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Integrated Framework for Implementing Sustainability into Architectural Design Process: Case of Saudi Architectural Practices

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Abstract. The purpose of this study is to develop an integrated framework for implementing sustainability into architectural design process. Qualitative and quantitative approaches used to develop the framework; basically soft system methodology (SSM) with its seven interrelated stages is used to shape interventions in the problematic situation encountered in system management. The model is validated based on observational quasi-experiments, interviews with designers and professors of architecture. Besides, structured questionnaire have been used to measure the applicability of sustainable parameters into architectural process. The principal outcomes of this research are that sustainable practices are of increasing interest in many levels and complex dimensions. This approach, which is cyclic in its nature, takes into consideration a pool of ideas and intuitions of many design members. Moreover, there is a strong orientation in academic realm and among design studios in Saudi universities toward sustainability application as the backbone of design. The students, and professors as well, consider sustainability a need rather than a design movement.

1. Introduction

Sustainable building is a recent design philosophy that requires the consideration of energy, resources depletion and waste emissions during its whole life cycle in addition to minimizing cost and creating a healthy environment for people (Wang *et al.*, 2005). Applying sustainable development concepts to the design, construction, and operation of buildings can enhance both the economic well-being and environmental health of communities around the world (Public Technology Inc., 1996).

A sustainable design approach prioritizes the reduction of excessive use of energy to provide comfortable conditions inside buildings. This can be achieved by means of careful consideration of the building shell when designing buildings (Ali and Al Nsairat, 2009). Before the design of the building fabric is discussed, it is necessary to consider the various aspects associated with comfort inside buildings.

Green building has now become a flagship of sustainable development that takes the responsibility for balancing long-term economic, environmental and social health (Yoon and Lee, 2003). It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants is reduced (Architectural Institute of Japan, 2005). A comprehensive and effective building assessment tool is required to design sustainable buildings and to provide comprehensive assessment of building performance across a broader range of environmental considerations using a set of criteria and targets (Ali and Al Nsairat, 2009). In order for the environmental building framework tool to be useful as a design instrument to achieve sustainability, it must be introduced as early as possible even before a design is conceptualized (Ding, 2008). It is implemented early enough at the conceptual design phase where modification in the design is possible and economically feasible and where the life cycle consequences of the build on the environment are mostly determined. The framework can guide the designer toward producing buildings with low environmental impacts and healthy indoor environments (Ali *et al.*, 2009). It will provide a clear objective function and has the ability to show designers where effort can be best prioritized.

The design of buildings requires the integration of many kinds of information into a synthetic whole. An integrated process, or "whole building" design process, includes the active and continuing participation of users, code officials, building technologists, cost consultants, civil engineers, mechanical and electrical engineers, structural engineers, specifications specialists, and consultants from many specialized fields (Bachman, 2003). The most fundamental goal of integrated building systems design is the elimination of redundant resources, usually achieved through strategic combinations of the systems that are deployed in concert with their shared mandates of space, image, or function (Cooper, 1999). It is important that integration measures provide these and sufficient other tangible benefits to justify the effort involved (Kim, 1998). Exposing structure or mechanical systems components, for example, is a popular and often highly visible aspect of integration. But exposure itself is not inherently good, no matter what level of integration is attained (Bachman, 2003). Some design intention or programmatic goal must actually be served.

Universities have sometimes demonstrated support towards sustainable design integration in the academic realm. Architectural education should embrace the concern between disciplines, across the different disciplines, and beyond all discipline. There is a shifting in the paradigm of teaching architectural design, from Disciplinary, Multidisciplinary, Interdisciplinary and Trans-disciplinary that will focus on trans-disciplinary which is a meta level above interdisciplinary and is best described as a way to find the patterns and the differences that make a difference by taking the epistemologies from each discipline to drive inquiry (Ibrahim, Fruchter and Sharif, 2007). It becomes important to take a step back to review and learn from the previous efforts in integrating sustainability and energy education in architectural academia.

The purpose of this study is to develop a conceptual design 'framework' that is definable from within a number of strategies and criteria, that should be systematically evaluated and developed within the building design process. The study also aims to establish a supplementary tool that assists in developing a sustainable approach towards architectural design. The main premise is that practitioners need more adequate conceptual models in order to be able to understand issues of sustainable development, and integrate such issues into architectural design. The framework is examined in both academic and professional realms. The expected results will be useful as conceptual, integrated models and an enriched repertoire of design tools. Furthermore, the framework applies inter-disciplinary procedures to educate architectural students. Trans-disciplinary architectural education embraces the interest among across and beyond disciplines (Ibrahim, Fruchter and Sharif, 2007). It helps understand the built environment, of which one of the necessities is the unity of knowledge from design, engineering, socio-cultural, management, and other related areas. The objectives of the research are:

- To study, analyze, and evaluate the existing architectural design practices in both academic and professional institutions in the Kingdom of Saudi Arabia.
- To develop a conceptual framework that integrates sustainable parameters into the design phases (from programming, concept, development, construction, operation). This framework is used as a tool to assess the performance in different phases.
- To validate the framework through testing on architectural students and professionals.

2. Integration and Architectural Design Process

2.1. Integrated design

Sustainable architecture takes into consideration the relationship between building and environment and the flow of resources and energy. It required the holistic integration of all architectural activities into design process throughout the life cycle of the building. Architectural design requires the appropriate selection, configuration, and implementation of architectural systems and technologies. The combination of design synthesis and technological procedures are so interwoven in architecture that are difficult to distinguish between them (Architectural Institute of Japan, 2005). All buildings have to achieve these basic levels of the integration of systems to a certain degree before they can be built and occupied. It is also obvious that a different level of integration among the systems is possible and that a more highly integrated building is more likely to enjoy better degrees of fit, image, and function. If building components are the hardware of integration, then design can be thought of as the software complement (Bachman, 2003). Design establishes major architectural goals and objectives of a project and then directs the process of accomplishing them. Therefore, integration is about bringing all of the building components together in a way and emphasizing the synergy of the parts without compromising the integrity of the pieces (Bachman, 2003). Integration topics incorporate large and expensive new systems into buildings design, construction, and operation.

The most fundamental goal of integrated building systems design is the elimination of unneeded resources, usually achieved through strategic combinations of the systems that are deployed in concert with their shared mandates of space, image, or function (Zunde and Bougdah, 2006). It is important that integration measures provide these and sufficient other tangible benefits to justify the effort involved. There is an infinite number of possible integrations between the major building systems, between the subsystems of each, and among subsystems of different major systems (Bachman, 2003; Zunde and Bougdah, 2006).

