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SETTING THE KEY ISSUES AND A PRIORITIZATION STRATEGY FOR DESIGNING SUSTAINABLE INTERIOR ENVIRONMENTS

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INTRODUCTION

The aim of the designer is to enhance the quality of human life for a safe and comfortable environment. Human Factors as a discipline that focuses on the interaction between people and their environment is always seen within the context of design. Since built environments are designed for human beings, the interaction between humans and their environment should sustain their presence, as should the characteristics of the environment itself. There is continuous and mutual interaction between sustainability features and human needs. Both influences how buildings and interiors are designed as well as user-environment interactions are managed. Designed built environments should contribute positively to the balance of energy in the environment, making it healthy and comfortable for humans. Further, humans themselves should have a positive impact on the environment (Caple, 2010; Hendrick, 2008; Scott, 2008).

At present, there is an increasing demand for sustainable and healthy interior environments. However, design problems can be difficult to solve because of a multitude of physical and symbolic factors affecting human interaction with sustainable systems (Kumazawa et al., 2009; Miller, 2013). Environmental, social and economic factors, which are the main three facets of sustainability (Birkeland, 2002), should be carefully analyzed when undertaking a design project. Especially if the aim is a sustainable interior environment, all factors should be assessed to ensure that a user-responsive space is achieved. This study proposes a target framework for how to design interior environments that contribute positively to humans' well being through the efficient use of site, energy, water and materials and resources.

Although the concept of building sustainability is mostly analyzed by economic, environmental and social indicators, different assessment methods are used to determine the impact of the built environment on sustainability (Sanya, 2010). The Leadership in Energy and Environmental

Design (LEED) for Homes Rating System includes topics such as site, energy, water, materials and resources and interior environmental quality. A sustainable built environment is the result of efforts to actively integrate the efficient use of the first four factors to provide the fifth. Although many studies relate human factors in an office environment to human health and comfort, it should also be related to the building and business performances (Roussac, de Dear, Hyde, 2011; Roussac, Steinfeld, de Dear, 2011). Human Factors, which has been characterized as functionality, usability, efficiency, effectiveness, comfort and satisfaction (IEA Council, 2000), can serve as a holistic tool to formulate and integrate sustainability from the early stages of the design process. Moreover, although there are already many assessment techniques related to sustainable design, "[t]o avoid being swamped by statistics, the designer needs a simple toolkit for assessment based on readily understood principles and values (Edwards, 2010, 66).

This paper suggests the C-K theory, which defines the design process as an interaction between the space of concepts (C) and the space of knowledge (K), as an innovative approach to design practice. In this respect, the following research questions are formulated to develop a framework for designing sustainable interior environment: (i) How to set the priorities of interior environments through the C-K theory?; (ii) what are the priority categories of the key issues for a sustainable interior environment? A sustainable interior environment contributes positively to the well being of the individual through the efficient use of site, energy, water, materials and resources of the general environment. In this study, the key issues that are required for a sustainable environment are derived from the previous models found in the relevant literature. This derivation process is based on three phases: (**1**) Concept to Knowledge Phase; (**2**) Sustainability Framework Phase (**3**) Prioritization Phase. In "Concept to Knowledge Phase", the key issues for efficient use of the enviorment, which are energy, water, materials and resources and site, are determined in relation to their concept and knowledge space. In "Sustainability Framework Phase", the concept and knowledge issues in providing sustainable interior environment quality for C-K theory are summarized. In the third phase, "Prioritization Phase", human-environment interaction matrix is constructed based on the interaction of the interior environment issues defined in the previous two phases. Later, a morphological box for providing a sustainable interior environment is presented under four concept categories, which are adequete thermal comfort, visual comfort, acoustical comfort and good air quality. Consequently, the study categorizes the components of a sustainable interior environment into most, moderately and least important groups.

DESIGNING SUSTAINABLE INTERIOR ENVIRONMENTS THROUGH C-K FRAMEWORK

The design process distinguishes itself from other problem-solving tasks in that most of the knowledge and principles of design are stored in the memory of designer and must be called upon the requirement of each stage in design process (Afacan and Demirkan, 2010; Demirkan 2005). As Gagnon, Leduc and Savard (2012) stated the conceptual framework for sustainable design process can be defined as the interactions of the designer-artifact and user system. These interactions can be characterized in the conceptual framework depending on the experience from previous

