequate, in scope and in quaility, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

Assist. Prof. Dr. Semiha Yılmazer
Examining Committee Member

I certify that I have read this thesis and have found that is fully adequate, in scope and in quaility, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

Prof. Dr. Mualla Erkılıç
Examining Committee Member

I certify that I have read this thesis and have found that is fully adequate, in scope and in quaility, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

Prof. Dr. Halime Demirkan
Director

ABSTRACT

A USER-CENTERED APPROACH TO GREEN EXISTING BUILDINGS:
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Okutan, Reyyan Sena
MFA, Department of Interior Architecture and Environmental Design
Advisor: Assist. Prof. Dr. Yasemin Afacan

July, 2016

Decision-making in green design is a very complex process as it contains several alternatives for various criteria. In order to overcome this complexity, a holistic approach for the decision making process is needed. However, when green design is discussed, the main concerns of researchers or decision makers are reducing energy consumption. In fact, user involvement in sustainable decision making process is also a critical factor for the project success. Unfortunately, user centered design approach to green existing buildings especially the educational ones are scarce in the research area. Therefore, this thesis aims to develop a decision making model through a user centered design approach for Bilkent University Library. To achieve this, firstly user needs were identified and then they were prioritized via Analytical Hierarchy Process (AHP) by the designers. As result, acoustic comfort had the most importance weightings among the other design factors. Additionally, the needs of the different user groups of the library building, the students and the staff, compared, and it was observed that the library staff need the green solutions more than the students do.

Keywords: Analytical Hierarchy Process, Decision Making Process, Greening Existing Buildings, Library Buildings, User Involvement

ÖZET

BİLKENT ÜNİVERSİTESİ KÜTÜPHANESİ ÖRNEĞİNDE YAPILI BİNALARIN YEŞİL RENOVASYONUNA KULLANICI ODAKLI BİR YAKLAŞIM

Okutan, Reyyan Sena
İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı
Tez Yöneticisi: Yrd. Doç. Dr. Yasemin Afacan

Temmuz, 2016

Yeşil bina renavasyon projelerinde karar verme süreci bir çok alternatife ve aynı zamanda değerlendirme kıstasına sahip olduğundan oldukça karışık bir süreçtir. Bu süreci iyi yönetibilmenin yolu sürece bütünsel bir bakış açısıyla yaklaşmaktan geçer. Fakat yeşil tasarım söz konusu olduğunda, araştırmacılar veya tasarımcılar tarafından göz önünde bulundurulan ana yaklışım enerji tüketimini azaltmaktır. Kullanıcı katılımının yeşil renovasyon projelerine özellikle de eğitim amaçlı olanlara olası katkısı sık sık göz ardı edilmektedir. Böylece bu tezin amacı Bilkent Üniversitesi kütüphane binasının olası bir yeşil renovasyonu için kullanıcı odaklı bir karar verme süreci geliştirmek olarak ifade edilmiştir. Bu bağlamda, ilk olarak kullanıcının ihtiyaçlarının belirlenmiş daha sonra da tasarımcılar tarafından Analitik Hiyerarşi methodu ile bu ihtiyaçların önceliklendirilmesi sağlanmıştır. Sonuç olarak, kullanıcı ihtiyaçları arasından en önemli faktör akustik komfor olarak belirlenmiştir. Buna ek olarak, kütüphanedeki iki farklı kullanıcı grubunun ihtiyaçları karşılaştırılmış ve kütüphane çalışanlarının öğrencilerden daha çok sürdürülebilir çözümlere ihtiyaç duydukları saptanmıştır.

Anahtar Kelimeler: Analitik Hiyerarşi Methodu, Kullanıcı Katılımı, Kullanıcı Odaklı Tasarım, Kütüphane Binalarının Yeşil Renovasyonu, Yapılı Binaların Yeşil Renavasyonu

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CHAPTER 1

INTRODUCTION

It is an undeniable fact that built environment is one of the main factors leading to energy consumption in the world (Zaraket, Yannou, Leroy, Minel, & Chapotot, 2015; Luther and Rajagopalan, 2014; Zhao, He, Johnson, & Mou, 2015). This trend is also the same for energy consumption pattern in Turkey. According to information provided by Turkish Ministry of Energy and Natural Resources, the energy produced in Turkey is mostly consumed by the building sector (İklim Değişikliği ve Binalar, n.d.). In this respect, greening current building stocks is crucial because the sustainable green renovation or refurbishment of the buildings decrease the energy consumption by reducing environmental pollution, maintenance and transportation costs, and waste of materials (Carroon, 2010; Douglas, 2006). However, greening an existing building involves complex and demanding decision making process due to its multi-dimensional nature (Menass, 2011; Kabak, Köse, Kırılmaz, & Burmaoğlu, 2014; Wu, & Pagel, 2011). To be more clear, it requires to take into consideration of social and cultural, economic, environmental constraints simultaneously (Ferreira, Pinherio, & Brito, 2013; Mickaityte, Zavadskas, Kaklauskas, & Tupenaite, 2008). To deal with this complexity, a systemic and holistic decision making approach to green renovation is needed (Alshuwaikhat, & Abubakar, 2008; Wu, & Pagell, 2011). The main concern of the green building is generally about energy consumption caused by the buildings (Pyke, McMahon, & Dietsche, 2010; Wu, & Pagell, 2011). This situation leads occupant experience and needs to be underestimated (Pyke et al., 2010; Voelker, Beckmann, Koehlmann, & Kornadt, 2013; Wood, Wang, Abdul-Rahman, & Abdul-Nasir, 2016; Zhao et al., 2015).

In fact, the most satisfied results from a green design are obtained when different group needs are evaluated. For this reason, decision makers should adopt a holistic approach by integrating energy consumption solutions with the user perspectives (Alshuwaikhat, & Abubakar, 2008). However, although the green building concept has been being discussed and researched for many years, user needs towards sustainable building has remained scarce (Nousiainen, & Junnila, 2008; Zhao et al., 2015). Moreover, the scarce ones are mainly related to residential or commercial buildings rather than educational buildings like campuses and schools (Too, Bajracharya, & Khanjanasthiti, 2013, Lourenço, 2014). In this respect, it was considered that a research on developing a user-centered decision making method for a campus building can contribute to fill this gap in the research area.

1.1.Problem Statement and Aim of the Study

In the light of the literature reviews, problems about greening an existing building can be summarized in three items;

1. To green existing buildings is a complex decision making process.

2. Even though user-centered design thinking and application of its methods have considerable advantages to meet the requirements of green design, its implication in green design is still rare.
3. The previous studies about greening generally focus on user impact on residential and office buildings. Campus buildings are not commonly addressed.

Thus, research aims are determined as to develop a decision-making model for a green design of a campus building through a user-centered design approach and as to identify key green design attributes and its importance weightings from a user perspective.

1.2. The Structure of the Thesis

The chapters of thesis are organized as follows. In Chapter 2, since green building is a broad term, firstly definition and key dimensions of a green building is explained. Then, after giving brief information about history of the green building concept, the regulations and the certification programs depending on the regulations are introduced. The chapter is finished by mentioning greening an existing building and the significance of the sustainable campuses and library buildings in order to lighten why specifically a library building in the campus is a chosen as a case. In Chapter 3, user-centered approach is defined and explained detail. After that, user involvement in general context is explained and the essential role of the user involvement in green design is clarified. In Chapter 4, the decision making process in greening existing building and crucial function of the prioritization for this process is investigated.

Finally, prioritization techniques are defined and Analytical Hierarchy Process is briefly introduced.

After analyzing three main pillars for greening existing buildings; green design, user-centered design, decision making process, in Chapter 5, the methodology of the research is introduced. Firstly, the hypothesis and the research question of the thesis are presented. Then, before clarifying the procedure of the research, the case building and the case building are explained. After that, the methods of the research are analyzed; the walkthrough visits and the user survey. The remaining parts of the chapter encompass statistical methods in order to obtain results for the research. In this context, exploratory factor analysis, analytical hierarchy process and uncorrelated t-test are explained respectively in detail. In Chapter 6, firstly the descriptive statistics results of the survey data are given to draw a general frame to investigate the basic understandings of the users towards green building design. After this, acquired information from the walkthrough visits is displayed. The chapter 6 contains results and discussions of obtained data through qualitative and quantitative methods. In Chapter 7, main aspects of the thesis are summarized and some additional methods are suggested for the future research.

CHAPTER 2

GREEN BUILDING DESIGN

2.1. Definitions, the Key Dimensions of Green Design

Sustainability is a broad and sometimes a relative concept depending on, who interpret it and what for it is interpreted. Therefore, every fields of study have their own sustainability meaning; in environmental studies, it is defined as conforming requirements of current situation without endangering our descendants' future to meet their requirements (United Nations' Brundtland Commission on Environment and Development, 1987). This definition is still regarded as the best way to explain sustainability for many platforms and researchers (Ciegis Ramanauskiene, & Martinkus, 2009) but by years the standard definition was improved with three dimensions; social, economic and environmental. (United Nations Conference on Environment and Development, 1992; World Summit on Sustainable Development, 2002). Nowadays, with the emergence of new professions and research areas, the other aspects such as political, cultural, etc. are incorporated to these three dimensions (Morelli, 2011).

Although environmental sustainability covers the term green building, they are generally used interchangeably maybe because of huge impact on the built environment. Unfortunately, data about current environmental situation of countries show that the next generations are under risk in terms of having the same resource opportunities. Between 16 and 50 percent of worldwide energy consumption belongs to only building sector itself (Zaraket et al., 2015; Luther, & Rajagopalan, 2014) and the CO2 emission from the buildings generate 40% of CO2 produced worldwide (Zhao et al., 2015). The figures for Turkey are not opposed to the other countries. The buildings in Turkey consume 30 percent of generated energy and 43 percent of electric energy (*İklim Değişikliği ve Binalar*, n.d.). This situation motivates countries to focus on ‘green building’ term, which is basically offering healthy and convenient living for the habitants by taking into consideration energy efficiency and well-being of the environment, on both existing and new buildings.

For better understanding of green building, it is essential to acquire knowledge about its definition. Kats (2003: V) states that "green or sustainable buildings use key resources like energy, water, materials, and land more efficiently than buildings that are just built to code". As for Ali and Nsairat (2009), green building provides environmentally efficient design by implementing a holistic approach so that the drawbacks depending on the buildings affecting environment and occupants are decreased. On the other hand, United States Environmental Agency describes the green buildings as a "practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition" (Green Building, 2016). Although green building concept involves various definitions, yet the consensus upon its aspects, divided into three categories of environmental, societal and economical, can give an interpretation of what and what for green buildings is (Zhao et al., 2015) (Figure 1.). Environmental aspect encompasses providing natural resources conservation, source reduction, protecting biodiversity and ecosystem (Zhen, Routray, Zoebisch, Chen, Xie, & Cheng, 2005). Secondly, social aspect of the green building is mainly ensures occupants' health, comfort (e.g. offering the same standards for occupants from different backgrounds). On the other hand, the economic aspect is more related to the economic benefits obtained because of lower energy use and costs (Nilashi et al., 2015; Zuo & Zhao, 2014; Hossaini, Reza, Akhtar, Sadiq, & Hewage, 2015; Mansour & Radford, 2016). In today's research the green buildings assessment tools and the regulations of green buildings are designed by taking into consideration these three aspects.

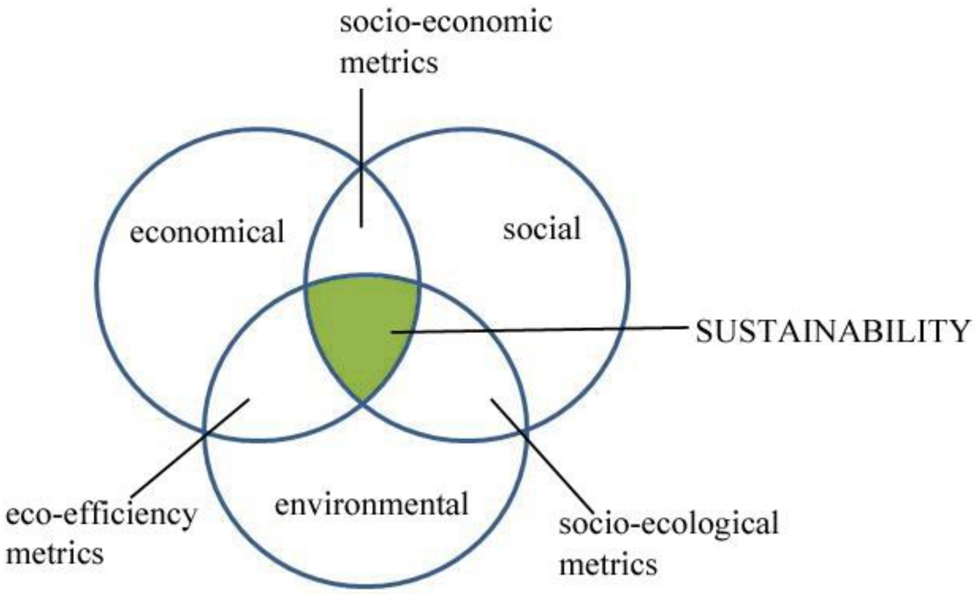


Figure 1. Three intersecting aspects of sustainability. Adapted from "Sustainable Development and Sustainability Metrics", by S. K. Sikdar, 2003.

2.2. History, Regulations, and Certification Programs

It is now an obvious fact that buildings have an incredible impact on both environment and economy. This realization is not recent; "green building" was addressed comprehensively for the first time with its three dimensions; social economic and environmental, at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 (Winchip, 2011; Zhao et al., 2015). Since then, many worldwide organization and conference were held and the countries became more conscious about environmental issues and so, green buildings. This resulted in appearance of various energy directives, national regulations and labels in the several countries in order to determine the requirements for green buildings. Certification programs like LEED (Leadership in Energy and Environmental Design**)** in United State, BREEAM (Building Research Establishment Environmental Assessment Method) in United Kingdom, Green Star in Australia , CASBEE (Comprehensive Assessment System for Built Environment Efficiency) in Japan, IISBE (International Initiative for a Sustainable Built Environment) (international) etc. introduce the standards to obtain environmental friendly built environment (Erten, 2011; Winchip, 2011). Among them, LEED is the most used certification program in the world with approximately 80,000 projects in 162 countries (Shutters & Tufts, 2016). The buildings can have four type of certification level; certified, silver, gold, and platinum. The assessment is operated according to 7 different topics; sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in operations and regional priority credits. To explain each topics briefly, sustainable site evaluates the building relationships with the regional and local ecosystem. Water efficiency examines the water as a whole and mainly focuses on water conservation. Energy and atmosphere is related to reducing energy consumption in general and energy efficient systems. Material and resources topic mainly concentrates on transportation, maintenance, and disposal of building materials. Indoor environmental quality focuses on indoor air quality, thermal and visual comfort, and users' satisfaction. Lastly, innovation in operations and regional priority credits are related to introducing the buildings with new technologies and the role of the building in a specific region.(LEED 2009 for Existing Buildings, 2014).

The Turkish government has also decided to introduce the regulation called "Regulation of Energy Performance in Buildings" in 2008, in compliance with

Kyoto Protocol. This regulation contains information about process and operations like, spatial design, mechanical and electrical installations of new or existing buildings. In 2011, Energy Identity Certification and to Building Energy Performance Tool; BEP-TR were launched to label both existing and new built building in Turkey. According to statement of Turkish Ministry of Energy and Natural Resources; each building in Turkey will have to hold Energy Identification Certificate by 2017 (*Binalarda Enerji Performansı*, n.d.) and it means that understanding of green building concept will be more and more important in terms of both buildings sector and the public in Turkey.

2.3. Greening Existing Buildings

It is widely known that existing buildings consume relatively higher amount of energy compared to new buildings (Zaraket et al, 2015; Luther and Rajagopalan, 2014; Zhao et al., 2015). Further, their performance is very poor regarding energy efficiency, comfort and it leads the building sector to a dilemma; if the existing buildings should be demolished or if they should be adapted for current needs. Unfortunately, even industrialized countries is more likely to choose the first choice for the reason that demolishing the existing buildings and redeveloping a new green site is perceived more economically valuable in short term (Douglas, 2006; Botta 2005). In sustainable design process, the usage of high energy efficient materials, such as insulation, openings and more technological ventilation operations can lead to additional cost compared to traditional buildings process (Zalejska-Jonsson, Lind, & Hintze, 2012). Moreover, for the reason that success of sustainable design implementations mainly depends on collaborative works of architects engineers, building investors, site workers and the occupants, the design process can be demanding and complex (Gagnon, Leduc, & Savard, 2012; Zalejska- Jonsson, 2013).

However, many researches indicate that there are several economic, social and environmental advantages of greening an existing building in the long term compared to demolition (Ma, Cooper, Daly, & Ledo, 2012; Sustainable refurbishment-Decision Support Tool and indicator requirements, 2014). A proper sustainable renovation can undermine the energy consumption by reducing environmental pollution, maintenance and transportation costs, and waste of materials (Carroon, 2010; Douglas, 2006). Yet, providing an energy saving environment is not the only aim of a green building, it should also offer a healthy environment for the occupants. Unfortunately, existing buildings have notoriety for poor indoor air quality among the users (Balaras, Dascalaki, & Kontoyiannidis, 2004; Zhao et al., 2015; Gupta, & Chandiwala, 2010) and HVAC energy consumption constitutes the main part of the overall energy consumption (Luther, & Rajagopalan, 2014). Therefore, a dilemma occurs at this point and creating sustainable solutions for indoor air issues in existing building is highly critical for a successful green renovation (Jensen, & Maslesa, 2015). In terms of economic benefit, it rejuvenates the local economy; provides low capital costs, ensures nations' energy reserves and provides job opportunity without damaging the environment (Ma et al., 2012; Wood, Wang, Abdul-Rahman, & Abdul-Nasir, 2015). On the other hand, in terms of social aspect, citizens do not have to be exposed to undesirable dust and noise depending on demolition. As cultural term, greening an existing building by increasing safety and comfort, preserves its architectural, historical and cultural values (Carroon 2010; Douglas, 2006; Sustainable Refurbishment-Decision Support Tool and Indicator Requirements, 2014) and thus, the place attachment of the public towards a specific built environment can also be preserved. As result, sustainable retrofitting has lots of advantages in comparison with demolishing and building a new one when it is analyzed with respect to key dimensions (economic, social, and environmental) of green design.

2.4. Importance of Green Campuses and Green University Libraries

Approximately 300 university all over the world signed Talloires Declaration mentioning universities role in teaching and implementation of sustainable dimensions in 1990 (Jankowska & Marcum, 2010; Alshuwaikhat & Abubakar, 2008, Olszak, 2012). Since then, universities became more aware of their social and environmental impacts on the environment; National Association of College and University Business Officers conference stated that, universities interest in environmental sustainability is tend to be increase in comparison with other academic institutions (Posner & Stuart, 2013). In fact, universities have a special place among the academic institutions because campuses are consisted of buildings with complex functions; like laboratories, lecture halls, sport centre, accommodation units etc, (Lukman, Tiwary, & Azapagic, 2009; Filho 2011; Sesana, Grecchi, Salvala, & Rasica, 2016). It means that campuses consume high amounts of energy and resources like any other complex buildings and therefore need concrete sustainable operations. According to Lourenço (2014), the need for sustainable solutions in educational building is likely to increase more in the future because of high electricity demand for technological devices and regulations about ventilation.