Integration can be defined as the environmental objectives representing the whole building process as a series of interweaving systems. However, building, in itself, is a system with subsystems of varying life spans. A system is a kind of a representation consisting of elements, relations between the elements and a boundary (Winter *et al.*, 1995). A system has two kinds of qualities in relation to the elements has established an order between various elements in a building from a sequential perspective (Edén, 2003) (Fig. 1).

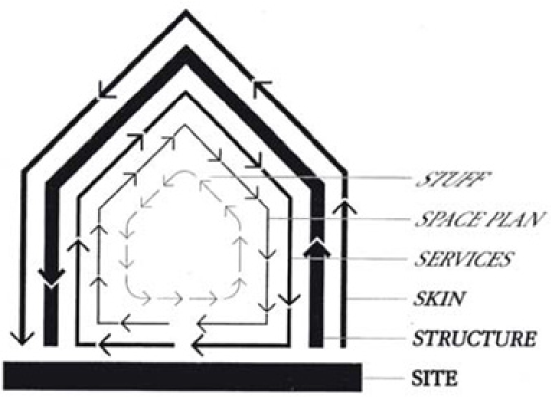


Fig. 1. Framework represents the building as a group of systems/subsystems over different life time (source: Edén, 2003).

Brand (1994) defined a framework that illustrates the building as a group of subsystems with different life-times. Through analyzing the resource flows and emissions, it is important to estimate the life-time of different elements, flexibility and potential to exchange elements, and which elements, already in the initial stages, decide future performance from a long-term perspective (Brand, 1994; Edén, 2003).

2.2. Architectural design process

Design, construction, and operation process of a building can be described as a series of phases; pre-design, program, design, concept formation, building permit, systems design, detailing, construction, procurement, building, management, daily use, maintenance, repair, refurbishment, discharge, demolishing. These phases are not always chronological. Instead of regarding the steps as phases over time, they can be regarded as different levels of systems' complexity (Kim, 1998). An architect can be able to move between the levels throughout the process, for example anticipating details in the pre-design or changing program goals in the detailing phase.

The conventional model of the building design is a linear process consisting of four major phases: design, construction, operation and maintenance, and demolition (Fig. 2). These phases are connected, and the boundaries between them are not obvious. The phases can be developed into life cycle design strategies that are focusing on minimizing the environmental impact of buildings (Kim, 1998). The problem associated with this model is that it is too narrowly defined; it does not deal with environmental issues related to the designing and construction of building materials or waste management reuse and the recycling of architectural resources.

2.2.1. Pre-design phase

Architectural design must begin with appropriate research and analysis of the characteristics of the project and its surroundings. This phase includes site selection, building design, and building material processes, up to, but not including, installation. Under the sustainable-design strategy, we examine the environmental effects of the structure's design, orientation, and impact on the landscape, and materials used (Architectural Institute of Japan, 2005). Building materials impact the environment, for example cutting trees could result in deforestation; transporting these materials can be a highly polluting activity, depending on their weight and distance from the site (Kim, 1998). The manufacturing of building products and transportation of these materials also requires energy (embodied energy) and creates environmental impact.

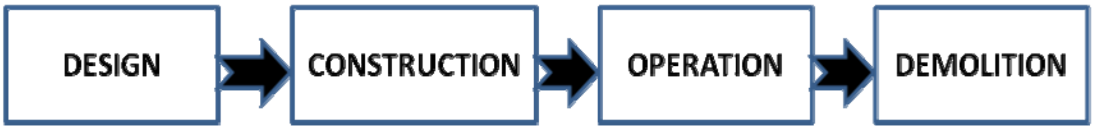


Fig. 2. Conventional linear design process model (source: Kim, 1998).

2.2.2. Design phase

This phase is when the plan is interpreted of physical space and architecture under the given conditions, based on the results of investigation and concept formation at the pre-design phase. The holistic approach is required for integration the various building systems; architectural design, structural, mechanical, etc., and landscape into the surrounding environment. Throughout this process from concept formation to execution, it is required to have a growing level of accuracy and detailing. Technical, legal, and cost issues should be address through this phase (Architectural Institute of Japan, 2005).

This phase includes the on site management of construction and finishes with the completion and handing over the building (Architectural Institute of Japan, 2005). There should be changes that will occur that are being made during the design stage. The compatibility of design system with other systems is crucial, for example, the structural quality of the building itself comes from its design, and architects should repeatedly check their own design to assess the loading that will impose on the environment. This could be done through checking and estimating the impact of building on the environment and the effect of the efficiency of structure on the efficiency on the environment. This procedure can be applied to all other building systems.

2.2.3. Post-design phase

This phase begins when the design and construction of the building has ended and has been occupied by users. In this stage, building materials become resources for other buildings or waste to be returned to nature. The sustainable design strategy focuses on reducing construction waste (which currently comprises 60% of the solid waste in landfills) by recycling and reusing buildings and building materials (Kim, 1998; Cooper, 1999). It is important for the architect to verify whether it provides the environmental performance efficiency as designed. If any failures and problems are found, it is important to take action to identify the cause and improve the design (Architectural Institute of Japan, 2005). This phase include various inspection phases ranging from physical characteristics to human factors (Cam, 2005). During this phase, data should be recorded from various relevant fields. Several techniques of investigation can be used such as physical monitoring, post occupancy evaluation, these techniques will lead to correction measures for future design.

2.3. The soft system methodology (SSM)

Based on the research goals, developing a framework requires aspects of both a qualitative and quantitative nature. Qualitative research seeks to gain insights and understand about systems integration related to architectural design process; in this case, the soft systems methodology is adopted. Quantitative approach focuses on determining relationships through factual data and to test the applicability of the proposed system/framework in the real world.

The framework development is based on soft systems methodology (SSM) that was developed by Peter Checkland (Williams, 2005). It is designed to shape interventions in the problematic situations encountered in management, organizational and policy contexts, where there are often no straightforward ‘problems’ or easy ‘solutions’. Though informed by systems engineering approaches, it breaks with them by recognizing the central importance of perspective or world-view in social situations (Williams, 2005).