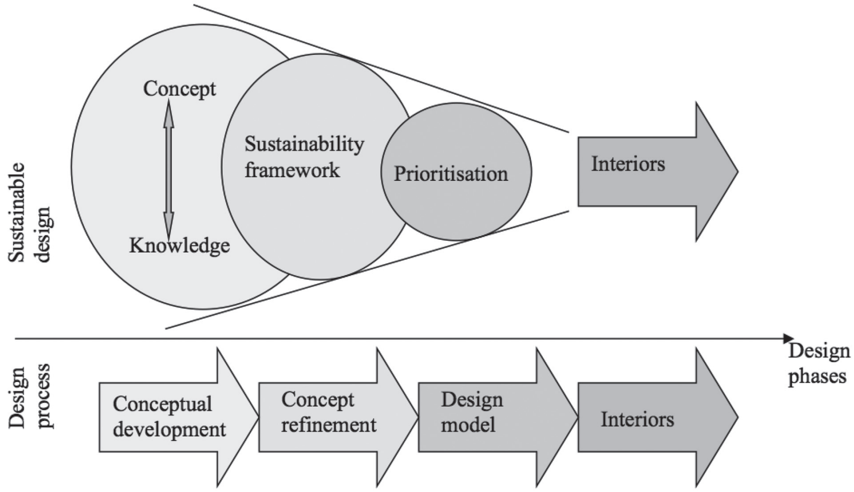

Figure 1. Sustainable and traditional design process phases

projects as well as scientific and technical literature. The defined interactions are neither exhaustive nor complete. At the beginning of the process, the designer must obtain knowledge about what is to be designed and the constraints and requirements related to the space (Demirkan, 1998). Although a designer accumulates knowledge of standards, codes and/or legislation, this knowledge may apply differently to different design processes and descriptions.

Design thinking is a creative process based on the transformations of the needs of diverse populations into solutions of (ideally) safe, comfortable and sustainable environments. The C-K theory, introduced by Hatchuel and Weil (2003), is appropriate when focusing on a sustainable environment. The theory provides a rigorous, unified and formal framework for design, based on the assumption that the design process can be modeled as an interaction between the space of concepts (C) and the space of knowledge (K) (Hatchuel and Weil, 2009; Zeiler and Savanovic, 2009). The challenge of realigning the present path of development on a sustainable practice of design, the design process needs to be modified in order for designers to efficiently tackle the sustainable issues. Instead of representing traditional and sustainable design as a dichotomy, this study places both approaches on a continuum along the design process (**Figure 1**).

The objective of a sustainable interior environment design is to accommodate a framework for design process as a general approach that changes according to designers needs while identifying, categorizing and organizing relevant data requirements. A sustainable built environment is the result of efforts to efficiently integrate the factors of site, energy, water, material and resources and the interior environment. Lee and Tiong (2007) classified sustainable sites, water efficiency, energy efficiency and materials and resources as environmental issues, while naming interior environmental quality as a social issue. In this study, interior environmental quality is considered in the ambient space where designers practice their profession for a sustainable environment. Therefore, design as a dynamic mapping process between the required abstractions and the selected descriptions can be modeled using the C-K theory discussed above. This section provides a brief description of each concept category in relation to their knowledge areas within the scope of sustainability, based on the relevant literature and previous experience of the authors.

Concept to Knowledge Phase

This phase (**Figure 1**) is made up of concepts and the related knowledge spaces that determine the key issues for the efficient use of energy, water, materials and resources and site. Each key issue is coded as it is specified (E: energy; W: water; M: materials and resources; and, S: site) in order to use the code in the interaction matrix and consequently, derive the relevant design solution as seen in **Table 1**.

Key issues	Concept space	Knowledge space	Code
Use of Energy	Tight building envelope	Insulation of building components (walls, floors, slabs, doors and windows)	E1
		Building orientation	E2
	High-level insulation	Exterior insulation	E3
		Interior insulation	E4
	High-efficiency	Energy-efficient building components	E5
		Energy-efficient artificial systems	E6
		Day-lighting systems	E7
		Renewable energy sources	E8
	User control mechanisms	Energy control	E9
		Temperature control	E10
		Operable systems (window- shading devices and shutters)	E11
Use of Water	Water-efficiency	Low-flow systems	W1
		Waterless systems	W2
	Water treatment	Innovative wastewater technologies	W3
		Grey water recycling	W4
		Rainwater collection	W5
	Easy-to-clean surfaces	Floor surfaces	W6
Use of Materials and Resources	Material usage	Reuse of materials	M1
		Natural materials	M2
		Recycled materials	M3
		Regional materials	M4
		Durable materials	M5
		Renewable materials	M6
		Waste management	M7
	Material characteristics	Thermal insulation	M8
		Sound insulation	M9
		Fire-resistant	M10
		Non-toxic and breathable features	M11
Use of Site	Reuse existing buildings	Reuse of building	S1
		Reuse of furnishings	S2
		Reuse of finishes	S3
	Respect natural landscape	Existing green fields	S4
		Existing natural habitats	S5
		Existing vegetation	S6
	Prevent expansion of built environment	Compact footprint	S7
		Light pollution reduction	S8
	Site selection	Brownfield redevelopment	S9

Table 1. Key issues for efficient use of the environment.

Key Issues for Efficient Use of Energy

A sustainable built environment should use as little energy as possible and utilize renewable energy sources. Sustainable strategies have prompted designers to pay considerable attention to effective ventilation and heating systems to optimize energy performance (Kalz, Pfafferot and Herkel, 2010). A building should minimize heat loss through building fabric by efficient construction and thermal bridges as well as have user control mechanisms for energy and temperature. Design solutions should involve the use of daylight (E7) and natural ventilation, as these factors improve the quality of the interior environment. Renewable energy sources such as wind, sun, water and geothermal energy should be considered in the design process, as long their use conforms to building legislation requirements (E8).