In many researches, greening a campus not only addresses solutions of environmental problems but also suggest a “living laboratories” for experiencing sustainability (Shriberg & Harris, 2012; Filho, 2011). Green Campuses can work as a showcase on an urban basis through attracting people’s attentions. This leads the public and as well as the building investors to be aware of importance of sustainability. On a campus basis however, libraries are the main representatives of green universities for several reasons (Binks, Braithwaite, Hogarth, Logan, & Wilson, 2014; Shane, 2012). First of all, the libraries are the one of the most used buildings at universities. They are used by both post-graduate and undergraduate students, staff, scholars and even the public (Hardesty, 2011). This means that green libraries have more opportunity in terms of being a role model, offering a new living standard, raising awareness regarding sustainability. As Shane (2012) indicates, a delicate designed green library project conveniently informs the community about environmental efficiency and motivates them to attend other green projects.

Secondly, today the libraries have numerous functions except from; supplying books and resources; they also provide lecture, workshop, refreshment, technological, group-working facilities with offering various spaces (Binks et al., 2014; Wilson, 2012). In this respect, resource consumption and waste caused by these various functioned spaces tend to damage the environment. However, the reverse also could be achieved. Libraries have genuinely great potential to guide the community as an environmental leader (Binks et al., 2014) with a delicate control of indoor and exterior environment (Boyden and Weiner, 2000; Jankowska and Marcum, 2010). Moreover, nowadays university libraries have to rely on sustainable solutions for lowering energy consumption depending on operating costs of their diverse functions. Therefore, by implementing green design features, libraries can promote their standards in more efficient and convenient way more than any kind of building type in the campus (Boyden and Weiner, 2000). . Therefore, by implementing green design features, libraries can promote their standards in more efficient and convenient way more than any kind of building type in the campus (Boyden and Weiner, 2000).

Yet saving energy is not only aim of a sustainable library building; it should ensure occupants' comfort, satisfaction and health as well (Boyden and Weiner, 2000; Shane, 2012). In this respect, indoor environmental quality (IEQ) factors become more and more important while designing a green building. Today, people spend most of their time in the indoor spaces (Asmar, Chokor, & Srour, 2014) and this leads designers to consider IEQ as a critical attributes of a green building. IEQ is also one of the categories of LEED assessment system. However, this category is only focusing on the six criteria; indoor air quality (IAQ), low emitting materials, indoor unhealthy source control, controllability of system, thermal comfort and daylighting and views (Lee, & Guerin, 2009). Among them IAQ criteria dominate the others, maybe because of close relationship between air quality and the occupants health and work performances (Sarbu,& Pacurar, 2015; Asmar et al., 2014; Cha; & Kim, 2015). However, sometimes the importance of the IEQ attributes can vary depending on the different user profiles of the different buildings types. According to a research conducted by Cha and Kim (2015) the library users found, furniture comfort, noise level and cleanliness as more critical factor than the indoor air quality. By contrast, in LEED assessment, acoustical comfort is not even a separate criteria for IEQ category; it is evaluated under "Occupant Comfort" section. This reveals that libraries have their own distinct entities as any other building types and researches about assessment tools for sustainable academic libraries are still scare (Jankowska, & Marcum, 2010). Therefore, intention of this research is determined to find out these entities through a user-centric design approach.

In fact, there are several successful green library examples in the world; Concordia University, George R. White Library & Learning Center, Harvard University, Littauer Fine Arts Library, University of South Carolina, Special Collections Library, University of Florida, Library West in United State (Hardesty, 2011); Worcester Library; the Hive, Library of Birmingham in United Kingdom (*Worcester Library - 'The Hive'*, n.d.; Hornshaw, 2013); Library at Macquarie University (Brodie, 2012), Library at Dock in Australia (First 6 Star Green Star library, 2014). In Turkey, Özyeğin University is the first green campus holding LEED's gold certification of the country. The buildings of the university, including the library, were built according to assessment criteria of LEED. (*Yepyeni, Çevreci Bir Kampüs*, n.d.)

CHAPTER 3

USER-CENTERED DESIGN

3.1. What is a User-Centered Design?

The concept of user centered design (UCD) traces back to Donald's Norman research laboratory at University of California in the 1980's. Norman (1988; 188) describes the UCD in his book: "The Psychology of Everyday Things" as philosophy based on the needs and the interests of user with an emphasis on making products usable and understandable". User need is at the heart of the user centered design process. Detecting and then meeting the user needs is genuinely critical to reach a successful design (Sanders, 2002). To more specify user needs, it is a broad concept covering what user wants, desires or expects from a design (Kim, Lee, & Park; 2013). There can be several methods such as surveys, interviews or group mapping (Abras, Maloney-Krichmar, & Preece; 2004) to disclose user needs but the main point is in UCD incorporating the users into the design process in a way or another (Abras et al., 2004) and achieving this is crucial at the very beginning of the design process (Kim et al., 2013).

According to ISO 13407: Human-Centered design process for interactive systems, UCD is based on implementation of four activities; "understand and specify the context of use, specify the user and organizational requirements, produce design solutions, and evaluate designs against requirements" (Earthy, Jones, & Bevan, 2001), (Figure 2). Following this sequence of activities at the early stage of the design process covers the gaps between users and the design (Takeshi, & Shin'ichi, 2008). Although these activities are developed for informatics systems, practicing them in architectural studies is nearly the same when it is considered that all kind of design type is shaped according to their users. In fact, the philosophy and the motives behind architectural design and UCD intersect; which is making built environment convenient for users rather than shaping the people for the environment (Afacan, 2008). In this respect, design tends to result in failure when its designer considers him/herself as the only user of the project (Norman, 1988). For this reason, involving UCD and so user needs in every kind of disciplines of design (Mao, Vredenburg, Smith, & Carey, 2005) including architecture, has a vital importance.

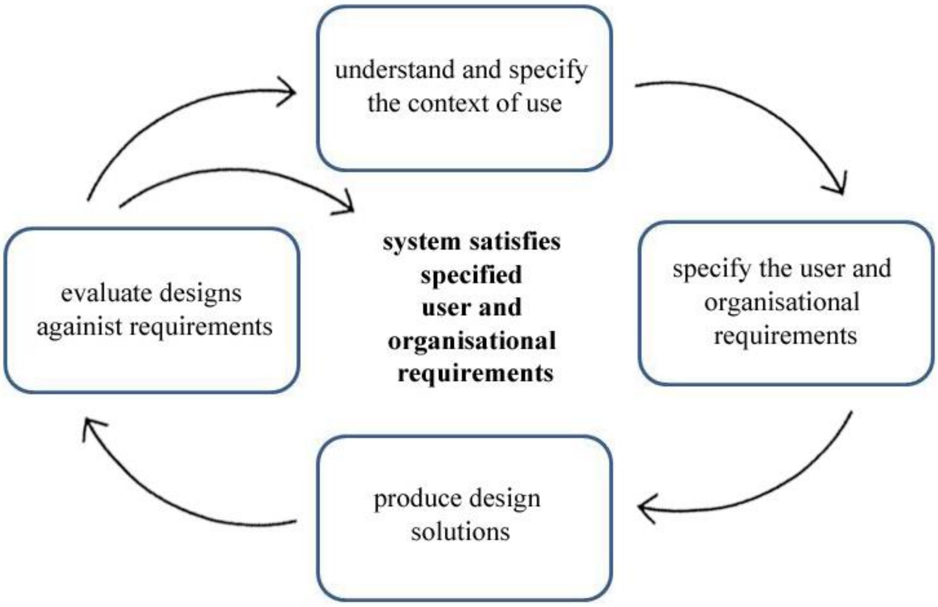


Figure 2. Activities of user-centered design. Adapted from The Standard of User-Centered Design and the Standard Definition of Usability, by T. Jokela, N. Iivari, J. Matero, & M. Karukka, 2003.

3.2. User Involvement

User involvement (UI) has different definitions according to different researchers. While Hartwick and Barki (1989: 53) explain the UI as "subjective psychological state reflecting the importance and personal relevance of a system to the user", Ives and Olson (1984) define as involvement of end-users into a design process. On the other hand, Kujula (2003) offers a broader explanation with a term referring to all approaches which possesses direct connection with users. For designers, identifying user needs and requirements is essential and acquiring knowledge about users' potential needs is only possible through involving the user in the design development (Grudin, 1991; Duverger; 2012; Moore, Hines, & Lilley, 2015). A designer can obtain the most accurate information by observing user participation (Kim et al., 2013; Kujula, 2003). There are several reasons behind why identification user needs and requirements is this much essential. It increases user satisfaction and experiences, provides more beneficial, suitable and acceptable design results (Duverger, 2012; Kim et al., 2013; Kujula, 2003; Moore, Hines, Lilley, 2015). After designers gather the data (user needs and requirements), they try to interpret these materials in order to set them as design criteria, inspirations or innovations (Sanders, 2002). Otherwise, -if designers design a service or product by following their instinct and by stepping themselves into the users' shoes-, the result will have to face with a difficult situation, in other words; failure since a design process is a joint process conducted by designers, stakeholders and its end-users. Therefore, being unaware of user needs and requirements leads a designer to lose the ability of creating a pleasant design (Norman, 1988; Jokela et al., 2003).

It is a fact that sometimes designers avoid using UI approaches because they find its implementations overwhelmingly difficult and so, time consuming (Mao, Vredenburg, Smith, & Carey, 2005). Further, there is an opinion that the users' point of views are commonly conservative, opposing to innovation and creativity, therefore, they can hardly imagine the end of the design process (Escande, Burkhardt, Christmann, & Richir, 2014). However these kinds of drawbacks may arise from not establishing an intimate relationship with the users (Kujula, 2003). Cooperation of the users and the design teams themselves, rather than research group investigating the needs and requirements, is highly advisable because having a direct connection is more valuable than reading or hearing information (Gould, & Lewis, 1985). And the collaboration between users and designers should continue from at the beginning of the design to the last phase (Olson, 2004). Thus, mutual understanding can be developed; designers are able to understand user needs or estimate the probable benefits of the final design, and in same way users can also figure out the needs and the motives of designers. At this point the role of designers is very critical; they have to interpret and detect the essential data obtained from this mutual interaction (Escande et al., 2014).

The level of user involvement in a design can depends on the situation. These levels are divided into 3 by Damodaran (1996); informative, consultative and participative. In informative level, users are considered only as a source of information. This kind of involvement is preferable when indirect users participation into the process is desired (Olson, 2004). Consultative involvement is advanced mood of informative involvement; now the users can contribute the design process (Kujula, 1997). On the other hand, in participative level, user involvement shapes all phases of the design process; from decision-making to final output (Owoseni, & Imhanyehor, 2011). In each level, it is important to evoke sense of collaboration for users because when users consider themselves as a part of design process, they use and understand the design more (Hartwick, &Barki, 1994). As reported by Damodaran (1996: 364-365), the researches proved that there are several advantages of a sufficient user involvement;

1. Improved quality of the system arising from more accurate user requirements

2. Avoiding costly system features that the user did not want or cannot use

3. Improved levels of acceptance of the system.

4. Greater understanding of the system by the user resulting in a more effective use.

5. Increased participation in decision-making in the organization.

To conclude, an effective user involvement in design process can highly contribute to the success of design process (Mcgill, & Klobas, 2008), user satisfaction (Kujula, 2003) and covering the gap between designer considerations and user opinions (Olson, 2004; Sanders ,2002).

3.3. Importance of User Involvement for Green Design Process

Green buildings and their occupants interact with each other continuously. The time spent by the people in the buildings accounts for 90% of the people's whole lives and with this respect, design of buildings has critical significance in terms of satisfying users' needs and comforts (Wang, Yang, Wang, & Dounis, 2011). Poor environmental qualities of a building regarding acoustics, lighting, ventilation, etc. can generate problem like discomfort and dissatisfaction among the users (Brown, Cole, Robinson, & Dowlatabadi, 2010). Green buildings however aspire the reverse; that is to ensure their occupants physical and psychological well-beings (Pyke, McMahon, & Dietsche, 2010). These discomfort and dissatisfaction perceived by the occupants can be prevented through user involvement and investigation of probable user needs at the outset of the project (Voelker, Beckmann, Koehlmann, & Kornadt, 2013). On the other hand, the usage pattern of the occupants has also great importance on environmental impact of buildings (Lockton, Harrison, & Stanton, 2008). In the sustainable design, focuses are generally on the design of the system; how can be undermined negative environmental effects of the buildings. In reality, habits of occupants, how they use a system or design on the regular basis, also has a huge impact on the energy consumption (Wever,Kuijk, & Boks, 2008). For instance, according to Owens and Wilhite (1988), if Nordic households' behavioral pattern changed, 10-20% of domestic energy would be preserved. Searching for user feedback can reveals the roots of energy misuse and at the same time can raise the awareness towards waste and energy use and so influence the user behavior positively (Gupta, & Chandiwala, 2010). As result, it can be stated that "energy saving features are sustainable if they are actually used by consumers" (Wever et al., 2008: 10).

In spite of the green building origin can be traced back to for decades, occupant perception towards sustainable building has remained scarce (Nousiainen, & Junnila, 2008; Zhao, He, Johnson, & Mou, 2015). The main concern is generally on technical issues and energy consumption caused by the buildings (Pyke et al., 2010). This situation leads occupant experience and needs to be underestimated (Pyke et al., 2010; Voelker et al., 2013; Wood, Wang, Abdul-Rahman, & Abdul-Nasir, 2016; Zhao et al., 2015). Rajat et al. (2015) state that the gap between designed and the actual energy consumption is due to the lack of user-centered analysis during the design process. Cole (2005) also expresses his reservation concerning failure of technical aspects of buildings owing to not taking into considerations of occupants' expectations and needs. According to Wood and his friends (2016) introducing user perception into a green design process along with the financial consideration is a must for a long term and successful operations of the buildings. Moreover, Kim, Oh, & Kim (2013) take this issue a step further by advocating a green building assessment method which encompasses the user needs besides energy and resource points. In fact, LEED contains credits potentially referring user experience and these can be improved to offer such an assessment system (Pyke et al., 2010).

Obviously green building has direct relation with the topic of energy and resource consumption. Incorporating occupant needs and demands into green building does not mean to dwarf the importance of these topics (Disterheft, Caeiro, Azeiteiro, & Filho, 2015; Pyke et al., 2010; Zhao et al., 2015). In fact, from very beginning of the green building design process, a holistic approach is needed to establish a balanced relationship between people and the environment (Pyke et al., 2010; Gupta, & Chandiwala, 2010; Too, & Bajracharya, 2015). Such an approach can give lots of benefits to both the design team and the occupants. Firstly making a pre-design survey helps to strengthen the connection between user requirement and technical solutions (Zhao et al., 2015). Therefore, the possible failure of green building design become more likely to be hindered because a holistic approach bridges the gap between expectations (what user expect) and the outcomes(what designer think) (Gupta, & Chandiwala, 2010). In terms of user perspective, a holistic approach at the outset of the green building design process enables them to acquire information about the new techniques, to possess sustainable behavior pattern (Wever et al., 2008) and to experience comfort and satisfaction with the design (Zhao et al., 2015). Buildings have not been designed to take advantage of ergonomics and user needs; they may save energy, perform well and consume less water, but if they are not suitably designed for human capabilities, limitations and characteristics, they are unsustainable (Sev, 2009)

CHAPTER 4

DECISION-MAKING PROCESS TO SELECT RIGHT SET OF REQUIREMENTS

4.1. Decision Making Process in Greening Existing Building

Decision-making in greening an existing building is a very complex process because it encompasses several alternatives for various criteria (Menass, 2011; Kabak, Köse, Kırılmaz, & Burmaoğlu, 2014; Wu, & Pagel, 2011). Thus, refurbishment projects are generally associated with many uncertainties and high level of risk. A green renovation should be energy saving, comfortable, healthy and safe, long lived, economical and environmentally friendly at the same time (Mickaityte, Zavadskas, Kaklauskas, & Tupenaite, 2008). In other words, a green building has to take into consideration of social and cultural, economic, environmental constraints simultaneously and these criteria can sometimes contradict each other (Ferreira, Pinherio, & Brito, 2013). Moreover, as the green building renovation involves wide range of stakeholders (owners, managers, occupants, contractors) and has various and conflicting needs, decision making process evolves to more complex operation

(Miller, &Buys, 2011; Ferreira et al., 2013). Decision makers in greening an existing building have to deal with many criteria simultaneously by considering both quantitative data coming from building assessments and qualitative data from volatile human thoughts and feelings (Kabak et al., 2014). Users of the buildings do not always really know what they need or do not need (Clarkson, Coleman, Hosking, & Waller, 2011). People could have two kinds of needs; expressed (explicit) and potential (latent) (Kim et al., 2013). While explicit need can be easily expressed to designer, users do not aware of their potential needs until designers or suppliers provided them (Kim et al., 2013; Afacan, & Demirkan 2010; Wagner, & Hansen 2004). Therefore, understanding and uncovering user latent needs are completely significant yet a challenging issue in decision-making process. Further, increasing market value of a renovated building; one of the main objectives of building owners, also should not be disregarded and it highly depend on decision making process (Menass, 2011; Mickaityte et al., 2008). Thus, decision makers always have to bear economic issues in their mind while taking green renovation decisions. Unfortunately, this complexity and uncertainty can lead building sector to demolish the existing buildings and constructing the new ones because creating a new building obviously has less benchmark and so, more simple decision-making process (Miller, & Buys, 2011).

To overcome this complexity, plenty of technologies are produced and this makes the situation more unclear (Luther, & Rajagopalan, 2014). The reports upon green renovation reveal that the used decision-making technologies can cause building to save energy both only %10 or %40 and more (Shairo, 2011). This means that choosing a suitable decision-making for a project is essential. For this reason the researchers work on developing a systematic and optimal decision-making process to ensure of project success. Tupenaite and her friend's offer a strategy consisted of four parts (Tupenaite, Zavadskas, Kaklauskas, Turskis, & Seniut, 2010). It begins with data collection and analysis, in other words, determining objectives, task and main participants of the project. Second phase is decision modeling phase in which the evaluation criteria are selected and alternatives are characterized. After that, decision selection phase is created to decide the best alternative and trade-offs. The process is ended with final decisions to be conveyed to the implementers. In Hassanien and Losekoot (2002) model however, there is an evaluation part in addition to these four parts. Ma et al. (2012) also offer almost a similar strategy but with a more detailed explanation (Figure 3). The first phase is consisted of determining scope of work, targets available resources and pre-retrofit survey, which provides valuble source of current problems of a building and the occupants' needs. The second phase is energy auditing and performance assessments. The energy use of the building is idenfied and the results are evaluated according to the selected performance indicators. Additionally, inefficient building componentscan be also diagnosed in this phase. In the third phase, retrofit alternatives are identified with the help of risk assessment, economic analysis, and energy saving estimations. Then, the retrofit alternatives are prioritized according to different factors. The fourth phase is named as site implentation and comissioning. The final decision is ready to implemention. In this phase, test and commissioning (T&C) is also conducted to guarantee operations in the buildings work properly. Upon completion of the implentation and comissioning, validation and verification process can be began through post measurement methods and post occupancy survey in order to investigate the satisfaction level of the building users.