Soft systems methodology deals with complex situations of elements that involve lacking of common agreement on what constitutes the problem to be addressed. In these situations, to move to a more sustainable way of conducting design process, there usually exist many different perspectives, values, and beliefs around what aspects of the situation are most important and how to address them (Winter, 1995). It is important in such situations to develop a reasonably comprehensive understanding of the interrelationships of the various aspects of the problem situation.

The aim of SSM is to bring about improvements in a situation perceived as problematic (Checkland and Poulter, 2010). By itself, it does not seek to solve ‘the problem’ but to facilitate a learning process which allows its users to gradually develop a more comprehensive understanding of the situation under study. To apply this procedure, stakeholders are likely to reach agreements about what changes in the situation the involved parties can live with (Winter, 1995). All the stakeholders fully agree that the proposed changes best serve all of their needs. However, this is a very rare state of affairs in most real-world situations, and that most of the time individual needs can only be partially met by collective propositions (Checkland and Poulter, 2010).

2.3.1. Stages of soft systems methodology

Soft systems methodology consists of a seven-stage process (Checkland and Poulter, 2010; Winter, 1995; Williams, 2005) as follows:

1. Identifying the problematic situation requiring intervention

This stage is concerned with identifying and providing a brief description of the situation which is in need to interfere in. This is normally done by those concerned with or affected by the issues coming to a broad agreement about the situation that needs attention. Care should be taken not to formulate the issue as a problem to be solved, as that can lead to too narrow an approach at too early a stage.

2. Researching the situation and building interpretive representation

The purpose of this stage is to create a deep representation of the case in which intervention is preferred. Part of this will involve information about and views on issues that have suggested an intervention, but the 'rich picture' should be much wider than this and describe the overall situation. A variety of methods can be used to gather information ranging from formal research techniques to serendipitous approaches. The advantages of the 'rich picture' are that it draws together information and perspectives from the widest possible range of sources. It is usual to represent the picture visually—often with several alternative depictions—rather than just as text. Using a mental-map or similar diagram is required as the final representation, even if it's backed by pages of research.

The first and second stages are usually used together to describe the real situation of the problem. Stages one and two should integrate with the real world and the description of this situation must be done considering structure, process, and the relation between structure and process.

3. Selecting perspectives and defining key processes that need to take place within the desired system

This part cares about three analyses of the people-dimension of the situation. It takes into consideration the key players in the situation; (1) the client who will cause the interventions to happen and the practitioner who will use or guide the SSM process; (2) the cultural environment of the situation and the roles, norms and values that would help in identifying the situation; and (3) the effect of power relations on the situation, the source of power and important relations on the situation, how power is obtained, used, challenged, defended, and passed on.

The methodology in this stage moves to the field of systemic thought, applying the concepts of outstanding system to describe how the system is. The elements of the system should be:

- The users and the beneficiaries affected by the activities of the system.
- The owners who have the power to create the system and also to end them (sometimes users and owners are the same).
- The actors who perform the main activities of the system.
- The transformation process and the ways in which inputs of the systems turn into outputs.
- The worldview that permeates the system.
- The restriction of the environment for these systems.

4. Developing a conceptual model of the change system

In this stage, the conceptual model should be created that reaches the transformation mentioned in earlier stages. This stage makes use of the system concepts to describe how the outstanding systems should be for this situation. This description can be done at different levels of detail, making use of the systems hierarchy concept. After creating the conceptual models, it is important to validate them through comparing them with the formal system or with other systematic conceptions. The formal system includes the following elements: purpose, performance measurement, process of making decision, connected subsystems, physical and human resources, and interaction with the surrounding environment.

5. Comparing the model with the real-world situation

This stage is concerned with comparing the proposed conceptual model with real world. The comparison can be at the level of what or how and focus again on the application of system hierarchy.

6. Defining the changes to be implemented

In this stage, it is important to take care of the changes in the process, structure and attitudes in the proposed concept. Once the desirable and feasible changes are defined, then a new problem formation will be created. These processes are cycles that can begin again.

7. Taking action

This stage will vary depending on the specific change project, but fundamentally it involves developing the revised change model into a concrete plan, and taking action to implement it. At this point, formal project management protocols may be useful or a less structured approach could be appropriate. While some change projects may be on-off interventions, it is more usual to think of the SSM process as cyclic in nature. In many projects an intermediate or short cycle is appropriate, where transition processes are re-examined in the light of early implementation and adjusted as necessary.

3. Developing and Validating the Conceptual Framework

The proposed conceptual framework is based on the soft system methodology. In this part of the study, the proposed framework will be applied and validate the procedure for implementing sustainability into architectural design process. Several techniques will be used that include observational and quasi-experiments to evaluate the applicability of the framework.

3.1. Validation methods

The observational quasi-experiments were structured observations where the participants performed specified tasks and the instructor recorded the detailed review of specific indicators. The researcher was recording observation for two years and four courses of teaching and instructing integrated design course (Arch 460) which is offered by the College of Architecture and Planning at King Saud University. This course was focusing on defining the building as group of systems that are related, coordinated and integrated. The aim was to implement these systems in an early phase of design. It adopted the integration of these building systems as early as possible. This course was designed according to the soft systems methodology (SSM) as procedure for integrating systems together.

Four design projects were used in this course during the four semesters: activity center for students, healthcare facility center, astronomy research center, and building science research center. For each semester, a course web site was developed to interact with students throughout the project timeline. The students understood the design process, overlapping of its phases, and the systems implanting in each phase. All students were able to do theoretical analysis through case studies, site analyses, and program formation. It was assumed that the project is real and students should negotiate with a virtual client (the instructor played this role). It was required from all students to define the architectural system according to spatial distribution, circulation, zoning, geometry, form and context. The first step also included some other systems such as structural, mechanical, and sustainability. The students studied each of these sub-systems together to evaluate them according to specific criteria proposed by the instructors. The evaluation criteria included: checklists, external reviewers, and evaluation software. After evaluation, the students defined their position from the outcomes and decided whether to continue developing the proposal or start over (not necessarily from the beginning, but form specific points requiring adjustment). The processes were cyclic in its nature.

3.2. Self reported questionnaires

Close and open ended questionnaires were developed to measure the applicability of the framework. Five-point Likert scale was used to evaluate the respondent's point of view regarding the use of sustainability from the pre-design phase of the design process. The tool was developed to figure out the weight of sustainable values and its importance in the design process. Sustainable factors used in this study included: site, energy efficiency, water efficiency, materials, indoor environmental quality, waste and pollution, and cost and economics. Each of these domains has sub-domains.