A building must provide a satisfactory thermal environment for its occupants; this depends on the components of the building envelope: walls, floors, roof, doors, windows and slabs (E1). Osbourn (1997, 53) stated that thermal comfort “involves the reduction of the rate of *heat losses* from the inside to the outside in colder climates, and the reduction of *heat gains* from the outside to the inside in warmer climates”. In a case, such as the building envelope should regulate heat transfer, a designer should select components (E5) and insulation (E3 and E4) that will eliminate leaks and reduces the transfer of heat and/or cold. The thermal resistance of insulation materials is determined by the relevant standards (ANSI/ASHRAE, 2004, 159). Sustainable insulation should be used in or on roofs, interior and exterior walls, door and window frames, floors and hot water pipes. Openings in the building envelope for electrical, plumbing and heating systems should be insulated. Sustainable design requires that windows be energy efficient and provide ventilation, and be without leaks and cracks. Framing materials also affect the insulation ability of a window.

The orientation of a building should maximize the penetration of sunlight in winter and control its heat in summer (E2). In the northern hemisphere, the building orientation “should be on the east-west axis, with a large area of glazing on the south-facing wall” (Winchip, 2007, 159). The walls of south-facing rooms should be covered with heat-absorbing materials. Window treatments should help control heat gain or loss. In the summer, sunlight-control strategies such as shade from trees, overhangs or awnings can be applied (E11). Appropriate use of insulation and ventilation also help keep a building cool.

To conserve energy, energy-efficient lighting and wattages should be presented (E6). Reducing or eliminating appliances and using dimmers, time controls and multiple-switch plans help conserve electricity (E9). Using programmable thermostats for energy control is important, as is thermostat location; the sun should not shine directly on it or on the wall nearest it (E10). Photo sensor controls also help to reduce energy consumption. The concept and knowledge issues related to efficient use of energy for C-K theory are summarized in **Table 1**.

Key Issues for Efficient Use of Water

Sustainable designs should conserve water. Sustainable water discharge also is a key issue, which means reducing the amount of water used and recycling water. Fresh (potable) water consumption can be reduced by the installation of water-efficient equipment. Rainwater harvesting and grey water treatment is the common methods for efficient use of water. Providing easy-to-clean surfaces can also reduce fresh water consumption.

Water shortage is an increasing problem, thus it is crucial to consider water consumption in the design process. Using water-efficient equipment and reusing water are two ways to conserve water (W1 and W2). Fresh water consumption can be reduced by installing water-saving fixtures. Sustainable solutions include water-efficient flush and flow fixture types. Flushing solutions involve low-flow or ultra-low-flow toilets and flow solutions include low-flow lavatories, sinks and showerheads. Composting water closets and dry urinals are options. Sustainable fixtures are not dependent on the behavior of the occupant(s) of the interior but rather on the technology of the fixture. A great deal of water is wasted by faulty and inefficient technologies (W3). The old and leaky units should be replaced with new equipment.

Easy-to-clean surfaces can reduce water consumption (W6). Floors in a building can be chosen from materials that do not need to be cleaned with water or are easy to clean (Active House- Specification, 2011). It is recommended that grey water (W4) and/or rainwater (W5) be used for toilets, gardening (Active House- Specification, 2011) and laundry (for laundry, grey water must be treated). The concept and knowledge issues related to efficient use of water for C-K theory are summarized in **Table 1**.

Key Issues for Efficient Use of Materials and Resources

Materials used in interiors have a huge impact in terms of sustainability. Building products and materials usually applied in design practice include finishes (carpet systems, wall coverings, ceiling treatments, paint) and furnishings (fabric for walls, upholstered pieces, window treatments). Finishes are less durable than furnishings (M5) and are usually replaced or redone many times during the life cycle of an environment, thus creating a lot of waste (Magar, 2010). Appropriate product and material selection and specifications should involve compliance with codes, building standards and sustainability guidelines (Guerin and Martin, 2001). Superior thermal, and fire-resistant, sound-insulating, non-toxic and breathable features are recommended as sustainable material qualities (M8-M11).

Material and product selection should also contribute to sustainability, energy efficiency and recycling. "In general, there are four main considerations when selecting building materials […]: embodied energy; performance over lifetime of building; appearance; salvage-ability" (Edwards, 2010, 129). The LEED system states that in order to minimize impact on the environment, buildings, structural components, equipment, furniture and furnishings should be reused (M1). Interior designers involved with renovation should consider reuse applications to reduce the consumption of new materials and to reduce waste (M7). Where reuse is not possible, the designer should use recycled materials (M3).

The sources of materials and resources are important when using virgin materials for sustainable designs (M2). The LEED system encourages locally sourced materials (M4) and suppliers to reduce the negative impact of transportation on the environment. Renewable materials such as fiber and animal products are recommended (M6). Bamboo flooring, wool carpets and bio-based plastics, made from cornstarch instead of petroleum, are examples of such products.

Sev (2009, 166) stated that "selecting durable materials is an effective way of extending the life of existing buildings as well as reducing material consumption". Using non-toxic building components, equipment, furniture and furnishings is vital to the health and safety of construction workers and the users of environments. Sustainable materials with fire-resistant characteristics improve the environment by minimizing consumption of natural resources and reducing pollutants and waste. Effective insulation in walls and on roofs reduces thermal exchanges. Sustainable insulation should be used on and in building components, building systems and furnishings. The concept and knowledge issues related to efficient use of materials and resources for C-K theory are summarized in **Table 1**.