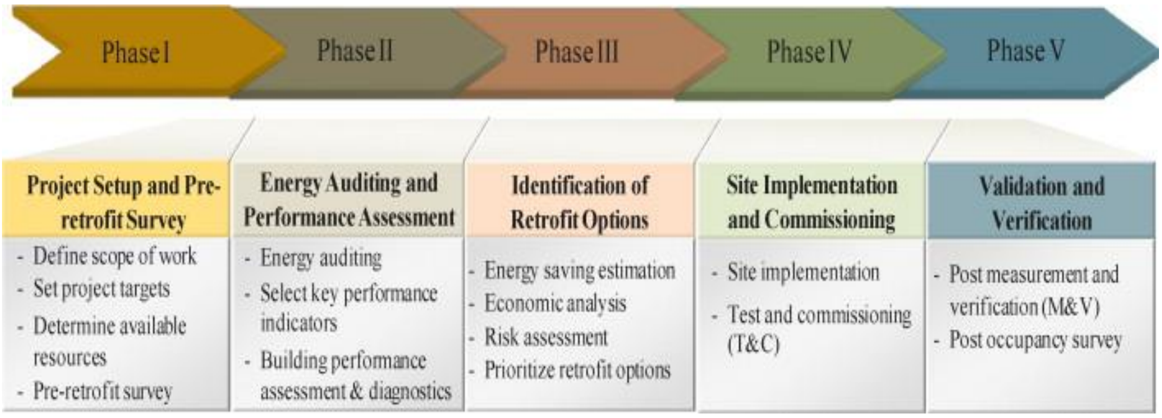


Figure 3. Key phases of a green retrofit programme. Adapted from “Existing building retrofits: Methodology and state-of-the-art” by Z. Ma, P. Cooper, D. Daly, & L. Ledo, 2012, *Energy and buildings*, *55*, 889-902.

Even though decision-making strategies for a greening an existing building differ from each other in one way or another, there is a consensus about what basics components of the strategies should be. Firstly, it is highly mentioned that identifying client needs at the outset of the project is essential (Ferreira et al., 2013; Miller, &Buys, 2011; Jensen, & Maslesa, 2015; Mickaityte et al., 2008; Alshuwaikhat, & Abubakar, 2008; Ma et al., 2012). End users of the buildings are often ignored during the decision- making process and remembered at the end of the project (Jensen, & Maslesa, 2015). At the beginning of the implementation, all aspects of an ideal sustainable building should be considered rather than only taking into account the energy aspect of the buildings (Wu, & Pagell, 2011). Since a small enhancement of one sustainable building aspect can help to improve another (Tupenaite et al., 2010). In this respect, attaching importance on only energy saving constraints and disregarding other factors undermines the success of the project. The most satisfied results are obtained from a green renovation when different group’s needs are evaluated. For this reason, decision makers should adopt more systematic and integrated approach (Alshuwaikhat, & Abubakar, 2008) and always bear the end-users and the owner of the buildings in their mind at the beginning of the project (Jensen, & Maslesa, 2015).

4.2. Importance of Prioritization for Decision Making Process

Decision-making is a complex process, even when only two choices are discussed. In green design process, designers have to deal with several alternatives. The ideal is providing all alternatives to meet the all requirements; however, there are lots of constraints about this issue. In real world, time is short and resources (technologies, budgets, labor force) are limited. Conflictingly, expectations are high and the project should be operated as quickly as possible in most satisfying way (Ma, 2009; Yager, 2004; Wiegers,1999). Satisfying all the requirements is very difficult for designers (Afacan, & Demirkan, 2010; Ma, 2009) and when multi-dimensional aspect of the sustainable design is considered, it becomes more impossible. Further, from an objective point of view, it is a fact that some aspects are more important than the others (Wiegers, 1999). Therefore, some methods optimizing the choices are needed. Requirements prioritization is one of the essential methods to eliminate the alternatives and overcome the complicated decision problem (Berander, & Andrews, 2005). It helps to identify the most critical requirements for the project. Thus, the right selection of a given requirements and getting rid of the unnecessary ones can be a solution to time and resource based problems (Berander, Khan, & Lehtola, 2006). Prioritization of the requirements can be conducted with respect to different aspects like importance, time, cost, and penalty. These aspects can diverge from a project to another. Especially “importance” can has multi-faces depending on the project. The most significant point is keeping aspects simple to reach the result in a most practical way (Ma, 2009). According to Herrmann and Daneva (2008), the most critical part in the requirement process is to identify the appropriate needs and the best method is prioritization to achieve this goal. It is may be because requirement prioritization has lots of advantages. Firstly, it gives the core features of the requirements and therefore provides optimal implementations. This benefit also brings solutions to conflicting features of the design like budget, resources, quality, time, market value. As another advantages, proper estimation of user satisfaction can be predicted beforehand. Different stated requirements by the users from various backgrounds can produce a negotiation for sustainable decision. Determining importance level of different requirements can cope with this situation (Berander, & Andrews, 2005).

It is true that requirement prioritization has many benefits and also some challenges for implementation, because the process can be ambiguous and very complex. To begin with, the words of priority can be interpreted differently by the people. While it can be perceived as the importance of a requirements, in some cases it is regarded as how soon the requirements are implemented (Lehtola, Kauppinen, & Kujala, 2004). Further, the extensive gap between decision makers and the stakeholders can be a problem. Developers cannot always notice which requirements are the most important for the end- users (Wiegers, 1999). Additionally, users and the designers can be skeptical towards each other. Users feel uncomfortable because they consider that decision makers will apply only the most important elements to the design. On the other hand, designer can be unconvinced about the occupant needs as they assume that users are not sure of their real needs (Yager, 2004). In such cases, it is highly critical to construct factors which are comparable or somehow related to each other (Berander, Khan, & Lehtola, 2006). If the decision makers do not overcome these challenges, the success of the project is undermined. Many projects have to face with the failure due to disregard end-user needs, unrealistic goals and late implementation of the prioritization methods (Ma, 2009). Therefore, determining a concrete prioritization technique is crucial, specifically for in green design decision-making process.

4.3. Techniques of User Requirement Prioritization

Since prioritization process contains many complexity and challenges, various techniques and methods were developed. In the literature, there are different classifications in order to clarify numerous techniques. Bernard and Andrews (2005) divided the techniques into two groups; qualitative or quantitative. The qualitative techniques provide subjective measures and they are more preferable to imply once the requirements has undetectable relationship with each other. However, quantitative approach assigns values to requirement according to different criteria. According to Karlsson and her friends (2007), techniques can be grouped with respect to assignment types. While some are about assigning absolute importance to each requirement e.g., essential, conditional, optional is critical, the others are determined with respect to relative importance of the requirements and requires an expert for their evaluation. Techniques also can be grouped depending on measurement levels (nominal, ordinal, interval/ratio) of the outputs obtained from the prioritization (Aasem, Ramzan, & Jaffar, 2010; Ma, 2009). As nominal scale methods, numerical assignment and MoScoW method can be exemplified. In these techniques requirements belong to different priority clusters but the requirements in the same priority group has the same importance. Simple ranking, Bubble Sort, Binary Search Tree are the ordinal scale methods, which is mean that the prioritization is constituted by ordered list of requirements. On the other hand, ratio scale methods like Hundred Dollar Method, AHP (Analytical Hierarchy Process), Minimal Spanning Tree, offer relative differences between the requirements (Aasem, Ramzan, & Jaffar, 2010; Bernard, &Andrews, 2005; Ma, 2009). The techniques based on ratio interval scale are found to be powerful in terms of providing more accurate and informative results compared to ordinal and nominal ones (Karlsson, 1996). Further, in literature AHP is regarded as an distinct option among the other ratio scale techniques because it offers trustworthy results and has a consistency check (Karlsson, Wohlin, & Regnell, 1998; Khan, Rehman, Khan, Khan, & Rashid, 2015). In this respect, AHP was chosen as the prioritization method for this research. (For detailed information see Chapter 5, section 5.3.2.2.2. Analytical Hireracy Process)

CHAPTER 5

METHODOLOGY

5.1. Research Question and Hypotheses

This thesis addresses the following research question:

What are the Bilkent Library user requirements and their importance weightings to green an existing library building?

To achieve the response to this research question, the thesis formulated the following two hypotheses:

H1: According to the user-centered design approach, indoor air quality attributes have the highest importance weightings compared to other green design attributes.

H2: Student user needs for green library design are statistically different than the staff user needs.

5.2. Method of the Study

5.2.1. The Case Building: Bilkent University Library

In 1987, Turkish and International Children's Center (TICC) building was converted into Bilkent University Library building. In 1994, an additional building block designed by architect Erkut Şahinbaş was built to the north of TICC building. These two buildings were combined through the corridors and became one building block together (B block). Two years later, accordance with the increasing needs, a collaborative project (A Block) of Erkut Şahinbaş and İlhan Selim Kural was built 11 meters west of the current library building. Thus, two building blocks were obtained for the library use and they were linked by a tube to provide circulation with ease (Erdoğan, 2011) (Figure 4.). Today, the library offers 13.275 m2 usage area for its visitors and it is one of the most used buildings in the campus; in 2015, approximately 770.845 university students used the library building (*Bilkent University Library*, n.d.).

Bilkent University Library is consisted of several quiet rooms and one multi-media room. The quiet rooms have open plan spaces providing both study areas and shelving areas which contain books and other written materials. The multi-media room is arranged for only group working by offering both open plan study areas and private cells. All rooms, quiet and multi-media, are linked with the circulation areas and they are isolated from the copy center and the conference rooms. The survey was conducted in multi-media room in order to not disturb the people who studied. However, before starting the survey it was stated that the participants should have answer the questions in the survey according to their general use of the library.

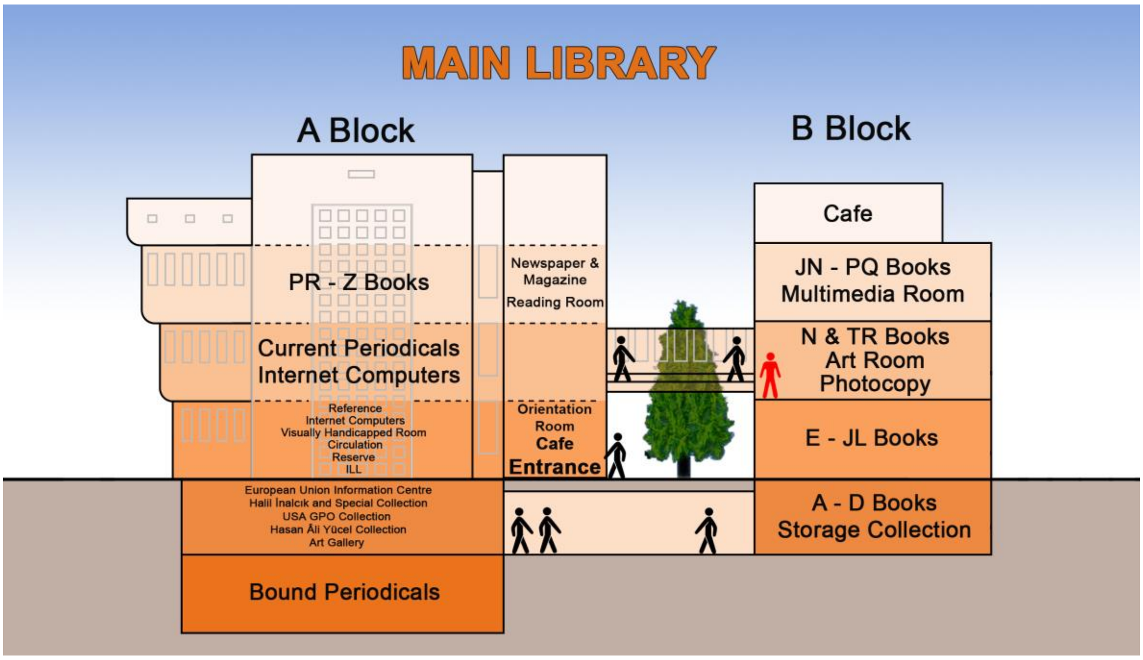


Figure 4. Shematic plan of Bilkent University Library. Adapted from Bilkent University Library, n.d., Retrieved from http://library.bilkent.edu.tr/tr/sanat-koleksiyonu-plan

5.2.2. Sample Group

According to a research on sustainable renovation of Alexandria National Museum in Egypt, the people, who were more familiar with the museum and the renovation process, were more satisfied with the sustainable renovation solutions compared to temporary users of the buildings; visitors (Elsorady, 2013). This research led the researcher to suspect about the needs of the different users of the library; librarians and the students. Therefore, the sample group in this research was divided into two groups; one group is the university students (both graduate and undergraduates) and the other group is the library staff at Bilkent University. This division was made according to the time spent in the library because while students can visit the library for unrestricted durations like exam weeks, library staff have to be there during a certain time duration; every day from 9 am to 5 pm. Thus, they are more familiar with the library concept in general and the library building itself. It is considered that this situation may create different type of requirements. The samples from both two groups were chosen randomly among the people who wanted to participate in the survey voluntarily. Therefore, it can be stated that the stratified sampling method was used in for sampling which is a method preferred when “the population is partitioned into non-overlapping groups, called strata and a sample is selected by some design within each stratum" (*How to Use Stratified Sampling*, n.d.).

In order to conduct a survey with the human participants, the required procedures were applied. The approved ethics form from the Bilkent Univesity Ethics committee is attached in Appendix A. 287 undergraduate and 63 graduate students (347 students in total with the mean age 22.46) participated the survey and while 187 of them were male, 160 students were female students. As for the library staff, 19 male and 21 female staff (40 staff in total with the mean age 41.43) participated to the research.

5.2.3. Procedure

Identifying key indicators and key strategies while greening an existing library building through a user-centered decision-making model is the main objective of this research. In order to achieve this goal, a series of three analysis steps was planned (Figure 5). The first step is ascertaining green attributes by implementing a user survey and conducting a walkthrough visit. The second step is grouping these attributes with the help of exploratory factor analysis conducted in SPSS 21.0 package software. The third step is calculating importance weightings of the groups by Analytical Hierarchy Process conducted in Matrix Laboratory (MatLAB) R2016a to identify genuine needs and demands of the library users. Obtained results would lead the researcher to determine key indicators and key strategies before greening an existing academic library building. Finally, uncorrelated t-test was implemented on data collected from both library staff and the students in order to compare the needs of subjects using library different time duration. The following sub-sections explain each step in a detailed manner.

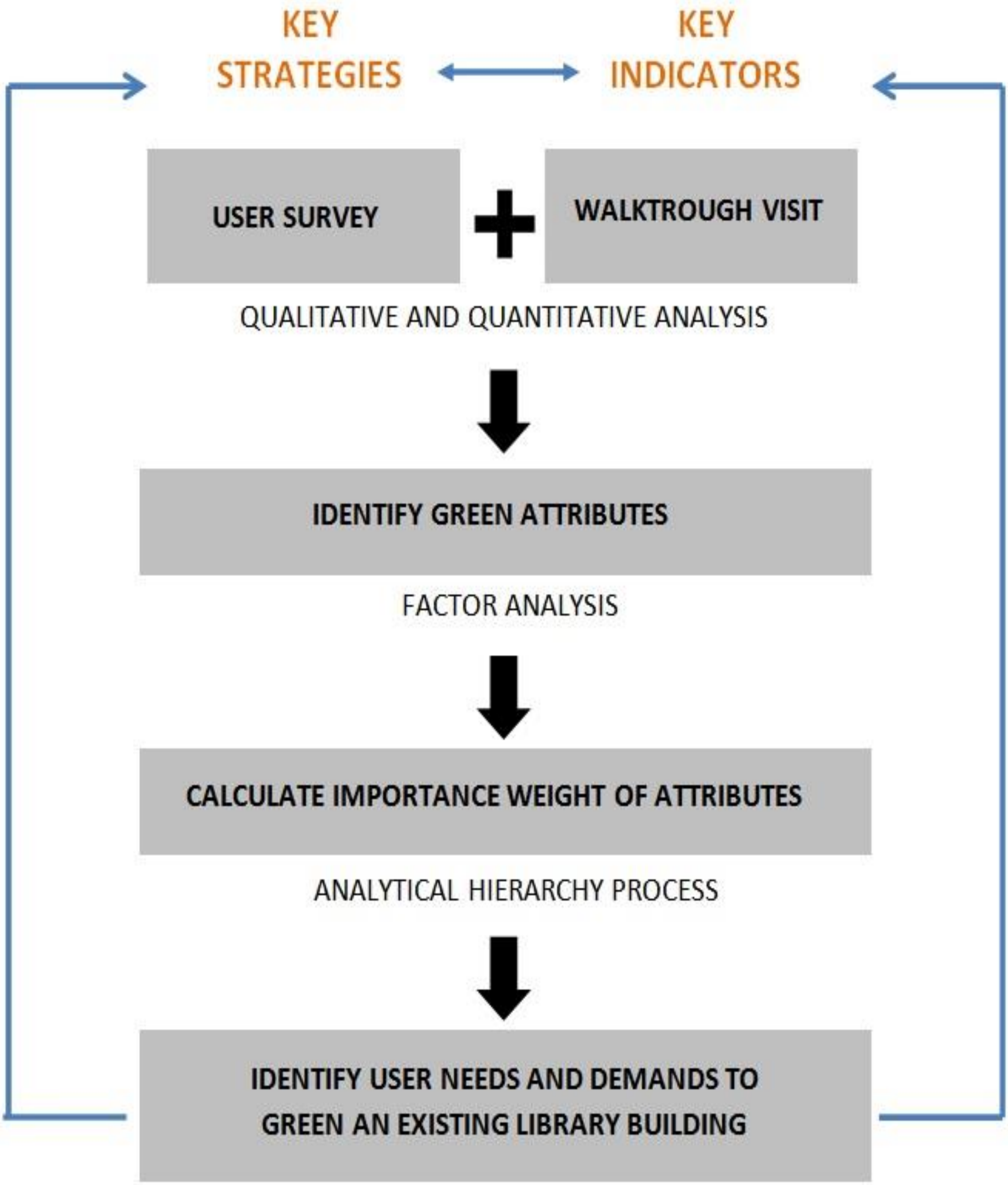


Figure 5. Theoretical framework of the research, drawn by author, 2016.

5.2.3.1. Walkthrough Visits

The walkthrough visits were carried out by both the researcher and 40 students taking IR 352 Environmental Issues and Ecological Sustainability course in Bilkent in the fall semester, 2015-216. First visit was conducted by the researcher in 14 December 2015. The availability of the statements of section 3 in the user survey was investigated. The visit was started in A Block from the basement to the second floor and after examining the Block A; the visit was continued with the same process in B Block. The intention of the walkthrough visit was specifying the current situation of the building and collecting some data in order to interpret the obtained results from the user survey.

IR 352 is an elective course examining environmental issues; energy water, global warming, disaster, climate change, food production, etc. Student visits were led by the course instructor Jennie Farber Lane to different places at the campus including the library. Then students, individually or in a group, analyzed various topics about the campus with respect to these questions; what natural resources are involved, what environmental issues exist on the campus, what contributes to these issues, who is affected by this issues. At the end of the course the written report was expected from the students about their focus topics. Part of the information needed to interpret the survey was acquired from the report written by the student Faria Pitafi and in-class survey conducted about Bilkent Library.

5.2.3.2. User Survey

The user survey is consisted of three sections. The first section, named basic information, is prepared to collect demographic data from the users. For the second section, a survey prepared by Zhao and his friends (2015) was modified to identify what and how the users understand the term of green building. Finally, the third part of the survey was developed to investigate green building needs of Bilkent University Library Occupants. Although both LEED 2009 for Existing Building Operations and Maintenance (EBOM) and Energy Performance of Buildings Regulations in Turkey (ENBR) (Binalarda Enerji Performansı Yönetmeliği) were used for the survey, the main source was EBOM because ENBR's main focus is on only energy and EBOM automatically comprises the ENBR with its topics; sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in operations, and regional priority. The project checklist of EBOM provides these topics and their sub topics serving as criteria for accreditation (see Appendix B). Each statement in the survey was formed by considering these sub topics and by the relating them with the library users' needs. In this respect, the topics of innovation in operations and regional priority and the some sub- topics under the other topics were omitted for the reason that they were found inconvenient to be evaluated by the library user-perspective and to be more related to building operations. Further, the topic of resource was separated from the materials and resources part and integrated into topic of energy, because resources and effective use of energy were found to be intrinsically linked. Again, while waste was mentioned under the title of 'material and resources' in the checklist, for this research, managing waste was found so important that it appeared as an independent topic. To conclude, topics were determined as; site, water, energy, material, indoor environmental quality and waste and statements were prepared for each topic by taking into consideration LEED 2009 for Existing Building Operations and Maintenance and Energy Performance of Buildings Regulations in Turkey (Appendix C).