The study population includes two groups: practitioner architects and architectural students. Thirty architectural offices working in Saudi Arabia were selected randomly from a list of 90 offices. The selection criteria were based on the size of the office in terms of the number of architects, size and diversity of the projects, and awareness of sustainable practices. Systematic sampling was used in this case by choosing a number of architects within the same office with different job specialties. For example, architects who work as concept generation, development, specifications and quantities are site architects. Three architects were selected from each office.

On the other hand, the selection of students was based on their academic level and their awareness of sustainable/green concept in design and integrated design. Ninety students were selected from the Department of Architecture and Building Science at King Saud University.

3.3. Survey results an analysis

The conceptual framework is based on a new integrated paradigm that considers all system's elements and sub-elements in the early phases of the design. Despite a wide range of positions and opinions on the subject of sustainability, there is a general agreement that the current paradigm of linear development, which disregards constraints to material or energy consumption, is unsustainable. In this model, several systems are linked in a linear process that begins with both renewable and non-renewable natural resources such as air, water, soil, mineral or biological resources. Also, exploitation and use of primary natural resources occurs to provide inputs for industrial processes (Subsystem 1). The outputs of this system become the principal inputs for two other systems.

The linear approach processing has two important outputs from each of its systems, which are at the core of many problems facing the world today: increasing amounts of hazardous and non-hazardous waste, and increasing levels of environmental impact.

The framework composition is based on redirecting the development toward sustainability. A cyclic process is adapted to response to the challenges and problems raised by linear process and offers a mechanism to overcome the problems of unsustainablity.

In this paradigm, the cyclic and adaptive architectural design process is integrated into sustainable systems and sub-systems to maximize the positive and minimize the negative impacts.

3.3.1. Sustainable system components

As shown in Table 1, seven components are adopted as the driven forces for architectural sustainable development. These include: site, energy efficiency, water efficiency, materials, indoor environmental quality, waste and pollution, and cost and economics. These categories have some sub-category systems.

3.3.2. Architectural system components

Several components are incorporated within the integrated framework to tackle sustainable components. These components included different design phases: pre-design, design, and post-design. In the pre-design phase, the program and initial analyses are crucial to be produced by root and complex techniques such as Ideological Concepts concerning needs and services, Diffuse Concepts regarding spatial organization, technical systems or details, and Compact Target Values for environmental impacts in a life cycle perspective. Several sub-phases of the design phase are related and integrated. These phases are: concept phase, deign development, building permit, system design, and detailing.

Table 1. Sustainable system components (source: Ali *et al.*, 2009)

Selected Sustainability Components	Sub-category Systems
Site	• Microclimate • Site design • Landform • Land use • On-site energy recourses • Infrastructure efficiency • Relation between the building and its immediate surroundings • Landscape design • Low-impact construction site techniques • Housing density (No. of units/area) • Transportation
Energy efficiency	• Building envelope performance • Renewable energy • Natural lighting • Energy-efficient heating/cooling • Mechanical systems • Green house gas emission • Machines/appliances
Water efficiency	• Water conservation • Innovative reduction water technologies • Water use • Water efficient landscape/external
Materials	• Local/regional materials • Renewable material • Recycle material • Resource reuse • Environmental impact of materials
Indoor environmental quality	• Occupant health and safety • Indoor air quality performance • Quality of life • Increase ventilation efficiencies • Thermal comfort • Daylight • Acoustic and noise control • Visual quality
Waste and pollution	• Waste reduction and management strategies
Cost and economic	• Site • Energy efficiency • Material and construction • Water efficiency • Waste management

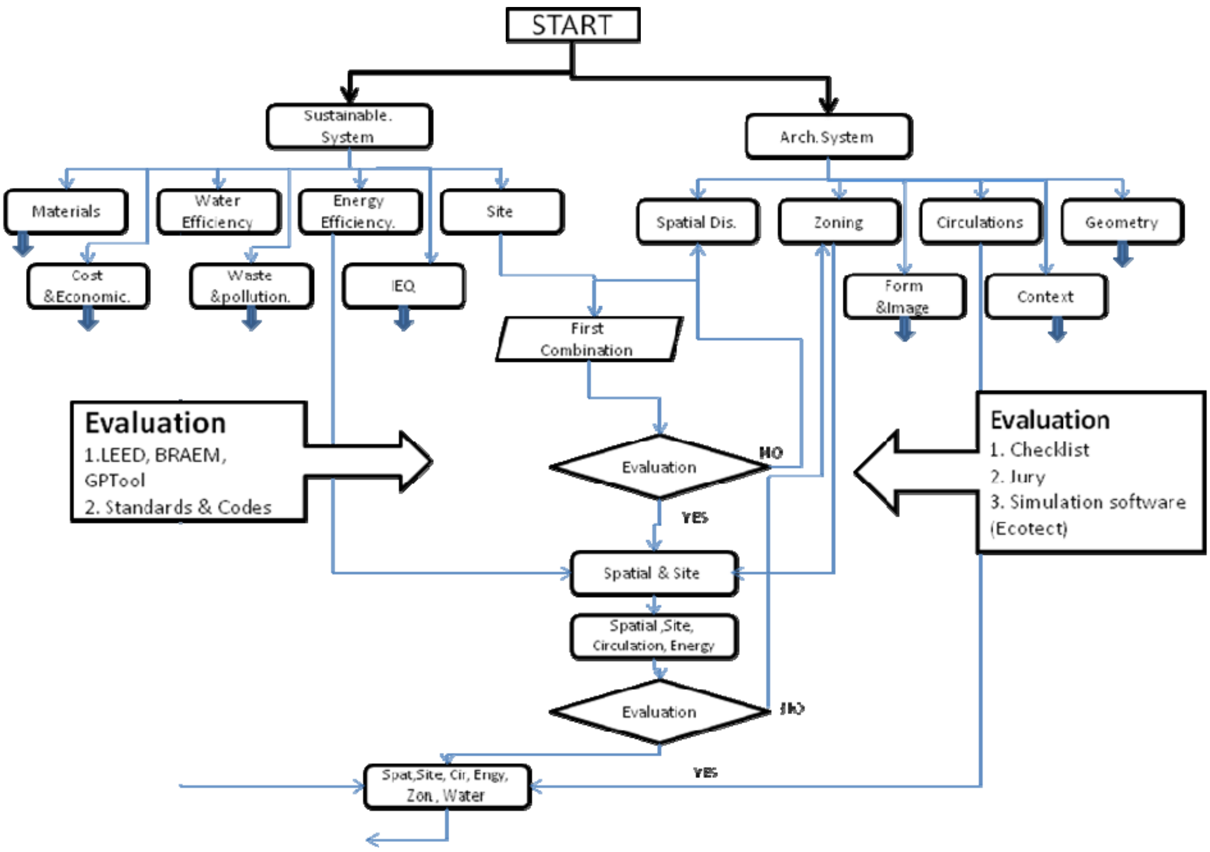


Fig. 3. Framework describes the design process of the architectural system and sustainable system with the integration of various system components (source: Author).