Key Issues for Efficient Use of Site

To use a site efficiently, it is necessary for designers to understand how humans will interact with the built environment. In order to maintain the natural environment, expansion of the built environment must be prevented. A building unit should be integrated with its site; this adds to the architectural quality and human well being. Reuse of an existing building helps conserve resources (S1-S3), minimize impact on the environment and reduce material use.

Disturbance of the building's footprint has a negative impact on the environment (S7). The building should respect the natural landscape by keeping any fields (S4), habitats (S5) and vegetation (S6). When renovating a building, designers should keep in mind that an expansion may compact the soil and/or destroy the landscape. Removing natural landscaping results in soil erosion that affects the flow of water on a site; removing topsoil affects the nutrient levels of vegetation.

A designer should guide the client in determining how well the site fulfils sustainability criteria. Generally, the site location is recommended for urban and brownfield redevelopments (S9). "This involves reusing land that has been occupied by a building, parking lot, or any condition that has polluted a site" (Winchip, 2007, 141). A designer should also consider how much light pollution is produced through the design (S8). Light pollution negatively affects the interior and exterior environments and wastes energy.

The location of the building should reduce the environmental impact caused by cars. The chosen site should encourage occupants to walk, cycle or use public transportation (S10). This results in less pollution, minimizes the infrastructure required for cars and saves valuable land and resources. The concept and knowledge issues related to efficient use of site for C-K theory are summarized in **Table 1**.

Sustainability Framework Phase

Designers are responsible for the health, safety and well being of the occupants of the proposed interior space (Kang and Guerin, 2009). In the past 10 years, interest in the sustainable design process has increased substantially. This approach is not only about saving energy and recycling, but comprises of a holistic way of the interior planning, with services and products considering environmental, ecological and economic impacts. To support this process, designers must ensure good interior air quality, an adequate thermal climate and appropriate visual and acoustical comfort (Active House- Specification, 2011).

Adequate thermal comfort is essential for the well being and comfort of humans. Built environments should minimize overheating in summer and optimize temperatures in winter without unnecessary energy use (Active House- Specification, 2011). Where possible, natural ventilation should be used; if this is not possible, programmable control for heating, ventilation and air conditioning (HVAC) systems, adjustable thermostats or occupant-controlled temperature and ventilation systems should be used (I1 and I2) (**Table 2**).

Adequate lighting and daylight in interiors provide many health benefits and positively influence mood and well being. A good design allows optimal daylight and reduces overall lighting energy consumption (I3). The design of interior environments should avoid glare (I4) and provide for occupant-controlled lighting. Some design features should be present for controlling sunlight in the summer. In addition to lighting for visual comfort, the reflectance and color of floors, ceilings and walls should be considered.

An optimal acoustical environment positively affects occupants' well being and efficiency. Interior environments should be designed to minimize noise from the outside and to optimize the acoustic level inside by controlling system noise from ventilation or heating (I5). Sound insulation for facades to reduce noise levels from traffic and industry may be required (I6). Internal insulation may be needed for adjacent houses or rooms to control interior noise and provide acoustic privacy. Designers are responsible for specifying finishes such as ceilings, floorings, carpet systems, wall coverings and paint for clear sound transmission, as well as window treatments and furniture.

Interior environments should provide good air quality for the occupants. Natural ventilation reduces internal air pollution and limits energy needed for the ventilation system (I7). A fresh air supply with the appropriate dampness can be a good design solution (I8). In wet spaces (kitchens, bathrooms and toilets) dampness should be avoided through extraction. Low-emitting building components and materials should be chosen to maintain good air quality. If ventilation systems are required, occupants should be able to control them. The concept and knowledge issues in providing sustainable interior environment quality for C-K theory are summarized in **Table 2**.

Prioritization Phase

Potential relations (as codes) for sustainable design were identified for each issue stated in the previous sections (**Table 1-2**). Some of them such as efficient use of energy have a direct and obvious contribution, while efficient use of water did not directly contribute to the sustainable interior environment (**Table 3**). Efficient use of materials and resources and site knowledge spaces were mainly related to specific interior environment issues. The C-K theory aims to beyond the sustainable environment approach, as design process that relies on the generation of knew knowledge to validate partially unknown concepts, to generate new

Key Issue	Concept space	Knowledge space	Code
Interior Environment	Adequate thermal comfort	Temperature control	I1
		HVAC system	I2
	Visual comfort	Light control	I3
		Glare control	I4
	Acoustical comfort	Sound control	I5
		Sound insulation	I6
	Good interior air quality	Natural ventilation	I7
		Moisture control	I8