5 point Likert-scale statements were constructed (1 for the least important and 5 for the most important) for the section 3, because Likert-scale questionnaire are more "likely to produce a highly reliable scale and easy to read and complete for participants" (Bertram, 2007). The title of the topics was deleted and the statements were mixed as during the pilot survey, it was observed that participants tended to give the same rates to the statements under the same topics. After revising, the final version of the surveys both in Turkish and in English was conducted between the date of 15 December 2015 and 15 February 2016 (see Appendix D and E).

5.2.3.2.1. Exploratory Factor Analysis

Exploratory factor analysis (EFA) investigates correlations between plenty of items in a research. Therefore, items are divided into smaller groups containing items somehow similar with regards to content or meaning. While doing this, it also reduces the number of items by eliminating the unrelated items with the others. Therefore more reliable and sound results can be obtained (Hooper, 2012). In this respect, explanatory factor analysis was found quite suitable for this research in order to group the items in a meaningful manner or in other words, to identify the green attributes from the users' perspectives.

Before implementing an exploratory factor analysis, the researcher should ensure the suitability of the data. Firstly, when the researchers have to deal with the scale-based data, it is crucial to determine if they are reliable or not. The statistics used for this is called Cronbach's alpha (α), which basically assess the consistency between the items. Secondly, size of the samples has crucial importance; however there is not a consensus about this issue (Hooper, 2012). While Comrey and Lee (1992) suggest 500 is at the excellent level, Kahn (2006) offers 300 people optimum for a reliable analysis. Gorsuch (1983) on the other hand, recommended a number of sample accordance with the variable; 5 cases for per variable. In this research, this approach was taken into consideration. The aim was reaching to 270 (54X4) participants and this number was even exceeding with 347 students. Further, the sample should be chosen from a similar population group because even if the sample size is suitable for EFA, nonpresentative sample can lead to inaccurate results (Karami, 2015). In this research, the participants were only the library users, therefore it can be said that the sample was the representative.

After ensuring the convenience of the data, correlation matrix is constructed to checks the strengths of the correlation of the items. Then, the factors are rotated in order to obtain more meaningful and understandable data. Finally, rotated factors are interpreted and named according to its content (Hooper, 2012).

5.3.2.2.2. Analytical Hierarchy Process

Analytical hierarchy process (AHP) is a multi-criteria decision-making method developed by Saaty in 1980's. This method prioritizes the different alternatives by comparing. The subjective pair wise comparisons are transformed into the scores in other words the weightings (Chen 2006; Handfield, Walton, Sroufe, & Melnyk, 2002). These weightings indicate the importance of the each requirement, therefore the most suitable solution can be determined from the all alternatives (Saaty, 19980). As the decision-making is a very complex process in green design because of its multidimensional nature, a systematic approach is needed such as AHP. There are several prioritizing techniques indeed; however, AHP was chosen due to its some distinguished capabilities. To begin with, it is a fault tolerant method; when an error occurs, it can be easily interfered. Secondly, consistency check can be applied to the process and therefore it offers accurate and reliable results. Lastly, AHP provides efficient results in ratio scale, thus it gives opportunity to obtain the scores in order to compare and contrast (Karlsson et al., 2007; Khan et al., 2015).

In general term, AHP is consisted of three basic steps (Rangone, 1996; Chen 2006; Handfield, Walton ,Sroufe, & Melnyk, 2002). The first one is constructing a hierarchy tree of the requirements (Figure 6). At the top, the main goal of the problem is placed. The decision-making criteria are situated at intermediate level while the lowest part has the decision alternatives. In this research, identifying green attributes for sustainable conversion of an existing library building is at the top point of the hierarchy structure. The other levels of the hierarchy tree will be constructed according to the factor analysis to be applied on user survey data. The second is performing pair wise comparison to identify priorities. As green design process involves professions from different backgrounds, pair wise comparison should be conducted by experts from different fields. For this reason, 4 interior architects and 4 architects, who are expert in the sustainable design, compared the requirements in this research. The final step is synthesis of the prioritization; in other words ordering the requirements according to their importance weightings and so, reaching the final decision (Ramanathan, 2001).

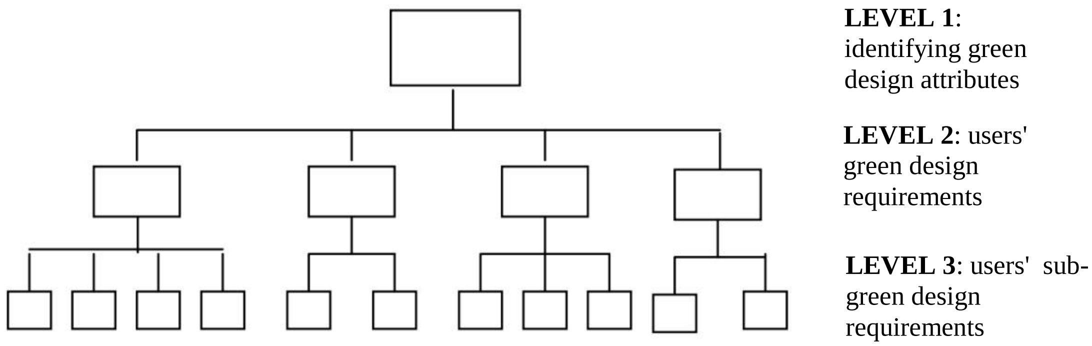


Figure 6. The hierarchical tree model for the specified green design requirements. Adapted from A Computer Assisted Universal Design Plug-In Tool for Architectural Design Process by Y. Afacan, 2008.

The original scale offered by Saaty (1980) for the comparison was a 9 to 9 point scale (Table 1). To more clarify, 1/9 means that the importance of one requirement is nine times smaller than another and 9/1 symbolizes that the importance of one requirement is nine time higher than the another one. In this research however, 5 point scale was preferred because of its some advantages. According to Karlsson et al. (2007), 5 point scale (1/5, 1/4, 1/3,........, 3/1, 4/1, 5/1) is more suitable for human cognition because people can get confused when more intermediate numbers involve the scale. Further, using 5 point scale is much more time saving and easy to deal with the inconsistency problem (ZhanG & Nishimura, 1996).

Table 1. The original scale of the AHP method. (Saaty, 1980)

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgments
Reciprocals	If requirement i has one of the above numbers assigned to it when compared with requirement j, then j has the reciprocal value when compared to with i

This paragraph is dedicated to examine stepwise process of the AHP more deeply. The first step is placing the requirements in an nxn matrix. The pair wise comparison of the requirements according to the given scale is the second step (Appendix F, Step 2). The matrixes will has a main diagonal consisted of value 1, because when requirements are paired themselves, they are always valued with 1. After obtained pair wise data, the next is normalization of the matrix (Appendix F, Step 3). Finally, the requirements are assigned according to the eigenvalues obtained from normalizing process (Appendix F, Step 4) (Karlsson, & Ryan, 1997). Then, consistency ratio (CR) has to be calculated to decide whether eigenvalues are consisted or not and if the CR is greater than 0.1, re-check of the pair wise comparison is needed.

5.3.2.2.2. Uncorrelated t-Test

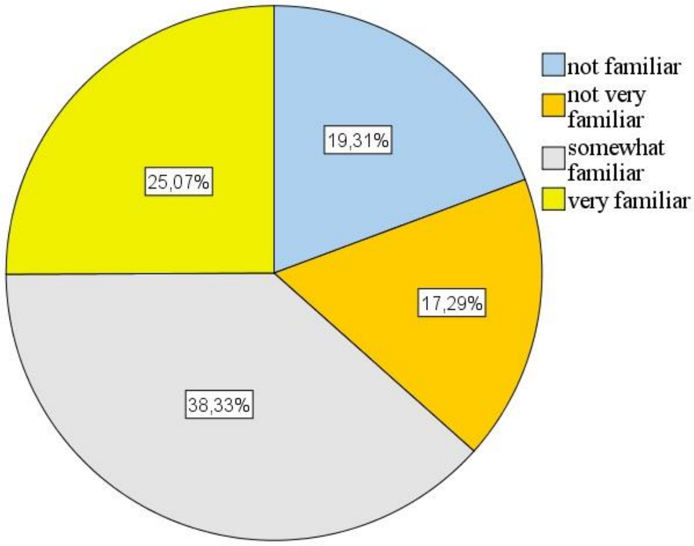
In this research, uncorrelated t-tests, in other words independent sample t test was chosen in order to analyze whether there are any differences between two different sample (library staff and the students) or not, because it compares descriptive data of two unrelated samples on the same variables. (Argyrous, 2011) This test assumes that mean differences between the dependent variables depend on the independent variables. Therefore, it can be claimed that indipendent t-test is an investigation of the dependence (*StatisticsSolutions*, n.d.). In order to implement this test, the samples should be completely independent and the variables should be continuous (interval/ratio level). Further, data should be collected randomly from a population (*SPSS Tutorials Independent Sample t Test*, n.d.).

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1. Basic Understanding of Green Building

Before identifying user needs, it was essential to examine how the users of Bilkent University Library interpret the green building concept. In this respect, descriptive analysis was implemented on the collected data from the user survey; section 2. According to the analysis, while the majority of students stated that they are very familiar (38%) or somewhat familiar (25.07 %) with the green building concept, the remaining defined themselves as not very familiar (17, 29%) and not familiar (19 %) with the green building term (Figure 7.). Again, a clear majority of the staff stated that they are very familiar or somewhat familiar with the green building (45% and 47.50% respectively). While none of them defined themselves as being not very familiar, 7% of staff stated that they are not familiar with the green building design (Figure 8.). Therefore, it can be observed that in both population groups, the percentages of people who defined themselves familiar (somewhat or very) with "the green building" are higher than the number of people being not very familiar and not familiar.



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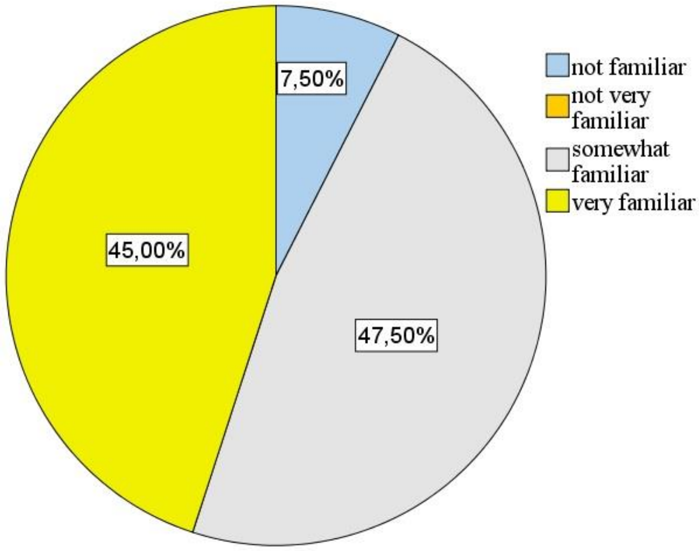
source: hypothetical survey, 2016

Figure 7. Familiarity of the students with the “green building"



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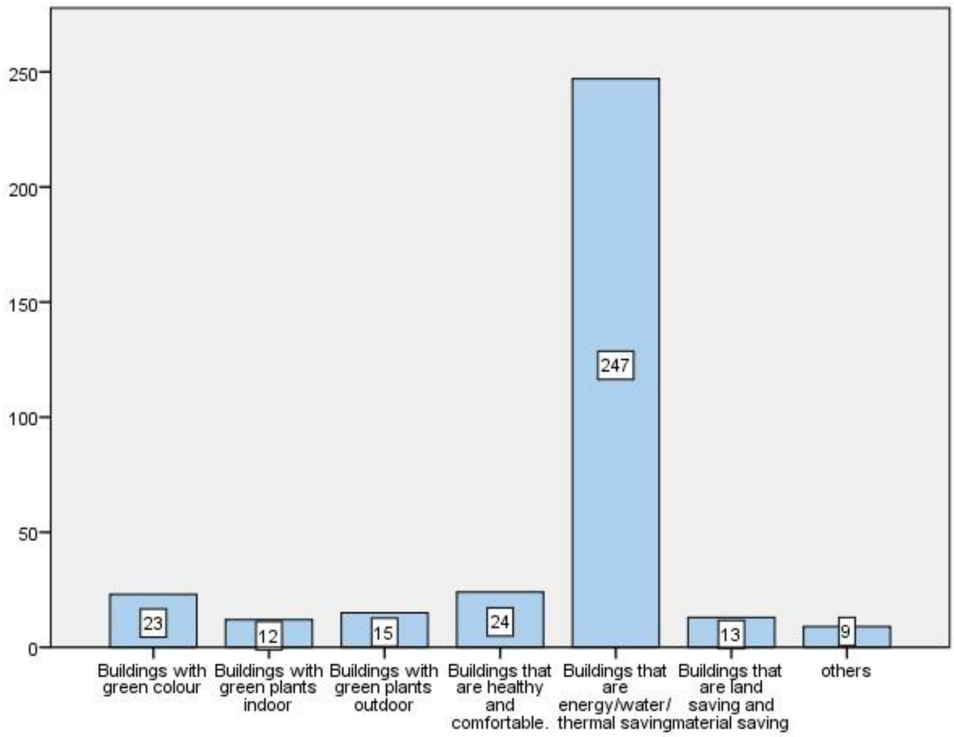
source: hypothetical survey, 2016

Figure 8. Familiarity of the staff with the “green building"

Secondly, how the users perceive green building concept was investigated. Among the students, 247 people considered the green building as "buildings that are energy/water/thermal saving". 24 and 23 number of students voted "building that are healthy and comfortable" and "buildings with green color" respectively. Between 12 and 15 number of people chose the "buildings with green plants indoor", "buildings that are land saving and material saving" and "buildings with green plants outdoor". Only 9 students considered the meaning of a green building must be something else (Figure 9.).



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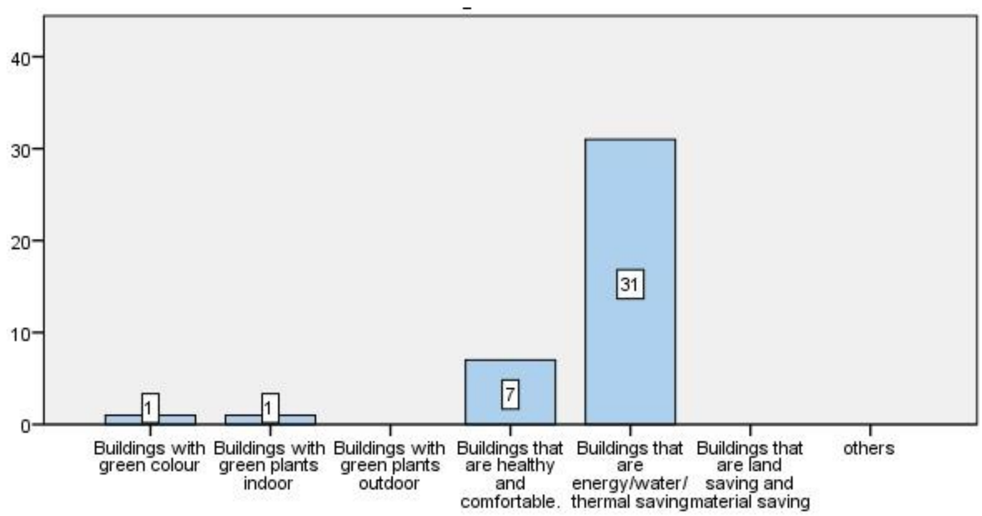
source: hypothetical survey, 2016

Figure 9. The meaning of the "green building" for the students

As for staff, 31 people described green buildings as "buildings that are energy/water/thermal saving". The second preferred statement was "building that are healthy and comfortable" with 7 staff. While the options of "buildings with green color" and “buildings with green plants indoor" voted by two people, the statements of “buildings with green plants outdoor", "buildings that are land saving and material saving" and “others" were not chosen by anyone (Figure 10.). After examining both sample group, it can be summarized that between both two sample groups, meaning of the green building concept found as "buildings that are energy/water/thermal saving" by a majority.



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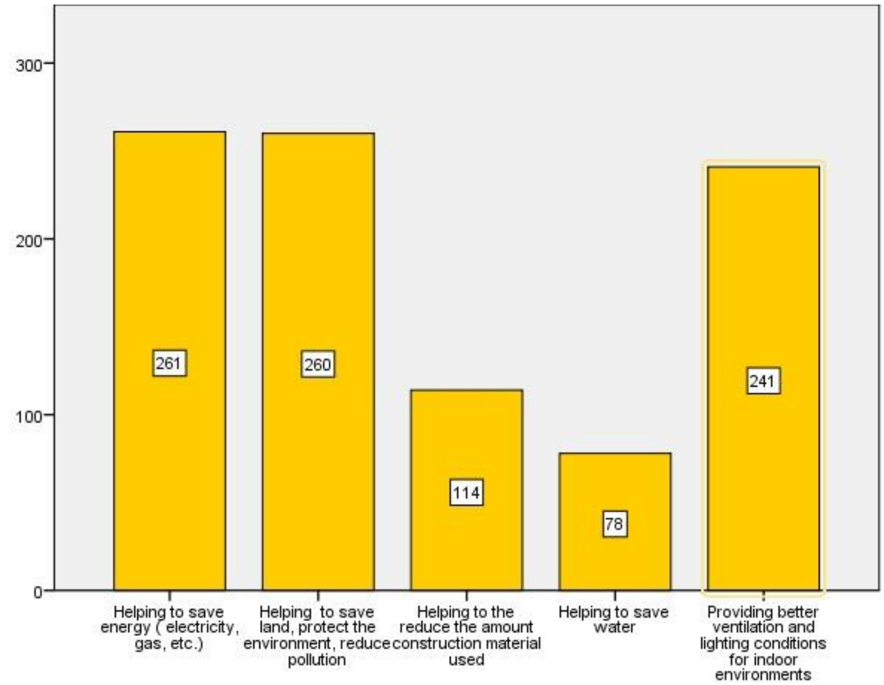
source: hypothetical survey, 2016

Figure 10. The meaning of the “green building” for the staff

Finally, from users’ perspectives, the aims of green buildings were evaluated. Nearly 260 of students found "helping to save energy (electricity, gas etc.)" and "helping to save land, protect the environment, reduce pollution" to be one of the most important aims of a green building. People perceived aims of "providing better ventilation and lighting conditions for indoor environments", "helping to the reduce the amount construction material used” and " helping to save water" as one of the most important purposes of a sustainable building with 241, 114 and 78 students respectively (Figure 11.).