In the concept phase, several techniques are applied: sketches, pictures, words, and computer programs for evaluation. In this phase, which is considered as a high level of complexity, will be elaborated through ideological concepts concerning the local context relatively compact, concepts concerning needs service and function, relatively diffused concepts concerning expression and spatial organization, diffused concepts regarding technical systems, and compact concepts regarding environmental impacts.

In the development phase, the concept is open for modification according to different conditions stated in the design guidelines. Spatial organization is flexible; zoning and geometry are also open for modification to the sustainable drivers. Form and envelope designs are compatible with the basic design requirements. The building permits, which are sometimes included in this phase, have flexibility in the spatial organization regarding the technical and building regulation systems. In the system design phase, the concept concerning construction, appliances, spatial organization and expressions are closed and half open for detailing. Life cycle analysis, models for environmental impacts analysis, checklists, and simulation programs are used to evaluate the result up to this phase. Detailing phase means the declaration of the project and adjustment for new products and materials. The design phase is cyclic within its sub-phases and with the pre-design phase.

The post-design phase includes the operation and the use of the building. Post occupancy evaluation techniques are a valuable opening for expansion and new interpretations of the users and those who want to learn from the project.

3.4. Framework validation and practical analyses

Three approaches are taken to validate the model to identify its applicability including the observational studio, interviews with designers and academics, and questionnaires delivered to students and architects. The first two approaches are combined together to validate the procedure with real projects (building science research center at King Saud University). The instructors who applied the framework noticed the efficiency in implementing the procedure. The students started with defining the problem in a sustainable perspective by interacting with the design parameters (spatial distributions, zoning, circulation systems, geometry, image and form and context) and sustainable factors which included (site attributes, energy efficiency, water efficiency, indoor environmental quality, waste and pollution, and cost and economics). The students and the interviewers indicated different understandings to the meaning of the sustainability in the context of the proposed project and design process.

For further validation of the framework, numerical values were deduced from the questionnaire distributed to the students and professionals. As shown in Fig. 4, the meaning of sustainability varies between environment and the future of design practices. Some professionals reported that the sustainability means nothing for them. Both professionals and students understand sustainability as green architecture, healthy building and low impact architecture on the built environment.

Sustainable factors have different meanings and values for both professionals and students. Energy efficiency was considered a major factor in the design process. Cost and economics are considered differently between both groups; it has good value for practitioners with very low value for students. This result is expected as the architects are tackling real problems more than students. However, materials and site attributed were considered as major values for both groups as shown in Fig. 5.

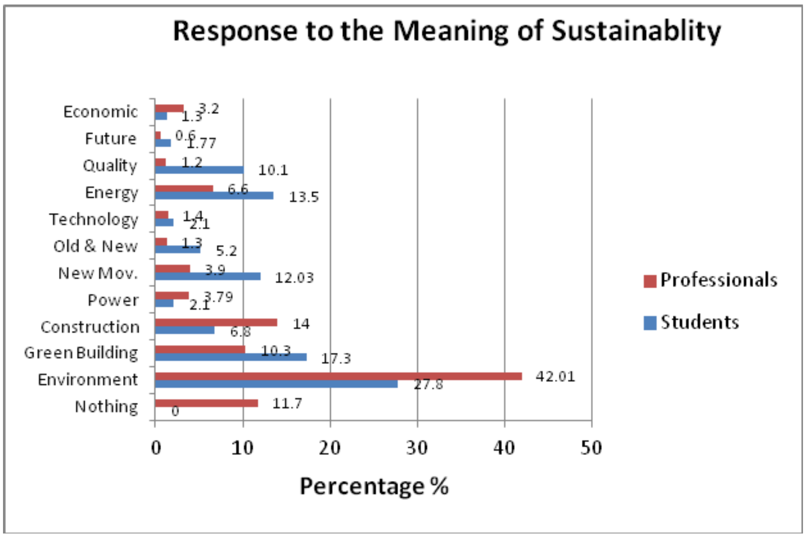
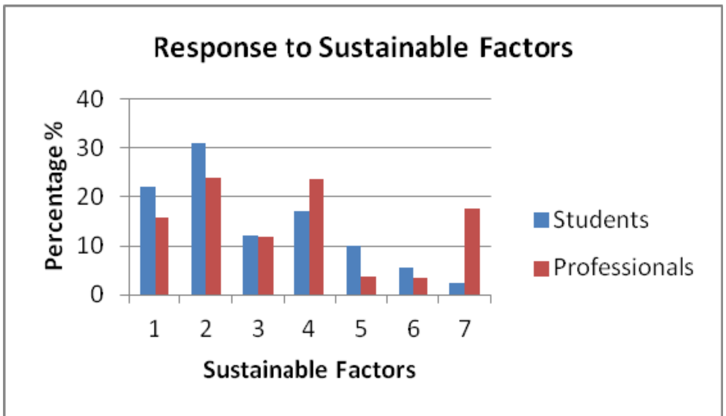


Fig. 4. Response to the meaning of sustainability between two groups (source: Author).



1. Site	5. Indoor Environment Quality
2. Energy Efficiency	6. Waste and Pollution
3. Water Efficiency	7. Cost and Economics
4. Materials	

Fig. 5. Response values to sustainable factors between two groups (source: Author).

The interactions among different sustainable factors presented in the conceptual framework and design process are presented in Table 2. The values represent the percentages of respondents with positive answers from both architects/professionals and students. Both groups have different understandings of the integration among these factors, and this represents multidimensional problems. The weight of factors varies between design phases. Energy efficiency is considered the valuable factor in both professionals and students. The second factor is the site forces in student's response, while the material is the second valuable factor in professional's response. Indoor environmental quality is considered the lowest factor affecting the design process in both the response of students and professionals.