Table 2. Key issues for providing a sustainable interior environment

General Environment			Interior Environment							
			Temp. control	HVAC system	Light control	Glare control	Sound control	Sound ins.	Nat. ventilation	Moisture cont.
			I1	I2	I3	I4	I5	I6	I7	I8
Energy	Insulation of building comp.	E1	●	●				●		●
	Building orientation	E2	●	●	●	●			●	●
	Exterior insulation	E3	●	●			●	●		●
	Interior insulation	E4	●	●			●	●		●
	Energy-efficient building comp.	E5	●	●					●	●
	Energy-efficient artificial systems	E6	●	●	●					
	Day-lighting systems	E7			●	●				
	Renewable energy sources	E8								
	Energy control	E9	●	●	●		●	●		●
	Temperature control	E10	●							●
	Operable systems	E11				●		●	●	●
Water	Low-flow systems	W1								
	Waterless systems	W2								
	Innovative wastewater technology	W3								
	Grey water recycling	W4								
	Rainwater collection	W5								
	Floor surfaces	W6								
Materials and Resources	Reuse of materials	M1								
	Natural materials	M2	●						●	●
	Recycled materials	M3								
	Regional materials	M4								
	Durable materials	M5								
	Renewable materials	M6								
	Waste management	M7								
	Thermal insulation	M8	●	●						
	Sound insulation	M9					●	●		
	Fire-resistant	M10								
	Non-toxic and breathable features	M11							●	●
Sustainable Sites	Reuse of building	S1								
	Reuse of furnishings	S2								
	Reuse of finishes	S3								
	Existing green fields	S4	●	●						
	Existing natural habitats	S5								
	Existing vegetation	S6								
	Compact footprint	S7								
	Light pollution reduction	S8			●					
	Brownfield redevelopment	S9								
	Alternative transportation	S10								

Table 3. Human-environment interaction (Interaction)

concepts and to develop sustainable interior environments. An efficient and effective knowledge support system is crucial for sustainable design process. The structuring and analyzing the relationships between general and interior environment is introduced by using the morphological analysis method.

METHODOLOGY

The study is built on a theoretical analysis that is based on the reading of the relevant literature followed by morphological analysis. Using morphological analysis with the cross consistency assessment (CCA)

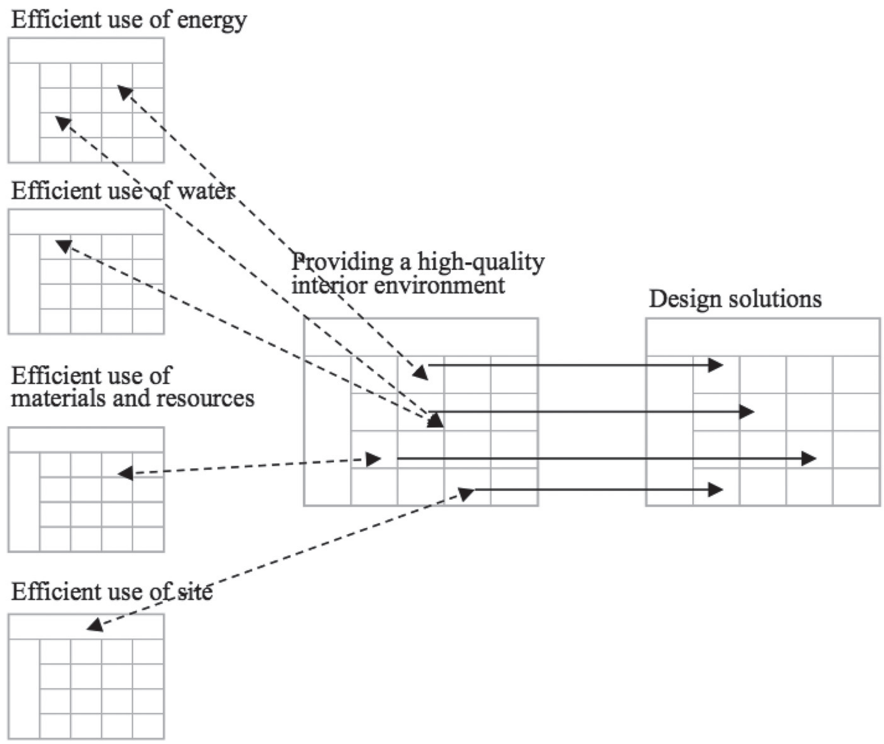

Figure 2. Example of a morphological analysis

technique, this study provides a framework for designers to apply a sustainable design approach. An overview of how the various concept and knowledge issues of sustainable design relate to one another is provided in the previous sections. Further, the study prioritized the components of a sustainable interior environment and emphasized how a less-important issue cannot be entirely compensated for by providing sustainable interior environment quality regarding other issues. An efficient overall design solution can be achieved by balancing all interior environmental quality issues.

Morphological Analysis

Although there is a general lack of knowledge how designers achieve solutions, they should operate an effective strategy to increase the possibility of creating promising concepts as early as possible (Afacan and Demirkan, 2011). Analyzing interior environmental quality raises a number of methodological difficulties involving correlated qualitative and quantitative variables. In the conceptual design phase, information related to these variables can be incomplete, missing or undetermined. Morphological analysis was developed by Fritz Zwicky as a method for structuring and analyzing the relationships in multi-dimensional complex problems (Zwicky, 1948). The technique is applied in diversified research areas to overcome methodological difficulties; and since the design process can be analyzed in components, it is suitable in this area as well (Hivid and Svendsen, 2007; Zeiler, Savanovic and Harkness, 2010). The method is helpful in decomposing related design issues and determining relationships between qualitative and quantitative variables (**Figure 2**). In this context, there is no difference between those two variables. The decomposition can be achieved as seen in **Table 4**; concepts with their