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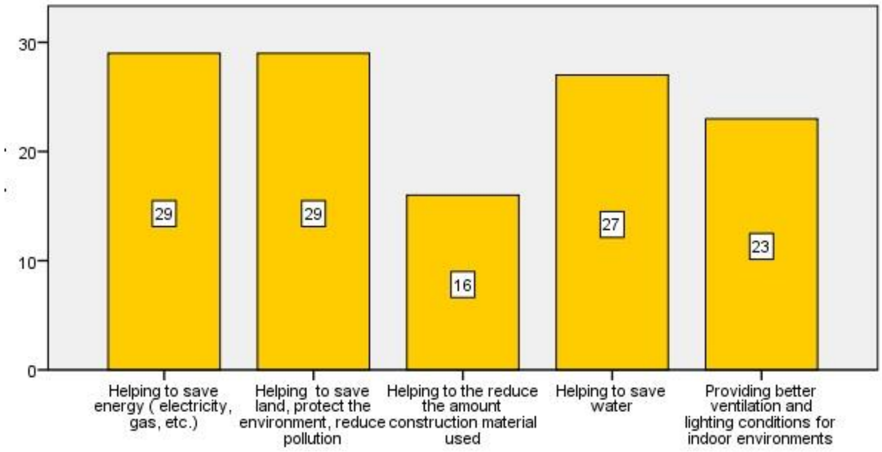
source: hypothetical survey, 2016

Figure 11. The number of students who voted the given green buildings goals as "most important"

29 staff found "helping to save energy (electricity, gas etc.)" and "helping to save land, protect the environment, reduce pollution" to be one of the most important aims of a green building. Aims of " helping to save water", " providing better ventilation and lighting conditions for indoor environments" and " helping to the reduce the amount construction material used " were perceived as one of the most important purposes of a sustainable building with 27, 23 and 16 staffs respectively (Figure 12.). It is clear that "helping to save energy (electricity, gas etc.)" and "helping to save

land, protect the environment, reduce pollution" were voted by more participants in both two sample groups. However, goal of saving water was identified differently by two sample groups; staff perceived helping to save water more significant comparison with the students.



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source: hypothetical survey, 2016

Figure 12. The number of staff who voted the given green buildings goals as “most important”

To conclude, in general, basic understanding of the participants; staff and students, showed the same tendency to green building concept. Both of them defined themselves as being mainly familiar with the green building concept and they considered that green buildings are the buildings which are energy/water/thermal saving. Further, "helping to save energy (electricity, gas etc.)" and "helping to save land, protect the environment, reduce pollution" appeared to be the most important goals of a green building for both staff and students.

6.2. Investigating Green Building Needs of Bilkent University Library Occupants

In order to explore the needs of Bilkent Library occupants, the data obtained from walkthrough visits and the section 3 in user survey were analyzed. Data of section 3 were investigated through three main methods; factor analysis to find out green design attributes, analytical hierarchy process to prioritize these attributes according to their weightings and finally uncorrelated t test to compare students and staff needs. However, before proceeding of them, some statements were omitted to refine extreme ends of the used scale, because eliminating extreme results strengthen the correlation between the factors (Krathwohl, 1997). In the survey 1-5 scale was used; (1) the least important, (2) less important, (3) moderately important, (4) very important, (5) most important. Therefore, the statements of number 4, 8, 16, 35 with the mean score 4.51, 4.59, 4.59, 4.54 respectively were omitted to refine extreme ends of the used scale. After refinement of the survey items, reliability of the survey was investigated and as result, the survey found to be hold an internal consistency with cronbach's alpha value 0.958. According to Nunnally (1978) this value should be above 0.7 therefore it can be stated that the survey indicates high level of reliability.

6.2.1. Walkthrough Visits

The aim of the walkthrough visit was detecting current situation of the library building and contributing to interpretation of results obtained from the survey. In this respect, a survey conducted in the scope of the course IR 352 provided some handful information. IR 352 students carried out a visit to Library and then they evaluated the current situation by rating the negative components of the building which are needed to be progressed. According to this in-class survey, food waste and smoking activity nearby the library environment found to be most negative side of the building. Following this, traffic noise from the outside and the poor indoor air quality were evaluated as other important disadvantages of the building. Further, in the report by Fariah Pitafi, the general atmosphere of the library was found to be not compromising with a green building ambience; therefore, the renovation of the library cafe and creating a recreational space were recommended to give a "green appearance" to the library.

The researcher also examined the library according to availability of the user survey items. As result, it was noticed that there was only one totally available item; nearness to public transportation and a few partially satisfied items; waste boxes, mechanical ventilation, light sensors, green elements in outdoor. The other items were not accessible. As a general term, air quality was found especially poor with the existence of nonhomogeneous heat disturbance between the spaces. The overwhelmingly hot air-condition with dust and odors in study rooms were also observed as a factor reducing the quality of indoor air.

6.2.2. Results from Factor Analysis

Exploratory factor analysis was carried out on the refined survey with 50 items via SPSS 21.0 package software in order to investigate related ones. Firstly, the correlation matrix was constructed to decide if the strength of the correlation between the questions is reliable for factor analysis. The elimination of the items scoring lower 0.30 is needed because while 1.00 is an indicator of a perfect correlation, the scores under 0.30 represent a weak association (Argyrous, 2005). All correlation scores of the items were above 0.30 and so, all statements were remained. Then, a rotated component matrix was constructed to determine factors from the set of the correlations. This matrix offered factors with their loadings that are essential to identify which statement is correlated to a specific factor. At the end of analysis of the rotated component matrix, the factors having 3 items and less were removed in order to ensure strong correlation system and 4 green factors were identified with 47.765 % variances (Table 2).

Table 2. Summary of the rotated factors

Factor	Scale	Eigenvalue	Variance(%)	Cumulative(%)	Means
1	Resource efficiency	16.903	33.806	33.806	4.011
2	Indoor air quality	3.343	6.936	40,502	4.333
3	Acoustic Comfort	1.936	3.873	44. 570	4.054
4	Waste management	1.598	3.195	47.765	3.794

Factor 1 was named as resource efficiency because its 9 corresponding items were related to the efficient use of almost all kind of resources; water, energy, materials (Table 3). It is noteworthy that the first three highest loadings belong to items about reserving and reusing of water; "rainwater harvesting to use for toilet flushing", "using grey water from the sink for toilet flushing" and "rainwater harvesting for irrigating landscapes around the building". The following item is about re-usage of material sources for construction purpose; "usage of recycled materials in walls, floors, ceiling, floors, etc." and the remaining items can be evaluated for mixture of efficient usage of water and electrical energy resources; "using renewable energy sources to supply hot water for the building", "usage of light sensors in the building", "dual flushing button system for toilets", "usage of water efficient faucets in sinks" and "usage of energy efficient electrical office tools".

Table 3. Items of factor 1 and their loadings

	Corresponding items	**Loadings**	**Means**
1	Rainwater harvesting to use for toilet flushing	0.793	4.06
2	Using grey water from the sink for toilet flushing	0.692	3.95
3	Rainwater harvesting for irrigating landscapes around the building	0.682	4.22
4	Usage of recycled materials in walls, floors, ceiling,	0.659	3.86
5	Using renewable energy sources to supply hot water for the building	0.649	4.10
6	Usage of light sensors in the building	0.639	3.80
7	Dual flushing button system for toilets	0.562	3.62
8	Usage of water efficient faucets in sinks	0.537	4.16
9	Usage of energy efficient electrical office tools	0.528	4.21
	Cronbach's Alpha	0.903	

Factor 2 was named as indoor air quality (IAQ) because its 6 items covered the common IAQ issues (Table 4). The first four highest loadings were about adequate thermal condition of the library interior; "heating systems providing adequate thermal comfort for occupants", "adequate indoor thermal comfort in cold and arid weather conditions", "cooling systems providing adequate thermal comfort for occupants" and "even heat distribution between different spaces of the building". Although thermal comfort is examined separately from IAQ under the topic of indoor environmental quality, IAQ is an umbrella including thermal and health requirements of the occupants (Brown, 1997), because humidity and temperature have a considerable impact on perception of the indoor air quality (Fang, Clausen, & Fanger, 1998). The last two items were related to clean air conditions and natural ventilation; "air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)" and "adequate natural air ventilation provided from doors and windows".

Table 4. Items of factor 2 and their loadings

	Corresponding items	**Loadings**	**Means**
1	Heating systems providing adequate thermal comfort for occupants	0.625	4.41
2	Adequate indoor thermal comfort in cold and arid weather conditions	0.603	4.41
3	Cooling systems providing adequate thermal comfort for occupants	0.592	4.33
4	Even heat distribution between different spaces of the building	0.555	4.24
5	Air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)	0.536	4.29
6	Adequate natural air ventilation provided from doors and windows	0.518	4.29
	Cronbach's Alpha	0.836	

Factor 3 was entitled with acoustic comfort since all 5 items were related to sound privacy and background noise control in specific areas of the library building (Table 5). The first two items were covered sound privacy issue in shelving and circulation areas; "sound privacy in shelving areas",” sound privacy in circulation areas". The following two items were about the noise control; “background noise level in circulation areas" and "noise level in shelving areas". The last items attracted attention with being related to study areas; "sound privacy in study areas".

Table 5. Items of factor 2 and their loadings

	Corresponding items	**Loadings**	**Means**
1	Sound privacy in shelving areas	0.656	4.09
2	Sound privacy in circulation areas	0.631	4.19
3	Background noise level in circulation areas	0.514	4.00
4	Background noise level in shelving areas	0.457	3.69
5	Sound privacy in study areas	0.452	4.29
	Cronbach's Alpha	0.722	

Lastly, the name of waste management is given to Factor 4, because it encompassed all the statment mentioned under the topic of waste in the survey (Table 6). All four corresponding items contains information about recycling and storage of the wastes; "existence of sufficient amount of separate recycling containers", "sufficient amount of recycling containers in every floor", "design of recycling containers (shape, color, size, etc.)" and "proper placement of recycling containers within the building".

Table 6. Items of factor 4 and their loadings

	Corresponding items	Loadings	Means
1	Existence of sufficient amount of separate recycling containers	0.721	4.15
2	Sufficient amount of recycling containers in every floor	0.648	4.01
3	Design of recycling containers (shape, color, size, etc.)	0.616	3.00
4	Proper placement of recycling containers within the building	0.525	3.77
5	**Cronbach's Alpha**	0.756	

In conclusion, students scaled the survey items accordance with their needs. Then, exploratory factor analysis was implemented to the collected survey data to eliminate unimportant statements and to obtain related statements in a systematic form. At the end, 4 design factors with different items emerged. In other words, these 4 green design attributes is an indicator of what user needs will be if Bilkent University Library is converted to a green building.

6.2.3. Discussion on Factor Analysis Results

Among the 4 factors, Factor 2: Indoor Air Quality has the highest mean score (4.33) which means that students' needs are dominantly defined by Factor 2 and its items. This was an expected result because in the literature, the common problems of existing buildings are related to indoor air quality (Balaras, Dascalaki, & Kontoyiannidis, 2004; Zhao, He, Johnson, & Mou; 2015; Gupta, & Chandiwala, 2010). Depending on the walkthrough visit conducted by the researcher, it can be also said that this situation was the same for Bilkent Library building. Correlations of IAQ related items with the high mean score, rather than other indoor environmental quality items related to daylight or acoustics, is an indicator of Bilkent Library users' adequate indoor air needs. When the Factor 2 items are analyzed one by one, it is observable that two items are associated with heating; "heating systems providing adequate thermal comfort for occupants" and "adequate indoor thermal comfort in cold and arid weather conditions" have the highest mean scores (4.41 for both). According to walkthrough visit, perceived heat in study rooms had been found extremely hot; however, the perception of the users' are different than this observation, maybe because of climatic condition of Ankara and specifically Bilkent University Campus. Ankara is in the arid continental climate zone (*İklim Sınıflandırması*, n.d.). Moreover, according to Google Earth Pro calculations, there is an altitude differences between Bilkent University Campus (1020 m) and the city center of Ankara (870 m), so this may cause cooler climate condition in winters for Bilkent University Library building occupants. Therefore, the highest mean scores which belong to the heating related items, especially cold and arid air condition related ones, is not surprisingly unexpected. The unexpected situation is that "cooling systems providing adequate thermal comfort for occupants" was found to be an important needs nearly as same as the heating related items with mean score 4.33. At this point a question arises; how could the users need both cooling and heating for the same building, under the same circumstances? This problem was clarified with the help of another item in the factor; the need of “even heat distribution between different spaces of the building". The heat differences between the spaces of the library building could lead to such a contradiction. Therefore, with this statement, determining as needs both cooling and heating related items at the same time seems to be possible.

The item of “air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)" is also another critical member of the factor because although there are other air quality related items in different areas of the library, specifically shelving area has the correlation with IAQ factor may be because of the dust caused by the books. The following item; the needs of “adequate natural air ventilation provided from doors and windows" is quite relevant with the previous one since this item can be regarded as a remedy for poor air quality in shelving areas. Further, correlation of natural ventilation needs of the users, with the IAQ factor, rather than mechanical ventilation related items in the survey, is a striking issue because according to literature; the energy consumption caused by the mechanical ventilation constitutes the main part of the overall energy consumption (Luther, & Rajagopalan, 2014) and this demand will increase by the years depending on the advance in the ventilation technology (Lourenço, 2014). As a result, statement of adequate natural air ventilation need by the users is promising in terms of establishing a balance between user needs and the aims of the sustainable building design.

Factor 3; Acoustic Comfort holds the second highest mean score with 4.054. This is not anticipated because when greening a building is discussed, acoustic comfort is not considered as a separate green goal. It is an undeniable fact that acoustic comfort is not examined as much as HVAC or energy saving features in the green building field. However, in this case, users' stated that they need acoustic comfort more than resource efficiency and waste management factors. The reason for this situation could be innate function of a library. Libraries are the buildings that not only provide sources but also place to work with them. Therefore, this result reveals that adequate acoustic performance in a library building is considerably significant like any other building type providing working places such as offices and the schools.

When the Factor 3 items is analyzed in terms of mean score, it can be clearly observed that the "sound privacy in study areas", "sound privacy in circulation areas" and "sound privacy in shelving areas" have the three highest mean scores; 4.29, 4.19, 4.09 respectively, in the factor. This ranking is meaningful once the numbers of the occupants using different areas of the building are taken into consideration because human density, in other words indoor sound source, gradually decreases from study room to circulation areas and from circulation areas to shelving areas. However, the relatively lower scores of items " background noise level in circulation areas" "background noise level in shelving areas" compared to sound privacy related items are noteworthy since it indicates that users firstly need solutions about sound privacy problem in the library. According to a research at Princeton University, libraries specified as quiet by the students have high background noise level. The author based acoustical comfort in the libraries on having the environment which is free from distraction (Markham, 2004). Therefore, the high mean scores of sound privacy related items and low mean scores of background noise level items can be explained with this respect. Although quiet rooms in Bilkent Library have relatively high background noise level (35-51 dbA) (Bora, Demirli, & Zeka, 2012), the participant stated that sound privacy is more important than the background noise level. This situation led the researcher consider that participants may link the background noise with the continuous sound source and sound privacy with the discontinuous sound source. Because, in many research related to the room acoustic, it was stated that users are more dissatisfied with overhearing irrelevant speak or intermittent noise like telephone calls or private conservations rather than the noise level especially while dealing with a task (Evans, & Johnson, 2000; Jensen, Arens, & Zagreus, 2005; Witterseh, Wyon, & Clausen, 2004). Additionally, according to a research conducted by Dökmeci and Kang (2012), library users are mostly annoyed with the mobile phones, personal music player and construction noise. In this respect, since Bilkent University Library contains several quite zones by its nature, discontinuous noises can distract occupants' attention with ease as well.

Factor 1, Resource efficiency has the third highest mean score (4.011). In this factor items can be grouped as water resources, material resources and energy according to their context. However, the same aggregation cannot be observed in the distribution of the mean score. For instance, the first four places of mean score ranking among the items are shared by statements related to rainwater, electric, water and renewable resources respectively. This situation indicates that users demand not only the energy saving related items but also preservation of various kinds of sources resources; water, energy, material. In the literature, the definitions of the green building are in line with users' demands. According to them, a green building should provide a holistic approach and should offer intelligent use of all the resources (Ali, & Nsairat, 2009; Green Building, 2016; Kats, 2003). The consensus between user needs and the intention of the green building concept is promising; however, there is an apparent contradiction between the users' demands and their response given in basic understanding of green building part of the survey. It is obviously seen that users perceive saving the energy as a more important goal than the saving water and the materials (see Figure 11 and 12). This contradiction maybe arises from latent, in other words, potential needs of the users. Sometimes people are not aware of their needs unless someone provides them (Kim et al., 2013; Afacan, 2008; Wagner, & Hansen 2004). Therefore, the library users might not aware of their potential needs at the beginning of the survey and they might realize their needs when they are introduced with the detailed statements about water and material saving items in the section 3.

Factor 4 has the lowest mean score among the other four factors (3.794). All of four statements related to the waste topic in the survey correlated with each other and created a factor. Therefore, it means that the needs for waste management is considered as a whole and separated from any other survey statements by the users. Such a factor addressing to waste management demand perfectly coincides with the intention of the green renovation concept. A successful renovation decreases the energy consumption by reducing environmental pollution, maintenance and transportation costs, and waste of materials (Carroon, 2010; Douglas, 2006). When the items are examined separately, it can be inspected that while the items "existence of sufficient amount of separate recycling containers", "sufficient amount of recycling containers in every floor" and "proper placement of recycling containers within the building of related to function of the waste box " generated a group in terms of holding close mean scores (4.15, 4,01, 3.77 respectively), the item; "design of recycling containers (shape, color, size, etc.)" was distinguished from them with

3.00 mean score. This situation indicates that user gives much more importance to serviceableness of the waste boxes rather than design of them.

6.2.4. Results from Analytical Hierarchy Process

Design process is a collaborative work of designer and the user. Therefore, after determining a set of user requirements, prioritizing these needs by the designers is essential to deal with the trade offs between multi-attributes. In this research, firstly 4 green attributes and then, the items of each attribute were compared by 8 designers; 4 architects and 4 interior architects (Appendix G). The pair -wise comparisons were performed with AHP method. To obtain the corresponding category for each green attributes, the mean value of the distributions by 8 designers was calculated. Finally, consistency check was implemented on the results to ensure reliability of the process. The consistency indexes of the all comparisons were below 0.1, which means that the results are reliable and there was no need to check the comparisons again (Saaty, 2008).

As result, the “acoustic comfort” was found the most important among the attributes. The following important attribute was “resource efficiency” and “waste management” was in the third place. Lastly “indoor air quality” was provided as the least significant factor (Table 7).

Table 7. Hierarchical order of green attributes

Factor	Green Attributes	Eigenvalues
1	Resource efficiency	0.377
2	Indoor air quality	0.254
3	Acoustic Comfort	0.216
4	Waste management	0.151

When acoustic comfort items were examined in terms of their importance levels, the statement of "background noise level in circulation areas" was found to be most significant among the other items. " Background noise level in shelving" area hold the second place and the order continued with "sound privacy in circulation areas" and "sound privacy in shelving areas" respectively. "Sound privacy in study areas" was perceived the least important item in the title of acoustic comfort with a clear difference compared to other items (Table 8).

Table 8. Hierarchial order of acoustic comfort items

	Items of Acoustic Comfort	Eigenvalues
1	Sound privacy in shelving areas	0.239
2	Sound privacy in circulation areas	0.235
3	Background noise level in circulation areas	0.210
4	Background noise level in shelving areas	0.197
5	Sound privacy in study areas	0.091

As for resource efficiency, the statement of "rain water harvesting to use for toilet flushing" found to be most important component. After this, two following items were also related to water reservation; “using grey water from the sink for toilet flushing” and” rainwater harvesting for irrigating landscapes around the building”. The order continued with the item reuse of material sources;” usage of recycled materials in walls, floors, ceiling, floors, etc.,” and the items containing information about efficient use of the water and the energy; "using renewable energy sources to supply hot water for the building", "usage of light sensors in the building", "dual flushing button system for toilets", "usage of efficient faucets in sinks". Finally, it can be observed that there is an obvious distinction regarding eigenvalue between the last items; “usage of energy efficient electrical office tools" and “the other components of the factor “(Table 9).