Seven phases of the design process were presented in Table 2: program phase, concept, schematic drawing/development, technical and working drawings that included quantities and specifications, construction phase, and post occupancy phase. Another item was added (none) to indicate the exclusive sustainable parameters in the design process. Table 2 indicated significant differences among both groups. The level of significance varies and depends on sustainable factors.

There is a significant difference within each group in different design phases. This is normal because the value of each sustainable factor is different in each phase as shown in Table 2. Site considerations have great interest in program and concept phases for both students and professionals but lower interest in working drawing, construction and completion phases. These variations are different among different sustainable factors. Nevertheless, materials, waste and pollution and cost and economics factors are highly valuable in later design phases as the technical drawing and construction phases.

Figure 6 indicates the response values of site attribute and its consideration in different design phases. It is obvious that the programming phase, which includes site analysis, has a major influence. Students consider site a major factor, while professionals considered it important in the schematic design phase. The lowest interest of site factors come in after compilation phase, while some professionals did not pay any attention to site factors as a valuable indicator of sustainable practices. Equally important, building design factor has valuable attention in program, concept and schematic drawing stages. Even though, there is a significant difference between the two groups of respondents in the implementation of this factor within different stages. In the technical drawing stage, professionals highly implement building design as a sustainable factor, while students gave it less attention in this stage as shown in Fig. 7.

Table 2. Responses of students and professionals about the applicability of sustainable parameters in deferent design stages (source: Author)

Design Phase	Site Considerations		Building Design		Energy Efficiency		Water Efficiency	
	Students	Professionals	Students	Professionals	Students	Professionals	Students	Professionals
Program Stage	45.7%	33.2%	32.8%	17.7%	14.1%	9.2%	8.9%	0.7%
Concept Stage	31.2%	22.3%	41.8%	15.2%	35.1%	22.2%	16.4%	1.4%
Schematic DRW.	12.7%	32.7%	14.8%	36.2%	30.4%	34.2%	23.2%	8.4%
Tech. Drawing	4.7%	3.2%	6.2%	21.8%	11.3%	21.8%	13.6%	17.3%
Const. Stage	3.2%	3.9%	3.7%	7.2%	7.2%	6.9%	21.7%	22.8%
After completion	2.5%	0.6%	0.7%	1.9%	0.6%	3.3%	11.7%	49.4%
None	0%	4.1%	0%	0%	1.3%	2.4%	4.5%	3.1%

Design Phase	Materials		IEQ		Waste /pollution		Cost and Economics	
	Students	Professionals	Students	Professionals	Students	Professionals	Students	Professionals
Program Stage	3.1%	1.4%	2.8%	5.4%	1.6%	1.2%	2%	13.2%
Concept Stage	6.7%	5.1%	15.3%	17.3%	4.3%	3.1%	0.9%	17.4%
Schematic DRW.	9.2%	9%	34.2%	31.9%	7.3%	14.2%	6.6%	15.3%
Tech. Drawing	46.3%	41.%8	35.3%	21.6%	29.6%	34.2%	32.1%	43.2%
Const. Stage	28.5%	35.2%	4..3%	10.2%	35.4%	37.1%	21.2%	9.3%
After completion	5.3%	7.5%	7.8%	5.4%	13%	9.7%	7.1%	1.6%
None	0.9%	0%	4.6%	8.2%	8.8%	0.5%	30.1%	0%

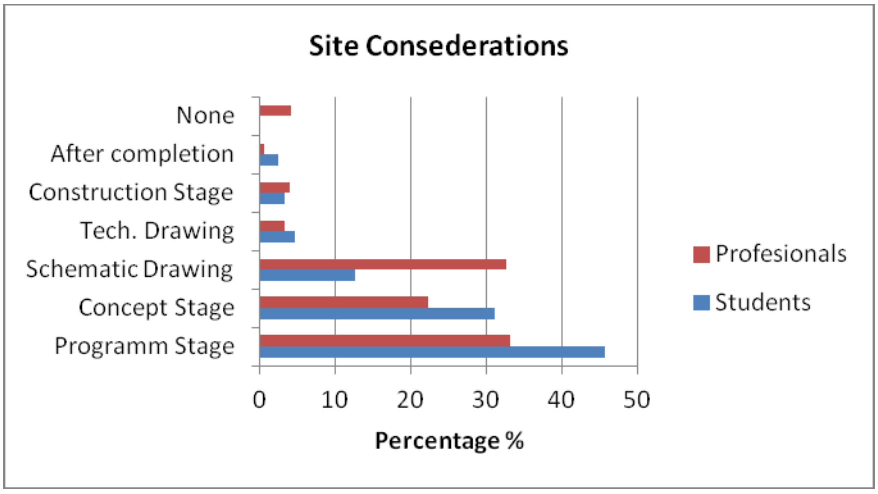


Fig. 6. Responses about site considerations in different design phases (source: Author).

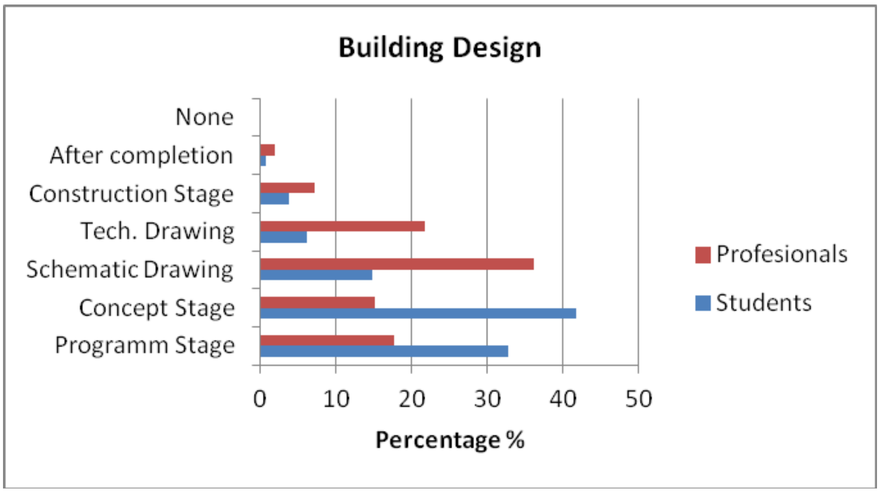


Fig. 7. Responses about building design factor in different design phases (source: Author).