Interior Environment		General Environment Interaction	Design solutions (C1)		
Concept (C)	Knowledge(K)				
Adequate thermal comfort	Temperature control (I1)	E1-E6, E9, E10, M2, M8, S4	Efficient heating	Efficient cooling	Controllability
	HVAC system (I2)	E1-E6, E9, M8, S4	Natural ventilation	Mechanical ventilation	
Visual comfort	Light control (I3)	E2, E6, E7, E9, S8	Daylight	Reduced energy	Controllability
	Glare control (I4)	E2, E7, E11,	Avoid glare	Reflectance of building components	Colour
Acoustical comfort	Sound control (I5)	E3, E4, E9, M9	Speech privacy	Clear sound transmission	Reduced noise effects
	Sound insulation (I6)	E1, E3, E4, E9, E11, M9	Exterior	Interior	
Good air quality	Natural ventilation (I7)	E2, E5, E11, M2, M11	Design	Reduced energy	Fresh air supply
	Moisture control (I8)	E1-E5, E9-E11, M2, M11	Design	Low emitting-building components	Low emitting-materials

Table 4. A morphological box for providing a sustainable interior environment

related knowledge are listed in the left columns and the related conceptual design solutions are listed in the corresponding rows.

Cross-Consistency Assessments

In order to provide a consistent solution space, internally consistent relationships in the total problem space should be determined. Using a grid box, the technique of cross consistency assessment (CCA) reduces the number of possible solutions by eliminating illogical solution combinations (Afacan and Demirkan, 2011; Ritchey, 2006). This method is based on the insight that there may be numerous pairs of conditions in the morphological field that are mutually incompatible. All the values in **Table 4** are pair wise, and have been compared by two experts for logical incompatibility (denoted by I). Operationally, the CCA begins by selecting the first two values in the first two parameters (**Table 5**) that are presented by a facilitator (Ritchey, 2015). Expert one has 38 years of experience in design discipline and involved with the sustainability studies more than 20 years. Expert two has 16 years of experience in the design field with specialization in sustainability issues and a well-trained rater. Besides having experienced raters, this study is based on the literature that is reported in Section 2. Also, the relevant scientific information for the calculation of a confidence interval for intra-class correlation to assess the inter-rater reliability of the studies was considered (Shoukri, Asyali and Donner, 2004). The experts rated the matrix independently and the internal validities were controlled by Alpha Cronbach tests; only the ones over 0.8 were taken into consideration. As Johansen (2017) stated the only information one can extract from CCA is whether a given solution whether it is consistent with something that may exist in the real world. The CCA reduction results in a controllable number of internally consistent relationships, which are classified into three categories: very strong, strong and weak. For example, the relationship between natural ventilation and fresh air supply is considered very strong and is assigned five points. The relationship between daylight and the heating system is strong and

Concept		Temp.control			HVAC system		Light control			Glare control			Sound control			Sound ins.		Nat. vent.			Moisture control		
	Knowledge	Heating	Cooling	Control.	Natural	Mech. Vent.	Daylight	Reduced energy	Control.	Avoid glare	Reflectance build. ccompcomp.	Colour	Speech privacy	Clear sound trans.	Reduced noise effect	Exterior	Interior	Design	Reduced energy	Fresh air	Design	LE build. comp	LE mat.
Temp. control	Heating	X																					
	Cooling	I	X																				
	Control.		●	X																			
HVAC system	Natural	○	●	○	X																		
	Mech. Vent.	○	●	○	●	X																	
Light control	Daylight	○	○	●	●	I	X																
	Reduced energy	●	○	●	●	I	●	X															
	Control.	△	○	I	●	I	●	●	X														
Glare control	Avoid glare	△	●	○	○	I	●	○	●	X													
	Reflectance build. comp.	△	●	○	○	I	●	○	●	●	X												
	Colour	I	○	I	I	I	●	●	●	●	●	X											
Sound control	Speech privacy	I	I	I	△	○	I	○	I	I	I	I	X										
	Clear sound trans.	△	△	△	○	○	○	○	I	●	●	I	●	X									
	Reduced noise effect	△	△	△	○	○	○	○	△	●	●	I		●	X								
Sound ins.	Exterior	●	●	I	I	●	●	I	○	○	○	I	●	●	●	X							
	Interior	○	○	I	△	●	○	○	I	I	●	△	●	●	●	I	X						
Nat. vent.	Design	●	●	●	●	●	●	●	○	○	○	I		●	○	●	●	X					
	Reduced energy	○	●	●	●	●	●	●	△	△	I	I	I	○	○	●	●	●	X				
	Fresh air supply	○	●	●	●	●	●	●	○	○	I	I	○	○	○	●	●	●	●	X			
Moisture control	Design	●	●	●	●	●	●	●	○	○	●	△	○	○	○	●	○	●	●	●	X		
	LE build. comp.	△	△	I	○	○	○	△	●	●	●	●	○	●	○	●	○	●	●	○	●	X	
	LE mat.	△	△	I	○	○	○	△	●	●	●	●	●	●	●	●	○	●	●	○	●	●	X

Table 5. Cross-consistency assessment matrix for providing a sustainable interior environment

Relationship: ● Very strong ○ Strong △ Weak I: Incompatibile

assigned three points. The relationship between heating and clear sound transmission is considered weak, and assigned one point (**Table 5**).