Table 9. Hierarchical order of resource efficiency items

	Items of Resource Efficiency	**Eigenvalues**
1	Rainwater harvesting to use for toilet flushing	0.133
2	Using grey water from the sink for toilet flushing	0.130
3	Rainwater harvesting for irrigating landscapes around the building	0.125
4	Usage of recycled materials in walls, floors, ceiling,	0.120
5	Using renewable energy sources to supply hot water for the building	0.113
6	Usage of light sensors in the building	0.107
7	Dual flushing button system for toilets	0.104
8	Usage of water efficient faucets in sinks	0.102
9	Usage of energy efficient electrical office tools	0.045

In the waste management factor “sufficient amount of recycling containers in every floor" had the highest importance weightings. "Proper placement of recycling containers within the building" was at the second level and design of recycling containers (shape, color, size, etc.) and " existence of sufficient amount of separate recycling containers" came next respectively (Table 10).

Table 10. Hierarchical order of waste management items

	Items of Waste Management	**Eigenvalues**
1	Existence of sufficient amount of separate recycling containers	0.777
2	Sufficient amount of recycling containers in every floor	0.663
3	Design of recycling containers (shape, color, size, etc.)	0.494
4	Proper placement of recycling containers within the building	0.291

Lastly , in indoor air quality factor , "air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)" was found to be most significant factor." Adequate indoor thermal comfort in cold and arid weather conditions" followed it with a close eigienvalue score and three items about thermal comfort came next; "cooling systems providing adequate thermal comfort for occupants",” heating systems providing adequate thermal comfort for occupants", " even heat distribution between different spaces of the building". The least importance weighting belonged to the statement "adequate natural air ventilation provided from doors and windows " (Table. 11).

Table 11. Hierarchical order of indoor air quality items

	Items of Indoor Air Quality	Eigenvalues
1	Heating systems providing adequate thermal comfort for occupants	0.625
2	Adequate indoor thermal comfort in cold and arid weather conditions	0.603
3	Cooling systems providing adequate thermal comfort for occupants	0.592
4	Even heat distribution between different spaces of the building	0.555
5	Air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)	0.536
6	Adequate natural air ventilation provided from doors and windows	0.518

To summarize, 8 designers compared the importance level of the green attributes determined by the user needs. Among the 4 these attributes , acoustic comfort had the highest importance weightings. When all factors was examined within their items; the statements of " background noise level in circulation areas", "rainwater harvesting to use for toilet flushing", "sufficient amount of recycling containers in every floor" and "heating systems providing adequate thermal comfort for occupants" were found as the most significant items in the scope of acoustic comfort, resource efficiency, waste management and indoor air quality respectively (Figure 13).

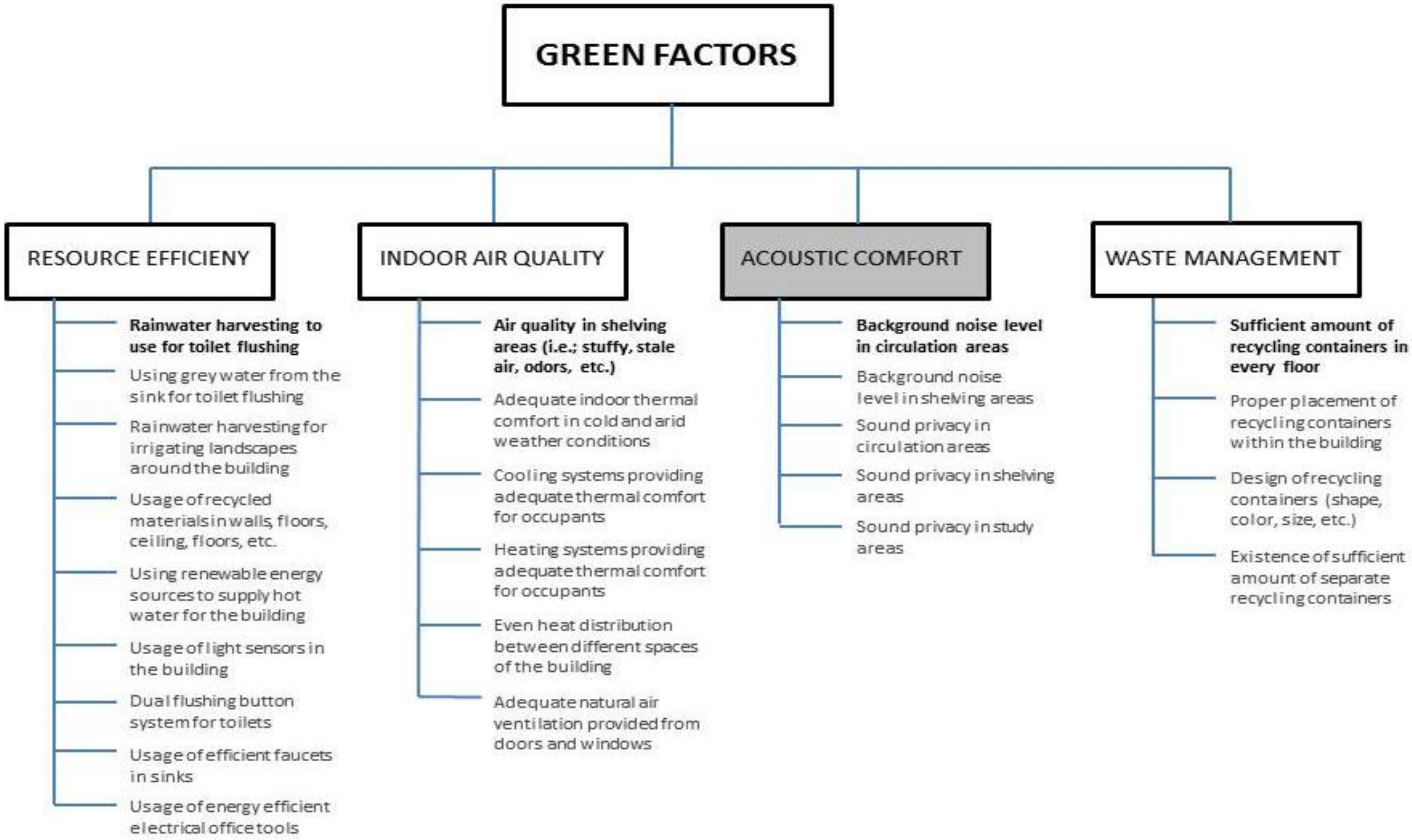

Figure 13. The hierarchical tree structure of the four green factors and their items, drawn by author, 2016

6.2.5. Discussions on AHP Results

When four factors were prioritized by the experts, Factor 3, acoustic comfort, had the highest eigenvalue score. Therefore, H1: "According to the user-centered design approach, indoor air quality attributes have the highest importance weightings compared to other green design attributes" is rejected. The H1 had been determined according to literature review based on user dissatisfaction about poor indoor air quality attributes of the existing buildings. (Balaras, Dascalaki, & Kontoyiannidis, 2004; Zhao, He, Johnson, & Mou; 2015; Gupta, & Chandiwala, 2010). Nevertheless, in this case, the experts found acoustic comfort in the library as the most important factor compared to the others. This situation can be explained by the innate function of the library. In other words, experts considered that a library firstly should operate its primary task; providing source and adequate working atmosphere. In fact, this approach is almost similar to approach developed by the users, while they were determining their needs. They had stated that they need acoustic comfort more than resource efficiency and waste management in the library building.

However, there is a significant contradiction between the designers and the users upon indoor air quality factor. While experts found the IAQ as the least important factor, the users had set IAQ items as their most important needs. This conflict can arise from the different roles shared by the designers and the users in the green renovation project. Although users only attach importance to their needs and comfort, designers have to consider different components of the renovation (Kabak et al., 2014). To be more clear, they have to also take into account economic benefits of the renovated building which is one of the main aim of green renovation (Menass, 2011; Mickaityte, Zavadskas, Kaklauskas, & Tupenaite, 2008). Nonetheless, it is a fact that HVAC energy consumption constitutes the main part of the overall energy consumption (Luther, & Rajagopalan, 2014) and it brings lots of economic and environmental burden to renovated building. In order to eliminate these burdens, experts may determine IAQ as the least important factor.

When the importance weightings of the acoustic comfort items are interpreted, it can be observed that, designers attached more importance to background noise level related items (" background noise level in circulation areas" and " background noise level in shelving areas") compared to sound privacy related items. However, users had given the higher score to sound privacy items. Designers assumed that "quite zone" rule is applied to all areas of the library building may lead to such a conflict between experts and the user perspectives. From this point of view, once the all areas are considered as completely free from the conservations or daily speeches, it is meaningful to assume the continual noise sources (such as mechanical ventilations) as the only disturbance in terms of acoustic comfort in the library building. However, libraries has a living environment occupied by the people like any other building types and therefore quiet zone rule can be easily broken for instance by the small speeches or footsteps etc.

There are three significant points when the eigenvalues of resource efficiency items are examined. Firstly, it is recognized that designers assigned relatively higher scores to items concerning water reuse. Unlike user needs preferences, designers set the items about preserving water and offering water a second use as the first three items in the importance ranking; “rainwater harvesting to use for toilet flushing", "using grey water from the sink for toilet flushing", "rainwater harvesting for irrigating landscapes around the building" respectively. In contrast, efficient use of water related items; "dual flushing button systems for toilets" and "usage of water efficient faucets in sinks" had the lower importance weightings compared to water reuse related items. This may explain that designers consider preserving and then reusing water resources as more sustainable solutions than using it in an efficient way. The second noteworthy point is that while users demanded the energy efficient electrical office tools in the library with comparatively high mean score, designers attached a little importance to this item. Therefore, designers did not consider the energy efficient office tools as critical items for efficient usage of the resources. Thirdly, even if user needs is relatively low for "usage of recycled materials in walls, floors, ceiling, floors, etc.", designers found it to be one of the most important items under the resource efficiency factor heading, placing it only one step below water reuse related items.

When Factor 3, waste management, is analyzed item by item, it is noticeable that while "sufficient amount of recycling containers in every floor" and "proper placement of recycling containers within the building" were placed on the top, " existence of sufficient amount of separate recycling containers" has the lowest importance weightings. However, users had identified this item as the most needed one among the others. This indicates that designers based the success of the waste management on sufficient number of containers and the feasible placement of them.

For as indoor quality, it can be stated that "cooling systems providing adequate thermal comfort for occupants" was found more important than the "heating systems providing adequate thermal comfort for occupants". However, another item about heating, "adequate indoor thermal comfort in cold and arid weather conditions" had the higher eigenvalue than the cooling system related items. Although this situation seems like a contradiction, it may mean that designers placed more importance on the heating system than the cooling system, only when arid and cold climatic condition in Ankara is taken into consideration. Another noticeable point is that "air quality in shelving areas (i.e.; stuffy, stale air, odors, etc.)" had the highest eigenvalue in the factor. While assigning such an importance to this item, the designers must have considered offering a healthy air condition for the user since IAQ encompasses providing not only the thermal comfort but only the healthy air standards for the occupants (Brown, 1997). This situation revealed that designers set the items concerning users' health in the first place rather than users comfort related ones.

6.2.6. Results from Uncorrelated t-Test

Uncorrelated t-test was conducted in SPSS 21.0 package software. According to the test results, it was found that student user needs are significantly different from staff user needs with 14 survey items at % 95 confidence levels. These are;

1. Usage of water efficient faucets in sinks.(t= 2.699, df=67.831, p= 0.009), (Student M=4.16, SD=1.002; Staff M=4.45, SD= 0.597)

2. Glare and reflection free indoor environment. ($t= 3.320$, $df=57.157$, $p=0.002$), (Student $M=4.14$, $SD= 1.012$; Staff $M=4.58$, $SD= 0.747$)

3. Existence of sufficient amount of separate recycling containers. ($t= 2.980$, $df=382$, $p= 0.003$), (Student $M=3.03$, $SD= 1.306$; Staff $M=3.68$, $SD= 1.163$)

4. Nearness to bike paths. ($t= 4.076$, $df=61.696$, $p= 0.0001$), (Student $M=3.69$, $SD= 1.306$; Staff $M=4.25$, $SD= 0.776$)

5. Sufficient number of electrical outlets in study areas. ($t= 2.699$, $df=67.831$, $p=0.009$), (Student $M=4.16$, $SD= 1.002$; Staff $M=4.45$, $SD= 0.597$)

6. Usage of natural and local materials in walls, floors, ceiling, floors etc. ($t=2.699$, $df=67.831$, $p= 0.009$), (Student $M=4.16$, $SD= 1.002$; Staff $M=4.45$, $SD= 0.597$)

7. Usage of waterless urinals in restrooms. ($t= - 3.180$, $df=383$, $p= 0.002$), (Student $M=4.47$, $SD= 0.828$; Staff $M=4.03$, $SD= 0. 862$)

8. Using grey water from the sink for toilet flushing. ($t= 3.506$, $df=63.919$, $p=0.001$), (Student $M=3.89$, $SD= 1.159$; Staff $M=4.35$, $SD= 0.736$)

9. Usage of light sensors in the building. ($t= 2.228$, $df=381$, $p= 0.026$), (Student $M=3.86$, $SD= 0.062$; Staff $M=4.28$, $SD= 0.152$)

10. Cleanness and maintenance of the building. ($t= 3.351$, $df=64.970$, $p= 0.001$), (Student $M=4.04$, $SD= 1.022$; Staff $M=4.45$, $SD= 0.639$)

11. Adequate daylighting in shelving areas. ($t= 2.234$, $df=52.739$, $p= 0.030$), (Student $M=4.29$, $SD= 0.970$; Staff $M=4.60$, $SD= 0.810$)

12. Even heat distribution between different spaces of the buildings. ($t= 2.365$, $df=58.342$, $p= 0.021$), (Student $M=3.25$, $SD= 1.432$; Staff $M=3.68$, $SD= 1.023$)

13. Heating systems providing adequate thermal comfort for occupants. ($t= 2.530$, $df=61.524$, $p= 0.014$), (Student $M=4.00$, $SD= 0.044$; Staff $M=4.33$, $SD= 0.115$)

14. Preventing undesired daylight by window blinds and/or curtains etc. at the south and west facades of the building. ($t= 2.429$, $df=61.710$, $p= 0.018$), (Student $M=4.09$, $SD= 0.054$; Staff $M=4.38$, $SD= 0.106$)

6.2.7. Discussions on Uncorrelated t-Test Results

Student and staff needs are found different with 14 items. Therefore, H2: "Student user needs for green library design are statistically different than the staff user needs" was retained. Except number 7, all items had the higher staff mean score, which means that staff needed remaining 13 items more than the students. If the items are grouped according to their contents, seven topics can be created. The first one is about the control of the indoor daylighting and contains number 2, number 11and number 14. The second group bases on the water usage especially in the restroom areas with the number 1 and 8. Number 5 and 9 are the third one and they are related to the energy. The next is concerning about thermal comfort of indoor space with number 12 and 13. Then, the material concerned items come; number 6 and 10. The remaining topics; waste management and site have only item; number 4 and 6 respectively.

When the groups are examined in detail, the comparatively high mean scores of the staff are based on the different amount of time spent by the users and the staff. Especially groups 1, 2, 3, 4, 5 can be mostly explained from this point of view. For group 1, the items are about controlling over the light and staffs need the light control since they work in the library from morning to evening. This means that they are exposed to different direction of sunlight in a day and they feel also the drawbacks derived from poor operations of the indoor artificial light more. Again, the water usage related items belong to only restroom area, which is an indicator of regular usage of restrooms by the staff. The number 5 and 9 are derived from tasks of the staffs; since they have a permanent task rather than the temporary ones like studying or searching in the building. Thus, they may need the electrical outlet and the light sensors more than the students. Staffs also need even heat distributions and adequate heating systems in the library more because they frequently use various kinds of library spaces (storage, corridors, halls, kitchenettes) compared to students. Likewise, the cleaning & maintenance of the building and usage of local materials in indoor area have much more importance for the staff due to the long period of time spent by them. To conclude, it can be stated that, permanent users of the library (the staffs) need the sustainable solutions more than the temporary users (the students) of the library building.

CHAPTER 7

CONCLUSION

Decision-making in greening existing buildings is a considerably complicated process, since it encompasses several alternatives for various criteria (Menass, 2011; Kabak et al., 2014; Wu, & Pagel, 2011). For this reason, decision makers should adopt a concrete and holistic approach in order to overcome this drawback (Alshuwaikhat, & Abubakar, 2008; Wu, & Pagell, 2011). The most satisfied results are obtained from a green renovation when different group needs are evaluated. From the outset of the green building design process, an integrated approach is needed to balance relationship between people and the environment (Pyke et al., 2010; Gupta, & Chandiwala, 2010; Too, & Bajracharya, 2015). Unfortunately, although the green building origin can be traced back to for decades, users factor in sustainable buildings is still scarce (Nousiainen, & Junnila, 2008; Zhao, He, Johnson, & Mou, 2015). Moreover, the scarce ones are mainly related to residential or commercial building rather than educational ones like schools and library (Too, Bajracharya, & Khanjanasthiti, 2013; Lourenço, 2014). In this respect, Bilkent University Library building was chosen as a case and a decision making model was developed through a user-centric design approach for its green design.

To achieve this, firstly the needs of the library users were determined with the help of a survey. Secondly, key green design factors were obtained from these data via exploratory factor analysis. Then, 8 designers prioritized these factors. As prioritization method AHP was chosen due to its advantages for multi-criteria decision-making. Finally, the users of the library divided into two; staff and students, and uncorrelated t-tests were applied to the survey data in order to investigate if there is any need differences between two groups.

According to statistics, three main results were obtained. Firstly, 4 key green design factors; indoor air quality, acoustic comfort, resource efficiency and waste management emerged from the survey data. Additionally, it was identified that among the factors they firstly need indoor air quality, secondly acoustic comfort, thirdly resource efficiency and fourthly waste management. The experts provided another important result via the prioritization. They prioritized the 4 green factors and their items. As result, they assigned the acoustic comfort as the most important factor, resource efficiency as the second, waste management as the third and indoor air quality as the last. Therefore, H1: "According to the user-centered design approach, indoor air quality attributes have the highest importance weightings compared to other green design attributes" was rejected. The fact that acoustic comfort has the most importance weightings was based on the innate character of the library. Additionally, the lowest placement of the indoor air quality factor in the ranking was explained with economic considerations. It was considered that since HVAC systems has the economic burden and consumes considerable amount of energy of energy (Luther, & Rajagopalan, 2014), the designers want to apply resource efficiency and waste management factors first to green renovation. As the last significant result, the differences were identified between the library staff and the students in terms of their sustainable needs. According to statistic, it was observed that the library staffs need the green solutions more than the students.

To conclude, this research identified the key green design attributes and its importance weightings from a user perspective in an existing library building and offered a decision-making process model through a user-centered design approach. By doing this, it contributed to both literature and the designers concerning over coming complexity of the green renovation decision-making process. Additionally, since user- centered design approach was used in the model, it will increase the user satisfaction and provides more beneficial, suitable and acceptable design results in case the green renovation project for the library is put in the practice (Duverger, 2012; Kim et al., 2013; Kujula, 2003; Moore, Hines, Lilley, 2015). Further, this research has a particular importance in terms of providing a data about user involvement in green library building design process because in the literature the researches concerning user-centric green library design are scare. Lastly, this research contributes to LEED assessment system. In this system, while acoustic considerations has a small place in occupant survey section, it was determined as the most important factor by the designers and as the second important factor by Bilkent Library users. Therefore, this research may lead LEED to produce different type of assessment system for different type of buildings.