Figure 8 indicates the responses to energy efficiency factor and its importance in different design stages. It is clear that the concept and schematic stages have the highest attention for this factor to students and professionals. This factor has an important value for professionals in the technical drawing stage, but less attention to students.

Building materials are considered a very important sustainable factor. It has high solicitude in technical drawing and construction stages. Very little attentions are paid to this factor in early design phases. This situation is not appropriate to validate the proposed conceptual model that is based on integrated design philosophy. This is clear in Fig. 9.

Indoor environmental quality and waste and pollution factors have less importance among all other sustainable factors. Nevertheless, their impact was clear in schematic drawings and working drawing stages. This is obvious in the responses of both students and professionals as indicated in Figs. 10 and 11 respectively. Unexpectedly, the indoor environmental quality factor has less importance in the early design phase. This might be elucidated as this factor is considered a hidden factor related to the building design factor.

On the other hand, waste and pollution has less important value than other factors. Some respondents reported that this variable is really considered in their design practices as shown in Fig. 11.

Building and construction cost is considered a major driving factor in sustainable practices. The respondents reply to this factor differently, and no extra attentions are given to this factor. It was highly presented on technical drawing stage for both students and professionals. Cost in this regards represents the life cycle cost of a building that includes initial design and construction cost, and ongoing expenses such as maintenance, energy, and repair costs (Fig. 12).

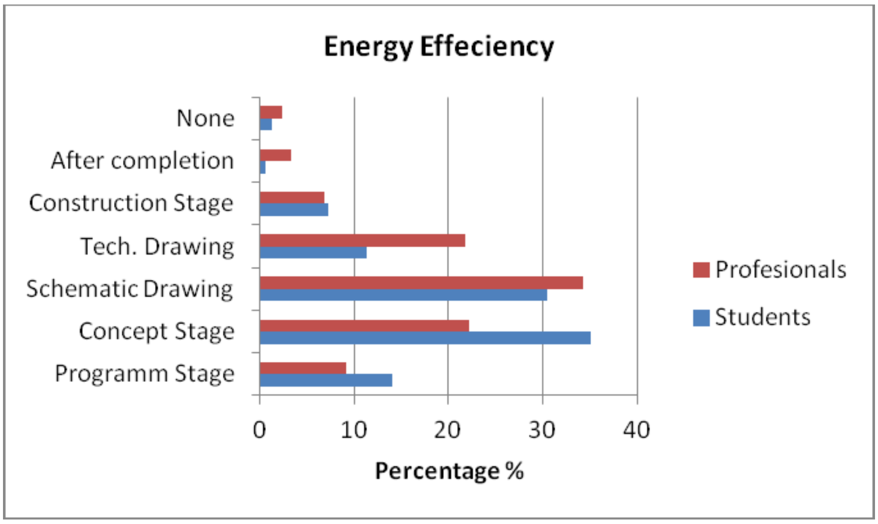


Fig. 8. Responses about energy efficiency factor in different design phases (source: Author).

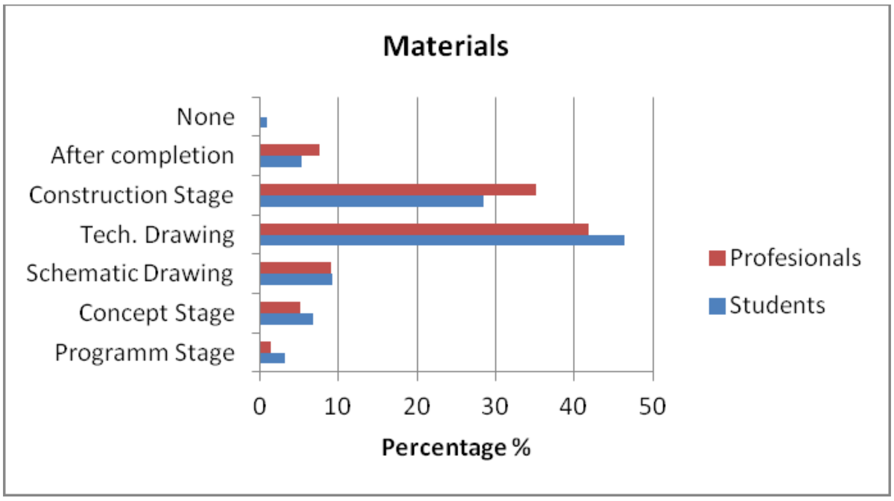


Fig. 9. Responses about building materials factor in different design phases (source: Author).

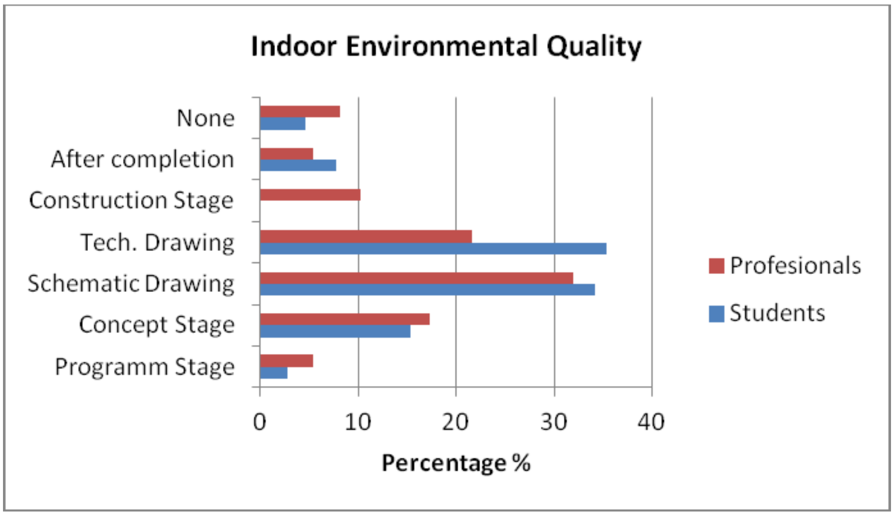


Fig. 10. Responses about indoor environmental quality factor in different design phases (source: Author).