Relative importance ranking		Design solutions (C1)
Most important	90 and more	Design for ventilation (90)
	85-89	Design for moisture control (89)
	80-84	Daylight (81)
Moderately important	75-79	Fresh air supply (79); Low-emitting materials (78); Reduced ventilation energy (76);
	70-74	Low-emitting building components (74); Exterior sound insulation (74); Reduce lighting energy (73); Natural ventilation (71); Reflectance of building components (71)
	65-69	Efficient cooling (69); Clear sound transmission (69); Avoid glare (68); Reduced noise effect (66)
	60-64	Interior sound insulation (63); Mechanical ventilation (61)
Least important	55-59	Controllability of light (58)
	50-54	Controllability of temperature (54); Efficient heating (50)
	45-49	-------------
	40-44	Speech privacy (44); Color (40)

Table 6. Relative importance rankings for a sustainable interior environment

As seen in **Table 5**, the CCA matrix is composed of design solutions (C1) and depicts all the compatible relationships with their assigned relationship values for providing a sustainable interior environment. For each design solution, the relative importance rankings were calculated by adding the assigned compatible weights. Two design experts grouped the relative importance rankings for each design solution obtained from the CCA matrix into one of three categories: most important, moderately important or least important, and ranked them from highest to lowest, as seen in **Table 6**. For example, natural ventilation (90 points), moisture control (89 points) and allowing daylight (81 points) were the three design solutions that were considered most important for providing a sustainable interior environment; speech privacy (44 points) and color (40 points) scored the lowest points. These outcomes showed that morphological analysis is as much a problem structuring tool as it is a means for analysis and modelling as stated by Johansen (2017).

RESULT AND DISCUSSION

An important aspect of designing sustainable built environments is to integrate the relative design issues. Knowledge regarding interior air quality, temperature control, HVAC systems, light control, glare control, sound control, sound insulation, natural ventilation and moisture control should be balanced against each other to provide a sustainable interior environment, as shown in **Figure 3**. The figure also shows that interior environment design solutions (C1) depend on active choices within each knowledge (K) parameter.

Greening an existing building or designing sustainable built enviroments involves complex decisions due to the multi-dimensional nature of user needs, demands and expectations (Menassa, 2011; Wu and Pagell, 2011). So, as explained in sustainable and traditional design process phases, the process of eliciting the right set of user requirements for sustainable design has been always a problem for architects. It requires considering a number of decisions and prioritizing environmental, social and cultural and

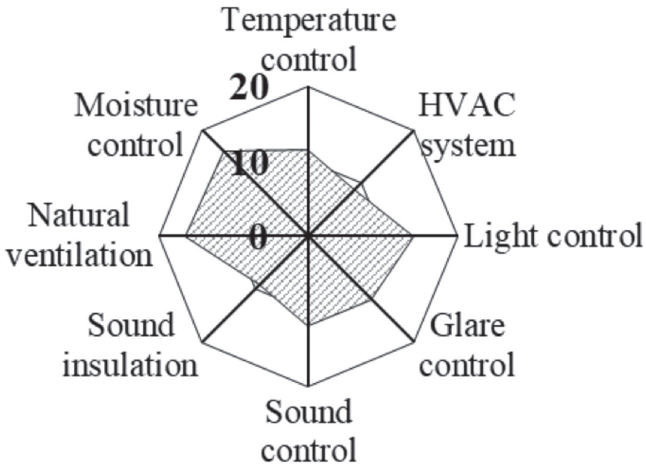

Figure 3. A balance of the interior environmental quality categories

economical constraints along users simultaneously (Mickaityte et al., 2008). To deal with this complexity, there is an urgent need of a systemic and holistic decision-making approach. In this respect, this study contributes to the literature by using morphological analysis with the cross-consistency assessment technique to define relative importance ranking of sustainable interior requirements.

According to the findings, the most imporant requirement is design for ventilation and daylight. Ventilation and daylight is dealt under indoor air quality parameters in sustainable design, because humidity and temperature have a considerable impact on perception of indoor air quality (Fang, Clausen and Fanger, 1998). Therefore, ventilation is an umbrella including thermal and health requirements of the occupants (Brown, 1997), While providing sustainable interior air quality, designers should be aware of the needs of diversified populations (Demirkan, 2007). The thermal, visual, acoustical and ergonomic comfort levels of people with physical, visual and/or hearing impairments, as well as the elderly, adults and children are different (Demirbilek and Demirkan, 2004). Comfort for all regarding such systems is the goal, and done properly, contributes positively to energy efficiency and cost savings. These systems do, however, require much in the way of product design, architecture and planning.

Addressing a proper thermal balance for all is the main concern when designing built environments suitable for cold winters and hot summers. In this respect, heating, ventilation and air conditioning systems need to be adapted to the users and the tasks. “HVAC systems simultaneously control temperature, humidity, air purity, distribution and motion of air in interior building spaces” (Bingelli, 2010, 228). For comfort and well being, manipulating air and regulating the thermal environment need to be integrated with ergonomics data such as adequate daylight, which is a critical element for natural ventilation and heating performance.