As future research, a focus group project can be offered. Since indoor quality has a direct impact on user comfort, its evaluation as the least important factor by the experts can create dissatisfaction and an obstacle for the probable project implementation. For this reason, a focus group consisted of students and especially the staff – because they had been stated that they need green solutions than the students-, can be arranged by the designers. Therefore, by sharing ideas, the optimum decisions can be made and more sustainable solutions can be explored concerning indoor air quality instead of energy consuming and costly HVAC solutions. Secondly, in terms of acoustic comfort, while designers placed the noise level related items at the top of the hierarchical tree, the users had demanded sound privacy related items more. A focus group can solve this conflict by exchanging ideas between designers and the users and identifying real distractions of the library users. Thus, in case a probable green implication on the library, more suitable selections among the several acoustical solutions (like sound masking, fostering sound isolation) can be implemented by the designers. Finally, experts from other disciplines like civil engineering, mechanical engineering also can attend to the prioritization process along with the interior architects and architects in order to obtain their point of views as well. However, pros and cons of this option should be cogitated because increasing the number of decision makers can lead to complexity and so delay of the decision making process.

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APPENDICIES

APPENDIX A

THE APPROVED ETHICS FORM CONSENT FORM FROM THE BILKENT UNIVESITY ETHICS COMMITTEE

Bilkent Üniversitesi
Akademik İşler Rektör Yardımcılığı

Tarih: 30 Aralık 2015
Gönderilen: Yasemin Afacan
Gönderen: Hitay Özbay
Provost Yardımcısı

Konu: *"A User-Centered ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 30 Aralık 2015 tarihli görüşme sonucu, *"A User-Centered Approach to Green Existing Buildings: Bilkent University Library as A Case Study"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri, ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmesine karşı gelmektedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Etik Kurul Üyeleri:

Ünvan / İsim	Bölüm / Uzmanlık	İmza
1. Prof. Dr. Hitay Özbay	Elektrik ve Elektronik Müh.	
2. Doç.Dr. Fatma Taşkın	İktisat	
3. Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	
4. Prof.Dr. Tayfun Özçelik	Moleküler Biyoloji ve Genetik	
5. Prof.Dr. Erdal Onar	Hukuk	
Yd.1. Yrd.Doç.Dr. Ali Osmay Güre	Moleküler Biyoloji ve Genetik	(yedek üye)
Yd.2. Prof.Dr. Cemal Yalabık	Fizik	(yedek üye)

Kurul karar/toplantı No: 2015_12_30_01

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

APPENDIX B

LEED 2009 EXISTING BUILDINGS: OPERATIONS AND MAINTANENCE

PROJECT CHECKLIST

LEED 2009 for Existing Buildings: Operations & Maintenance

Project Checklist

Project Name

Date

Y	?	N		Sustainable Sites	Possible Points: 26
			Credit 1	LEED Certified Design and Construction	4
			Credit 2	Building Exterior and Hardscape Management Plan	1
			Credit 3	Integrated Pest Mgmt, Erosion Control, and Landscape Mgmt Plan	1
			Credit 4	Alternative Commuting Transportation	3 to 15
			Credit 5	Site Development—Protect or Restore Open Habitat	1
			Credit 6	Stormwater Quantity Control	1
			Credit 7.1	Heat Island Reduction—Non-Roof	1
			Credit 7.2	Heat Island Reduction—Roof	1
			Credit 8	Light Pollution Reduction	1

Y	?	N		Water Efficiency	Possible Points: 14
Y			Prereq 1	Minimum Indoor Plumbing Fixture and Fitting Efficiency	
			Credit 1	Water Performance Measurement	1 to 2
			Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency	1 to 5
			Credit 3	Water Efficient Landscaping	1 to 5
			Credit 4	Cooling Tower Water Management	1 to 2

Y	?	N		Energy and Atmosphere	Possible Points: 35
Y			Prereq 1	Energy Efficiency Best Management Practices	
Y			Prereq 2	Minimum Energy Efficiency Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
			Credit 1	Optimize Energy Efficiency Performance	1 to 18
			Credit 2.1	Existing Building Commissioning—Investigation and Analysis	2
			Credit 2.2	Existing Building Commissioning—Implementation	2
			Credit 2.3	Existing Building Commissioning—Ongoing Commissioning	2
			Credit 3.1	Performance Measurement—Building Automation System	1
			Credit 3.2	Performance Measurement—System-Level Metering	1 to 2
			Credit 4	On-site and Off-site Renewable Energy	1 to 6
			Credit 5	Enhanced Refrigerant Management	1
			Credit 6	Emissions Reduction Reporting	1

Y	?	N		Materials and Resources	Possible Points: 10
Y			Prereq 1	Sustainable Purchasing Policy	
Y			Prereq 2	Solid Waste Management Policy	
			Credit 1	Sustainable Purchasing—Ongoing Consumables	1
			Credit 2.1	Sustainable Purchasing—Electric-Powered Equipment	1
			Credit 2.2	Sustainable Purchasing—Furniture	1
			Credit 3	Sustainable Purchasing—Facility Alterations and Additions	1
			Credit 4	Sustainable Purchasing—Reduced Mercury in Lamps	1
			Credit 5	Sustainable Purchasing—Food	1

Y	?	N		Materials and Resources, Continued	
			Credit 6	Solid Waste Management—Waste Stream Audit	1
			Credit 7	Solid Waste Management—Ongoing Consumables	1
			Credit 8	Solid Waste Management—Durable Goods	1
			Credit 9	Solid Waste Management—Facility Alterations and Additions	1

Y	?	N		Indoor Environmental Quality	Possible Points: 15
Y			Prereq 1	Minimum IAQ Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Green Cleaning Policy	
			Credit 1.1	IAQ Best Mgmt Practices—IAQ Management Program	1
			Credit 1.2	IAQ Best Mgmt Practices—Outdoor Air	1
			Credit 1.3	IAQ Best Mgmt Practices—Increased Ventilation	1
			Credit 1.4	IAQ Best Mgmt Practices—Reduce Particulates in Air Distribution	1
			Credit 1.5	IAQ Mgmt Plan—IAQ Mgmt for Facility Alterations and Additions	1
			Credit 2.1	Occupant Comfort—Occupant Survey	1
			Credit 2.2	Controllability of Systems—Lighting	1
			Credit 2.3	Occupant Comfort—Thermal Comfort Monitoring	1
			Credit 2.4	Daylight and Views	1
			Credit 3.1	Green Cleaning—High Performance Cleaning Program	1
			Credit 3.2	Green Cleaning—Custodial Effectiveness Assessment	1
			Credit 3.3	Green Cleaning—Sustainable Cleaning Products, Materials Purchases	1
			Credit 3.4	Green Cleaning—Sustainable Cleaning Equipment	1
			Credit 3.5	Green Cleaning—Indoor Chemical and Pollutant Source Control	1
			Credit 3.6	Green Cleaning—Indoor Integrated Pest Management	1

Y	?	N		Innovation in Operations	Possible Points: 6
			Credit 1.1	Innovation in Operations: Specific Title	1
			Credit 1.2	Innovation in Operations: Specific Title	1
			Credit 1.3	Innovation in Operations: Specific Title	1
			Credit 1.4	Innovation in Operations: Specific Title	1
			Credit 2	LEED Accredited Professional	1
			Credit 3	Documenting Sustainable Building Cost Impacts	1

Y	?	N		Regional Priority Credits	Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1

Y	?	N		Total	Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

APPENDIX C

THE STATEMENTS GENERATED FROM THE TOPICS MENTIONED IN LEED 2009 LEED 2009 FOR EXISTING BUILDING OPERATIONS AND MAINTENANCE CHECKLIST

A. SITE

1. Nearness to public transportation

2. Nearness to bike paths

3. Number of walking paths to the library

4. Existence of greenfield outside the library

B. WATER

5. Usage of water efficient faucets in sinks

6. Usage of waterless urinals in restrooms

7. Dual flushing button system for toilets

8. Using grey water from the sink for toilet flushing

9. Rainwater harvesting to use for toilet flushing

10. Rainwater harvesting for irrigating landscapes around the building

C. ENERGY

11. Accessibility of electrical outlets in study areas

12. Sufficient number of electrical outlets in study areas

13. Usage of energy efficient lighting fixtures

14. Usage of light sensors in the building

15. Usage of gradual lighting dimming systems

16. Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building

17. Efficiency of thermal insulation

18. Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)

D. MATERIAL

19. Usage of toxic free materials in walls, floors, ceiling, floors etc.

20. Usage of natural and local materials in walls, floors, ceiling, floors etc.

21. Usage of durable materials in walls, floors, ceiling, floors etc.

22. Usage of recycled materials in walls, floors, ceiling, floors etc.

23. Usage of high efficient glazing (in terms of heat and light gains)

24. Cleanness and maintenance of the building

E. INDOOR ENVIRONMENTAL QUALITY

25. Air quality in circulation areas (i.e. stuffy/ stale air, cleanliness, odours etc.)

26. Air quality in study areas (i.e. stuffy/ stale air, cleanliness, odours etc.)

27. Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)

28. Adequate natural air ventilation provided from doors and windows

29. Adequate mechanical air ventilation system for occupant comfort

30. Heating systems providing adequate thermal comfort for occupants

31. Cooling systems providing adequate thermal comfort for occupants

32. Adequate indoor thermal comfort in hot and humid weather conditions

33. Adequate indoor thermal comfort in cold and arid weather conditions

34.Preventing undesired daylight by window blinds and/or curtains etc. at the south and west facades of the building

35. Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings

36. Adequate daylighting in circulation areas

37. Adequate artificial lighting in circulation areas

38. Adequate daylighting in study areas

39. Adequate artificial lighting in study areas

40. Adequate daylighting in shelving areas

41. Adequate artificial lighting in shelving areas

42. Controlling the amount of light in study areas

43. Glare and reflection free indoor environment

44. Background noise level in study areas

45. Background noise level in circulation areas

46. Background noise level in shelving areas

47. Sound privacy in study (ability to have conversations without your neighbours overhearing and/or any other indoor noises)

48. Sound privacy in circulation areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)

49. Sound privacy in shelving areas. (ability to have conversations without your neighbours overhearing and/or any other indoor noises)

50. Outdoor noise (such as traffic) prevention

F. WASTE

51. Existence of sufficient amount of separate recycling containers (for plastic, paper, glass, etc.)

52. Sufficient amount of recycling containers in every floor (for plastic, paper, glass, etc.)

53. Proper placement of recycling containers within the building

54. Design of recycling containers (shape, size, colour, etc.)

APPENDIX D

FINAL VERSION OF THE SURVEY IN TURKISH

BÖLÜM 1. KİŞİSEL BİLGİLER

Vermiş olduğunuz bilgiler kamuya açıklanmayacak olup, iç mimarlık ve çevre tasarımı öğrencisi yüksek lisans tezinde veri olarak kullanılacaktır.

AD :

SOYAD:

CİNSİYET: **a.** erkek **b**. kadın

YAŞ:

MESLEK: **a.** yüksek lisans / doktora öğrencisi **b.**lisans öğrencisi **c.** öğretim kadrosu **e.** üniversite personeli

BÖLÜM 2. YEŞİL BİNAYA DAİR GENEL GÖRÜŞ ANKETİ

1. Yeşil bina size ne kadar tanıdık geliyor?

a. Hiç tanıdık gelmiyor

b. Tanıdık gelmiyor

c. Bir parça tanıdık geliyor

d. Oldukça tanıdık geliyor.

2. Sizce yeşil bina.....?

a. Yeşil renkli binalardır.

b. İçinde yeşil bitkiler barındıran binalardır

c. Dışarısında yeşil bitkilere sahip olan binalardır

d. Rahat ve sağlıklı binalardır

e. Enerji su ve ısı tasarruflu binalardır

f. Malzeme ve arazi iktisatlı binalardır.

h. diğer

3. Yeşil binalarla geleneksel binalar karşılaştırıldığında, yeşil binaların insan ve doğa arasında bir harmoni kurma amacı güttüğünü görüyoruz. Yeşil binaların başarmak istediği hedefler aşağıda verilmiştir. Kendi bakış açınızdan bu hedefleri önemlilik dercesine göre değerlendirebilir misiniz? (1 çok önemsiz, 5 çok önemli gibi).

HEDEFLER	çok önemsiz 1	2	3	4	çok önemli 5
Enerji (gaz, elektrik, ısı vb.) tasarruf etmeye yardımcı olma	☐	☐	☐	☐	☐
Çevreyi korumaya, atıkları azaltmaya, arazi kullanımı tasarrufuna katkıda bulunma	☐	☐	☐	☐	☐
Yapı malzemeleri tasarrufunda bulunması	☐	☐	☐	☐	☐
Su tasarrufuna katkıda bulunma	☐	☐	☐	☐	☐
Daha iyi havalandırma ve aydınlatma ortamı sağlayarak iç mekanı elverişli hale getirme	☐	☐	☐	☐	☐

BÖLÜM 3.

BİLKENT ÜNİVERSİTESİ KÜTÜPHANE KULLANICILARININ YEŞİL BİNA KULLANIM İHTİYAÇLARINI BELİRLEME ANKETİ

Bu çalışma kütüphane kullanıcılarının enerji verimli, sürdürülebilir ve yeşil binalardaki kullanım ihtiyaçlarını belirlemeyi amaçlamaktadır. Aşağıda bazı başlıklar altında toplanmış yeşil bina özellikleri sıralanmıştır. Bu özelliklere vermiş olduğunuz önemi 1 den 5 e kadar olan derecelendirme sistemine göre değerlendirmeniz istenmektedir (1 çok önemsiz, 5 çok önemli gibi) . Anketi doldururken lütfen kendi kütüphane kullanımınızı göz önünde bulundurunuz.

	çok önemsiz 1	2	3	4	çok önemli 5
1. Kütüphanenin toplu taşıma hizmetlerine olan yakınlığı	☐	☐	☐	☐	☐
2. Mekanik havalandırma sistemlerinin kullanıcı ihtiyacına cevap verebilmesi.	☐	☐	☐	☐	☐
3. Lavabolarda su tasarruflu musluk bataryalarının kullanılması	☐	☐	☐	☐	☐
4. Çalışma alanlarında prizlere erişilebilirlik	☐	☐	☐	☐	☐
5. Ortamdaki yansıma ve parlama miktarının azaltılmış olması.	☐	☐	☐	☐	☐
6. İnsan sağlığına zararı en aza indirgenmiş malzemelerin bina elemanlarında (duvar, yer, tavan yüzeyleri vb.) kullanımı	☐	☐	☐	☐	☐
7. Bina genelinde yüksek verimli (ısı ve ışık açısından) camların kullanımı	☐	☐	☐	☐	☐
8. Dolaşım alanlarındaki hava kalitesi (boğucu, havasızlık, kirli, kötü koku vb. açısından)	☐	☐	☐	☐	☐
9.Geri dönüşüm konteynerlerinin yeterli sayıda bulunması (plastik, kağıt, cam vb. için)	☐	☐	☐	☐	☐
10. Kütüphanenin bisiklet yollarına olan yakınlığı	☐	☐	☐	☐	☐
11. Raf alanlarındaki arka plan gürültü seviyesi	☐	☐	☐	☐	☐
12.Tuvaletlerde susuz pisuvar kullanımı	☐	☐	☐	☐	☐
13. Çalışma mekanlarındaki prizlerin yeterli sayıda olması	☐	☐	☐	☐	☐
14. Bina elemanlarında (duvar yer tavan yüzeyleri vb.) doğal ve yerel malzemelerin kullanılması	☐	☐	☐	☐	☐
15. Raf alanlarında uygun yapay aydınlatma	☐	☐	☐	☐	☐
16. Çalışma alanlarındaki hava kalitesi (boğucu, havasızlık, kirli, kötü koku vb. açısından)	☐	☐	☐	☐	☐
17. Geri dönüşüm konteynerlerinin her katta bulunması (plastik, kağıt, cam vb. için)	☐	☐	☐	☐	☐
18. Yürüme yollarının sayısı	☐	☐	☐	☐	☐
19. Çalışma mekanlarındaki arka alan gürültü seviyesi	☐	☐	☐	☐	☐
20.Dolaşım alanlarındaki uygun yapay aydınlatma.	☐	☐	☐	☐	☐
21. Pencere ve kapılarla sağlanan doğal hava akımı	☐	☐	☐	☐	☐

	çok önemsiz 1	2	3	4	çok önemli 5
22.Klozetlerde çift kademeli çalışan sifon sistemleri kullanımı	☐	☐	☐	☐	☐
23. Kütüphane genelinde yüksek verimli aydınlatma elemanlarının kullanımı	☐	☐	☐	☐	☐
24. Bina elemanlarında (duvar yer tavan yüzeyleri vb.) dayanıklı malzemelerin kullanılması	☐	☐	☐	☐	☐
25. Raf alanlarındaki hava kalitesi (boğucu, havasızlık, kirli, kötü koku vb. açısından)	☐	☐	☐	☐	☐
26.Dolaşım alanlarındaki konuşmaların veya başka diğer seslerin yakın çevresine duyulmaması	☐	☐	☐	☐	☐
27. Geri dönüşüm konteynerlerinin iç mekan tasarımına uygun bir şekilde yerleştirilmesi	☐	☐	☐	☐	☐
28. Kütüphane dış çevresinde yeşil alanların yeterliliği	☐	☐	☐	☐	☐
29. Sıcak ve nemli havalarda iç mekan ısı konforu	☐	☐	☐	☐	☐
30. Çalışma mekanlarında uygun yapay aydınlatma.	☐	☐	☐	☐	☐
31. Musluk suyunun arıtılarak tuvalet rezervuarlarında kullanılması	☐	☐	☐	☐	☐
32. Sensorlu aydınlatma sistemlerinin kullanımı	☐	☐	☐	☐	☐
33. Bina elemanlarında(duvar yer tavan yüzeyleri vb.) geri dönüştürülmüş malzemelerin kullanılması	☐	☐	☐	☐	☐
34. Dolaşım alanlarındaki uygun doğal aydınlatma	☐	☐	☐	☐	☐
35. Binanın temizliği ve bakımı	☐	☐	☐	☐	☐
36. Raf alanlarında uygun doğal aydınlatma	☐	☐	☐	☐	☐
37. Çalışma mekanlarındaki konuşmaların veya diğer başka seslerin yakın çevresine duyulmaması	☐	☐	☐	☐	☐
38. Mekanlardaki homojen ısı dağılımı (koridor vs çalışma mekanı, raflar vb..)	☐	☐	☐	☐	☐
39. Geri dönüşüm konteynerlerinin tasarımı (rengi, şekli, boyutu vb.)	☐	☐	☐	☐	☐
40. Kademeli (şiddeti kısılabilir ve artırılabilir) aydınlatma sistemlerinin kullanımı	☐	☐	☐	☐	☐
41. Çalışma mekanlarında uygun doğal aydınlatma	☐	☐	☐	☐	☐
42.Yağmur suyunun dönüştürülerek tuvalet rezervuarlarında kullanılması	☐	☐	☐	☐	☐
43. Enerji tasarruflu ofis elektrikli aletlerinin (bilgisayar, fotokopi makineleri vb.) kullanımı	☐	☐	☐	☐	☐
44. Isıtma sistemlerinin kullanıcı ihtiyacına cevap verebilmesi.	☐	☐	☐	☐	☐
45. Dolaşım alanlarındaki arka plan gürültü seviyesi	☐	☐	☐	☐	☐
46. Kuru ve soğuk havalarda iç mekan ısı konforu.	☐	☐	☐	☐	☐
47. Yağmur suyunun dönüştürülerek kütüphane bahçe sulamasında kullanılması	☐	☐	☐	☐	☐
48. Kütüphane ısı yalıtımının verimliliği	☐	☐	☐	☐	☐
49. Batı ve güneye bakan cephelerde fazla güneş ışığını engelleyen jaluzi, perde vb. sistemler.	☐	☐	☐	☐	☐
50. Raf alanlarındaki (raflar, özel koleksiyon alanları) konuşmaların veya başka diğer seslerin yakın çevresine duyulmaması	☐	☐	☐	☐	☐
51. Kütüphane sıcak suyunun yenilenebilir enerji kaynaklarınca (güneş, rüzgar, jeotermal vb.) sağlanması	☐	☐	☐	☐	☐
52. Soğutma sistemlerinin kullanıcı ihtiyacına cevap verebilmesi.	☐	☐	☐	☐	☐
53. Dış mekan gürültüsünün önlenmesi (trafik vb.)	☐	☐	☐	☐	☐
54. Çalışma mekanlarında aydınlatmada ve ışık miktarlarında kontrol edilebilirlik.	☐	☐	☐	☐	☐

APPENDIX E

FINAL VERSION OF THE SURVEY IN ENGLISH

SECTION 1. BASIC INFORMATION

This survey will not be shared with public. Data are going to be used in the thesis of an interior architecture and environmental design graduate student.