As illustrated in **Table 6**, the moderately important requirements are related with energy efficiency. It is a fact that HVAC energy consumption constitutes the main part of the overall energy consumption (Luther and Rajagopalan, 2014) and it brings lots of economic and environmental burden to sustainable building design. Hence, designers and architects should consider effective cooling and reduced ventilation energy in addition to low-emitting building materials (Kabak et al., 2014). Effective internal natural light maximizes visual comfort while reducing energy use and helps in wayfinding and navigation.

Clear space planning helps everyone by eliminating unnecessary complexity within working areas and circulation spaces. Sustainable design practices reduce the environmental impacts of site selection, water and energy use and material and resource selection. Taking the above-discussed factors into account, designers are able to enhance quality of life in a safe and comfortable environment.

CONCLUSION

The growing concern and increasing interest in sustainable built environments is changing the agenda of design strategies.The paper expanded the relationships within the design process to the wider scope of sustainability and suggested a prioritization strategy to balance interior environmental quality issues. The significance of this study lies on prioritizing the well-known components of a sustainable interior environment into most important, moderately important or least important. In this way, sustainable design could be defined as a decision making for all compatible relationships of sustainable design. Decision-making is a complex process, even when only two choices are discussed. In green design process, architects 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 building practice should be operated as quickly as possible in most satisfying way. Satisfying all the requirements is very difficult for architects 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. Therefore, some methods optimizing the choices are needed. In this respect, this study contributed to the current knowledge by developing a cross-consistency assessment technique model for sustaianble building design. The proposed model revealed the significance of the collaboration among architects and users. There could be some differences between the top needs of users and priority attributes of architects, like in the case of indoor air quality and acoustical comfort. Thus, involving users regarding their needs, demands and expectations for a successful and satisfied green design of buildings is inevitable.

The findings of the study are in line with the self-assessment sustainability criteria proposed by Edwards (2010). As Edwards (2010) proposed all projects do not need to assign equal weight to each C-K space, rather use of multipliers to give priority to certain sustainable values. In that sense, this study highlights also the importance of applying weights to a series of sustainability C-K spaces. Since the context of the study is interior design field, the above discussed factor interactions could be different in the planning, urban or landscape architecture contexts. This study is significant in terms of highlighting the importance of the relative importance rankings of design requirements and elimination of illogical solution alternatives for green design process. The discomfort and dissatisfaction perceived by the users can be prevented through user-centered design models at the outset of library projects. For future studies, interior environmental quality differences for diverse user groups (the elderly, disabled and/or able-bodied adults and children) could be investigated, and computerized tools to integrate human factors principles and interior environmental quality solutions into the design process as early as possible could be developed. This study presents an innovative approach to design practice, incorporating sustainable characteristics.

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Anahtar Sözcükler: Yapılı çevre; iç mekan çevresi; önceliklendirme; morfolojik analiz; sürdürülebilirlik.

SÜRDÜRÜLEBİLİR İÇ MEKAN TASARIMI İÇİN ANAHTAR KONULARIN VE ÖNCELİKLENDİRME STRATEJİSİNİN BELİRLENMESİ

Sürdürülebilir bir yapılı çevre yaratma olanağını arttırabilmek için, etkin bir tasarım stratejisi uygulanmalıdır. Bu çalışmanın amacı, verimli enerji, su, malzeme, kaynak ve arazi kullanımına dayanan, sürdürebilir özellikler ile insanların refah içinde yaşamasına olumlu katkıda bulunan, yapılı çevre tasarım sürecine temel oluşturacak bir çerçeve geliştirmektir. Bu çalışma, tasarım sürecini kavram alanı (C) ve bilgi alanı (K) arasındaki bir etkileşim olarak tanımlayan C-K kuramı ile, tasarım pratiğine yenilikçi bir yaklaşım önermektedir. Çapraz tutarlılık değerlendirme tekniği ile morfolojik analiz kullanılarak, tüm uyumlu ilişkiler ve bu ilişkilerin yoğunlukları belirlenmiştir. Ayrıca çalışma, sürdürülebilir bir iç mekan çevresinin bileşenlerini en önemli, orta önemli veya az önemli olarak önceliklendirmekte ve bu bileşenleri en önemliden en az önemliye doğru sıralamaktadır. Yapılan araştırma iç mekan tasarım uygulamalarına, yapılı çevre sürdürülebilir özellikleri ile bütünleyerek yenilikçi bir yaklaşım getirmektedir.

SETTING THE KEY ISSUES AND A PRIORITIZATION STRATEGY FOR DESIGNING SUSTAINABLE INTERIOR ENVIRONMENTS

Designers should operate an effective strategy to increase the possibility of creating sustainable built environments. This paper aims to evolve a framework that is composed of the sustainable interior environment issues acting as the basis that contribute positively to humans' well being through the efficient use of site, energy, water and materials and resources in the built environment. The C-K theory, which defines the design process as an interaction between the space of concepts (C) and the space of knowledge (K), is suggested as an innovative approach to design practice. Using morphological analysis with the cross-consistency assessment technique, all compatible relationships, with their assigned values, are determined. Further, the study prioritizes the components of a sustainable interior environment into most important, moderately important or least important and ranks them from highest to lowest. This study proposes an innovative approach to interior design practice that incorporates sustainable characteristics to the built environments.

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