NAME:

SURNAME:

GENDER: **a.** male **b**. female

AGE:

OCCUPATION: **a.** graduate student **b.** undergraduate student **c.** academic faculty **e.** university staff

SECTION 2. BASIC UNFDERSTANDING OF GREEN BUILDING

1. Please indicate how familiar you are with green buildings?

a. not familiar

b. not very familiar

c. somewhat familiar

d. very familiar

2. What does a green building mean to you?

a. Buildings with green colour

b. Buildings with green plants indoor

c. Buildings with green plants outdoor

d. Buildings that are healthy and comfortable.

e. Buildings that are energy/water/ thermal saving

f. Buildings that are land saving and material saving

h. others

3. Compared to a conventional building, a green building could achieve the goal of harmony between nature and human beings. Please rank the following goals according to their importance? (1 means the least important, 5 means the most important).

GOALS	least important **1**	**2**	**3**	**4**	most important **5**
Helping to save energy (electricity, gas, etc.)	☐	☐	☐	☐	☐
Helping to save land, protect the environment, reduce pollution	☐	☐	☐	☐	☐
Helping to the reduce the amount construction material used	☐	☐	☐	☐	☐
Helping to save water	☐	☐	☐	☐	☐
Providing better ventilation and lighting conditions for indoor environments	☐	☐	☐	☐	☐

SECTION 3.

INVESTIGATING GREEN BUILDING NEEDS OF BILKENT UNIVERSITY LIBRARY OCCUPANTS

This survey aims to investigate the green building needs of the library occupants. It lists the design features for a green building. Please rate the importance of each feature using a scale of 1 to 5 (1 being the least important and 5 being the most important) and mark the appropriate boxes.

	least important **1**	**2**	**3**	**4**	most important **5**
1. Nearness to public transportation	☐	☐	☐	☐	☐
2. Adequate mechanical air ventilation system for occupant comfort	☐	☐	☐	☐	☐
3. Usage of water efficient faucets in sinks	☐	☐	☐	☐	☐
4. Accessibility of electrical outlets in study areas	☐	☐	☐	☐	☐
5. Glare and reflection free indoor environment	☐	☐	☐	☐	☐
6. Usage of toxic free materials in walls, floors, ceiling, floors etc.	☐	☐	☐	☐	☐
7. Usage of high efficient glazing (in terms of heat and light gains)	☐	☐	☐	☐	☐
8. Air quality in circulation areas (i.e. stuffy/ stale air, cleanliness, odours etc.)	☐	☐	☐	☐	☐
9. Existence of sufficient amount of separate recycling containers (for plastic, paper, glass, etc.)	☐	☐	☐	☐	☐
10. Nearness to bike paths	☐	☐	☐	☐	☐
11. Background noise level in shelving areas	☐	☐	☐	☐	☐
12. Usage of waterless urinals in restrooms	☐	☐	☐	☐	☐
13. Sufficient number of electrical outlets in study areas	☐	☐	☐	☐	☐
14. Usage of natural and local materials in walls, floors, ceiling, floors etc.	☐	☐	☐	☐	☐
15. Adequate artificial lighting in shelving areas	☐	☐	☐	☐	☐
16. Air quality in study areas (i.e. stuffy/ stale air, cleanliness, odours etc.)	☐	☐	☐	☐	☐
17. Sufficient amount of recycling containers in every floor (for plastic, paper, glass, etc.)	☐	☐	☐	☐	☐
18. Number of walking paths to the library	☐	☐	☐	☐	☐
19. Background noise level in study areas					
20. Adequate artificial lighting in circulation areas	☐	☐	☐	☐	☐
21. Adequate natural air ventilation provided from doors and windows	☐	☐	☐	☐	☐
22. Dual flushing button system for toilets	☐	☐	☐	☐	☐
23. Usage of energy efficient lighting fixtures	☐	☐	☐	☐	☐
24. Usage of durable materials in walls, floors, ceiling, floors etc.	☐	☐	☐	☐	☐

	least important 1	2	3	4	most important 5
25. Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)	☐	☐	☐	☐	☐
26. Sound privacy in circulation areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)	☐	☐	☐	☐	☐
27. Proper placement of recycling containers within the building	☐	☐	☐	☐	☐
28. Existence of greenfields outside the library	☐	☐	☐	☐	☐
29. Adequate indoor thermal comfort in hot and humid weather conditions	☐	☐	☐	☐	☐
30. Adequate artificial lighting in study areas	☐	☐	☐	☐	☐
31. Using grey water from the sink for toilet flushing	☐	☐	☐	☐	☐
32. Usage of light sensors in the building	☐	☐	☐	☐	☐
33. Usage of recycled materials in walls, floors, ceiling, floors etc.	☐	☐	☐	☐	☐
34. Adequate daylighting in circulation areas	☐	☐	☐	☐	☐
35. Cleanness and maintenance of the building	☐	☐	☐	☐	☐
36. Adequate daylighting in shelving areas	☐	☐	☐	☐	☐
37. Sound privacy in study (ability to have conversations without your neighbours overhearing and/or any other indoor noises)	☐	☐	☐	☐	☐
38. Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings	☐	☐	☐	☐	☐
39. Design of recycling containers (shape, size, colour, etc.)	☐	☐	☐	☐	☐
40. Usage of gradual lighting dimming systems	☐	☐	☐	☐	☐
41. Adequate daylighting in study areas	☐	☐	☐	☐	☐
42.Rainwater harvesting to use for toilet flushing	☐	☐	☐	☐	☐
43. Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)	☐	☐	☐	☐	☐
44. Heating systems providing adequate thermal comfort for occupants	☐	☐	☐	☐	☐
45. Background noise level in circulation areas	☐	☐	☐	☐	☐
46. Adequate indoor thermal comfort in cold and arid weather conditions	☐	☐	☐	☐	☐
47.Rainwater harvesting for irrigating landscapes around the building	☐	☐	☐	☐	☐
48. Efficiency of thermal insulation	☐	☐	☐	☐	☐
49. Preventing undesired daylight by window blinds and/or curtains etc. at the south and west facades of the building	☐	☐	☐	☐	☐
50. Sound privacy in shelving areas. (ability to have conversations without your neighbours overhearing and/or any other indoor noises)	☐	☐	☐	☐	☐
51.Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building	☐	☐	☐	☐	☐
52 Cooling systems providing adequate thermal comfort for occupants	☐	☐	☐	☐	☐
53.Outdoor noise (such as traffic) prevention	☐	☐	☐	☐	☐
54. Controlling the amount of light in study areas	☐	☐	☐	☐	☐

APPENDIX F

ANALYTICHAL HIERARCHY PROCESS

THE ANALYTIC HIERARCHY PROCESS

To make decisions, you identify, analyze, and make tradeoffs between different alternatives to achieve an objective. The more efficient the means for analyzing and evaluating the alternatives, the more likely you'll be satisfied with the outcome. To help you make decisions, the Analytic Hierachy Process compares alternatives in a stepwise fashion and measures their contribution to your objective.[1]

AHP in action. Using AHP for decision making involves four steps. We'll assume here that you want to evaluate candidate requirements using the criterion of value.

Step 1. *Set up the* n *requirements in the rows and columns of an* n × n *matrix.* We'll assume here that you have four candidate requirements: Req1, Req2, Req3, and Req4, and you want to know their relative value. Insert the *n* requirements into the rows and columns of a matrix of order *n* (in this case we have a 4 × 4 matrix).

Step 2. *Perform pairwise comparisons of all the requirements according to the criterion.* The fundamental scale used for this purpose is shown in Table A.[1] For each pair of requirements (starting with Req1 and Req2, for example) insert their determined relative intensity of value in the position (Req1, Req2) where the row of Req1 meets the column of Req2. In position (Req2, Req1) insert the reciprocal value, and in all positions in the main diagonal insert a "1." Continue to perform pairwise comparisons of Req1–Req3, Req1–Req4, Req2–Req3, and so on. For a matrix of order n, $n \cdot (n-1)/2$ comparisons are required. Thus, in this example, six pairwise comparisons are required; they might look like this:

	Req1	Req2	Req3	Req4
Req1	1	1/3	2	4
Req2	3	1	5	3
Req3	1/2	1/5	1	1/3
Req4	1/4	1/3	3	1

Step 3. *Use averaging over normalized columns to estimate the eigenvalues of the matrix* (which represent the criterion distribution). Thomas Saaty proposes a simple method for this, known as averaging over normalized columns.[1] First, calculate the sum of the *n* columns in the comparison matrix. Next, divide each element in the matrix by the sum of the column the element is a member of, and calculate the sums of each row:

	Req1	Req2	Req3	Req4	*Sum*
Req1	0.21	0.18	0.18	0.48	*1.05*
Req2	0.63	0.54	0.45	0.36	*1.98*
Req3	0.11	0.11	0.09	0.04	*0.34*
Req4	0.05	0.18	0.27	0.12	*0.62*

Then normalize the sum of the rows (divide each row sum with the number of requirements). The result of this computation is referred to as the *priority matrix* and is an estimation of the eigenvalues of the matrix.

$$\frac{1}{4} \cdot \begin{pmatrix} 1.05 \\ 1.98 \\ 0.34 \\ 0.62 \end{pmatrix} = \begin{pmatrix} 0.26 \\ 0.50 \\ 0.09 \\ 0.16 \end{pmatrix}$$

Step 4. *Assign each requirement its relative value based on the estimated eigenvalues.* From the resulting eigenvalues of the comparison matrix, the following information can be extracted:

- Req1 contains 26 percent of the requirements' total value,
- Req2 contains 50 percent,
- Req3 contains 9 percent, and
- Req4 contains 16 percent.

Result consistency. If we were able to determine precisely the relative value of all requirements, the eigenvalues would be perfectly consistent. For instance, if we determine that Req1 is much more valuable than Req2, Req2 is somewhat more valuable than Req3, and Req3 is slightly more valuable than Req1, an inconsistency has occurred and the result's accuracy is decreased. The redundancy of the pairwise comparisons makes the AHP much less sensitive to judgment errors; it also lets you measure judgment errors by calculating the consistency index of the comparison matrix, and then calculating the consistency ratio.

Consistency index. The consistency index (CI) is a first indicator of result accuracy of the pairwise comparisons. You calculate it as $CI = (\lambda \max - n)/(n-1)$. $\lambda \max$ denotes the maximum principal eigenvalue of the comparison matrix. The closer the value of $\lambda \max$ is to n (the number of requirements), the smaller the judgmental errors and thus the more consistent the result. To estimate $\lambda \max$, you first multiply the comparison matrix by the priority vector:

$$\begin{pmatrix} 1 & 1/3 & 2 & 4 \\ 3 & 1 & 5 & 3 \\ 1/2 & 1/5 & 1 & 1/3 \\ 1/4 & 1/3 & 3 & 1 \end{pmatrix} \cdot \begin{pmatrix} 0.26 \\ 0.50 \\ 0.09 \\ 0.16 \end{pmatrix} = \begin{pmatrix} 1.22 \\ 2.18 \\ 0.37 \\ 0.64 \end{pmatrix}$$

Then you divide the first element of the resulting vector by the first element in the priority vector, the second element of the resulting vector by the second element in the priority vector, and so on:

$$\begin{pmatrix} 1.22/0.26 \\ 2.18/0.50 \\ 0.37/0.09 \\ 0.64/0.16 \end{pmatrix} = \begin{pmatrix} 4.66 \\ 4.40 \\ 4.29 \\ 4.13 \end{pmatrix}$$

To calculate $\lambda \max$, average over the elements in the resulting vector:

$$\lambda \max = \frac{4.66+4.40+4.29+4.13}{4} = 4.37$$

Now the consistency index can be calculated:

$$CI = \frac{\lambda \max - n}{n-1} = \frac{4.37-4}{4-1} = 0.12$$

To find out if the resulting consistency index (CI = 0.12) is acceptable, you must calculate the consistency ratio.

Consistency ratio. The consistency indices of randomly generated reciprocal matrices from the scale 1 to 9 are called the random indices, RI.[1] The ratio of CI to RI for the same-order matrix is called the consistency ratio (CR), which defines the accuracy of the pairwise comparisons. The RI for matrices of order *n* are given below. The first row shows the order of the matrix, and the second the corresponding RI value.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

According to Table A, the RI for matrices of order 4 is 0.90. Thus, the consistency ratio for our example is

$$CR = \frac{CI}{RI} = \frac{0.12}{0.90} = 0.14.$$

As a general rule, a consistency ratio of 0.10 or less is considered acceptable.[1] This means that our result here is less than ideal. In practice, however, consistency ratios exceeding 0.10 occur frequently.

REFERENCES

1. T.L. Saaty, *The Analytic Hierarchy Process*, McGraw-Hill, New York, 1980.

TABLE A
SCALE FOR PAIRWISE COMPARISONS

Relative intensity	**Definition**	**Explanation**
1	Of equal value	Two requirements are of equal value
3	Slightly more value	Experience slightly favors one requirement over another
5	Essential or strong value	Experience strongly favors one requirement over another
7	Very strong value	A requirement is strongly favored and its dominance is demonstrated in practice
9	Extreme value	The evidence favoring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals	If requirement *i* has one of the above numbers assigned to it when compared with requirement *j*, then *j* has the reciprocal value when compared with *i*.	

APPENDIX G

PAIR-WISE COMPARISION SHEETS

<u>PAIRWISE COMPARISION SHEETS OF THE FOUR GREEN BUILDING DESIGN ITEMS</u>

Which of the two requirements is more valuable to you?

	5	4	3	2	1	2	3	4	5	
Resource Efficiency	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Indoor Air Quality
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Acoustic Comfort
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Waste Management
	5	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	
Indoor Air Quality	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Acoustic Comfort
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Waste Management
	5	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	
Acoustic Comfort	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Waste Management

PAIR-WISE COMPARISION SHEETS OF ALL THE SUB-GREEN BUILDING DESIGN ITEMS

Which of two requirements is more valuable to you?

Factor I- Resource Efficiency

	5	4	3	2	1	2	3	4	5	
Rainwater harvesting to use for toilet flushing	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Using grey water from the sink for toilet flushing
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Rainwater harvesting for irrigating landscapes around the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of recycled materials in walls, floors, ceiling, floors etc.
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of light sensors in the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)
	5	4	3	2	1	2	3	4	5	
Using grey water from the sink for toilet flushing	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Rainwater harvesting for irrigating landscapes around the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of recycled materials in walls, floors, ceiling, floors etc.
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of light sensors in the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)

Factor I- Resource Efficiency

	5	4	3	2	1	2	3	4	5	
Rainwater harvesting for irrigating landscapes around the building	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of recycled materials in walls, floors, ceiling, floors etc.
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of light sensors in the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)
	5	4	3	2	1	2	3	4	5	
Usage of recycled materials in walls, floors, ceiling, floors etc.	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of light sensors in the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)
	5	4	3	2	1	2	3	4	5	
Using renewable energy sources (wind, solar, geothermal, etc.) to supply hot water for the building	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of light sensors in the building
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)

Factor I- Resource Efficiency

	5	4	3	2	1	2	3	4	5	
Usage of light sensors in the building	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Dual flushing button system for toilets
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)
	5	4	3	2	1	2	3	4	5	
Dual flushing button system for toilets	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of water efficient faucets in sinks
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)
	5	4	3	2	1	2	3	4	5	
Usage of water efficient faucets in sinks	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Usage of energy efficient electrical office tools (computers, copying machines, printers etc.)

Factor II- Indoor Air Quality

	5	4	3	2	1	2	3	4	5	
Heating systems providing adequate thermal comfort for occupants	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate indoor thermal comfort in cold and arid weather conditions
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Cooling systems providing adequate thermal comfort for occupants
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate natural air ventilation provided from doors and windows

Factor II- Indoor Air Quality

	5	4	3	2	1	2	3	4	5	
Adequate indoor thermal comfort in cold and arid weather conditions	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Cooling systems providing adequate thermal comfort for occupants
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate natural air ventilation provided from doors and windows
	5	4	3	2	1	2	3	4	5	
Cooling systems providing adequate thermal comfort for occupants	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate natural air ventilation provided from doors and windows
	5	4	3	2	1	2	3	4	5	
Even heat distribution between different spaces (corridors, rooms, atrium etc.) of the buildings	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate natural air ventilation provided from doors and windows
	5	4	3	2	1	2	3	4	5	
Air quality in shelving areas (i.e. stuffy/ stale air, cleanliness, odours etc.)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Adequate natural air ventilation provided from doors and windows

Factor III- Acoustic Comfort

	5	4	3	2	1	2	3	4	5	
Sound privacy in shelving areas. (ability to have conversations without your neighbours overhearing and/or any other indoor noises)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sound privacy in circulation areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Background noise level in circulation areas
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Background noise level in shelving areas
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sound privacy in study areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)
	5	4	3	2	1	2	3	4	5	
Sound privacy in circulation areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Background noise level in circulation areas
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Background noise level in shelving areas
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sound privacy in study areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)
	5	4	3	2	1	2	3	4	5	
Background noise level in circulation areas	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Background noise level in shelving areas
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sound privacy in study areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)
	5	4	3	2	1	2	3	4	5	
Background noise level in shelving areas	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sound privacy in study areas (ability to have conversations without your neighbours overhearing and/or any other indoor noises)

Factor IV- Waste Management

	5	4	3	2	1	2	3	4	5	
Existence of sufficient amount of separate recycling containers (for plastic, paper, glass, etc.)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Sufficient amount of recycling containers in every floor (for plastic, paper, glass, etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Design of recycling containers (shape, size, colour, etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Proper placement of recycling containers within the building
	5	4	3	2	1	2	3	4	5	
Sufficient amount of recycling containers in every floor (for plastic, paper, glass, etc.)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Design of recycling containers (shape, size, colour, etc.)
	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Proper placement of recycling containers within the building
	5	4	3	2	1	2	3	4	5	
Design of recycling containers (shape, size, colour, etc.)	<<<<	<<<	<<	<	=	>	>>	>>>	>>>>	Proper placement of recycling containers within the building