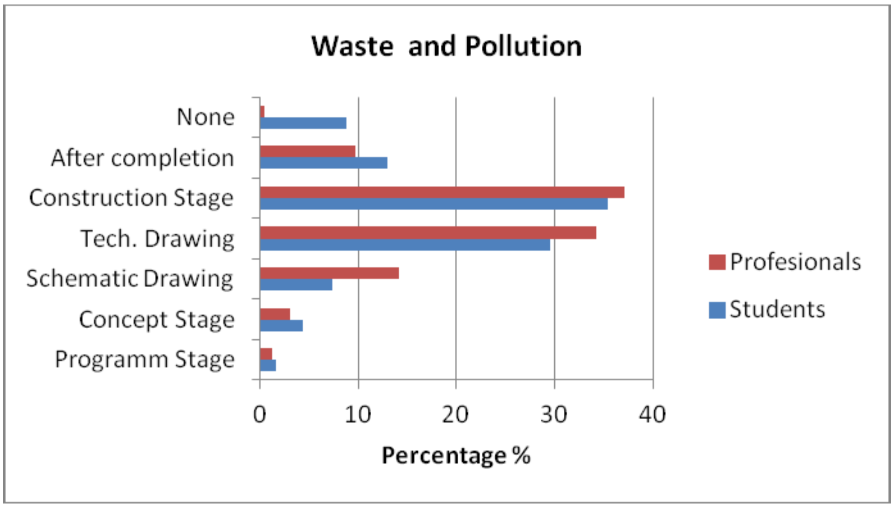


Fig. 11. Responses about waste and pollution factor in different design phases (source: Author).

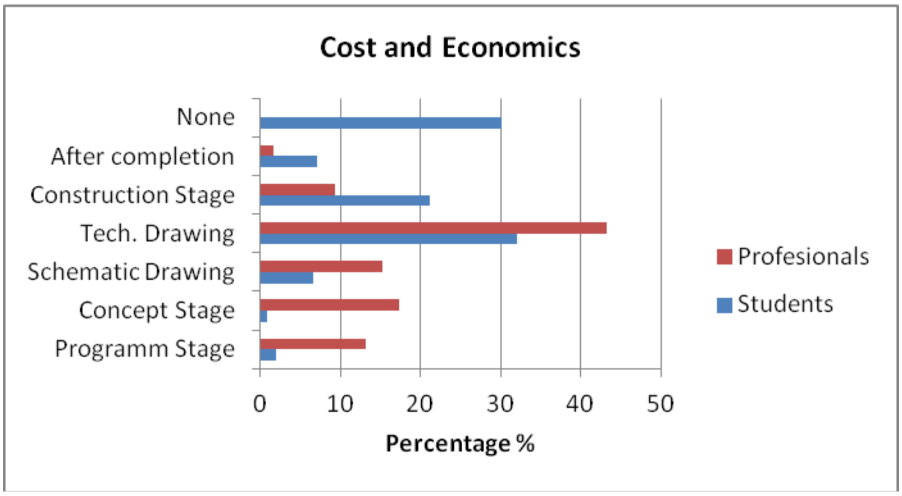


Fig. 12. Responses about cost and economics factor in different design phases (source: Author).

4. Conclusions

The principal conclusion is that sustainable practices is one of the increasing interests which has many levels and complex dimensions. In this paper, the researcher tried to provide a strategy for implementing sustainability into the architectural design process using integrated design approach taking into consideration different components of sustainable systems. The paper has stressed the need for adopting a new design process which is holistic rather than incremental system. The new approach, which is cyclic in its nature, takes into consideration a pool of ideas and intuitions of many design members including architects, planners, mechanical and electrical engineers in addition to owners, contractors and clients in the early phases of the building stages.

The proposed processes enhance the logical implication of sustainable parameters into different design processes that include different phases; pre-design, design and operation, with efficient interaction among several factors. Many iteration trials should be done to optimize the efficiency and enhance the design outcomes. This methodology shows prioritizing the idea of the integration of several design components with other sustainable factors. The efficient connection among several building systems and design items improve the implementation of sustainable/green concepts and system components into buildings. The systems management view of architecture presents a balancing design to that of integration. System thinking enhances inventive selection and connection of building system components into sustainable perspective. System methodology helps to bridge the gap among many actors of design, construction and operation of buildings. This process is based on soft system methodology (SSM) that takes into account satisfying the user of the building as much as possible. The first step in this process reasserts the requirements of the client through establishing a competent program that is systematically evaluated based on sustainable requirements. Exploring sustainable development requirement is done in the first and second steps. Other steps consider concept formations, evaluation with the real world to optimize the outcomes that satisfy the objectives of the main design. To acquire this optimization, several trials and iterations should be done.

Evaluation through process formation should be done through several techniques, such as applying rating and benchmarking systems (for example, applying LEED, GpTool, BRAEM or any other rating system). This should be considered early during idea generation. Other procedures include evaluation software such as Energy Plus, Ecotect, Derob, and others. These tools are essential to give initial an understanding of the applicability of the system. The use of checklists is crucial for the evaluation of the stage outcome and the final results outcomes.

One major conclusion extracted from this research is that there is a strong orientation in the academic realm and among design studios in Saudi universities toward sustainable application as the backbone of design. The students, and professors as well, consider sustainability a need rather than a design movement. They are both aware of the climate change and the impact of buildings on the global sphere. They believed that there is an urgent need toward restructuring design courses.

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نموذج تكاملي لتطبيق الاستدامة في مراحل التصميم المعماري

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الكلمات المفتاحية: العمارة المستدامة، منهجية الأنظمة اللينة، مراحل التصميم، التصميم التكاملي.

ملخص البحث. يهدف هذا البحث إلى تطوير نموذج تكاملي لتطبيق الاستدامة في مراحل التصميم المعماري، حيث إنه تم استخدام المنهج الكمي والنوعي لتطوير النموذج، واعتمد بشكل رئيس على منهجية الأنظمة اللينة مع مراحلها السبعة المتداخلة، والتي كان لها دور في فهم المفاصل الحرجة المتداخلة بين النظام ومبادئ الاستدامة واستقصائها. تم التأكد من مصداقية النظام بالاعتماد على أساليب بحثية مثل المشاهدة والتجربة، إضافة إلى المقابلات العلمية مع أساتذة العمارة والمصممين. كما تم استخدام الاستبانة كوسيلة قياس لإمكانية تطبيق مبادئ الاستدامة في مراحل التصميم المعماري.

أثبتت النتائج الرئيسة للبحث أن تطبيقات الاستدامة في اهتمام مستمر وعلى عدة مستويات في العمل المعماري. كما وأن هذا النظام المقترح والذي بطبيعته دوري يأخذ بعين الاعتبار مجموعة من العناصر والمبادئ للاستدامة لتطبيقها في عدة محاور تصميمية. إضافة لذلك هنالك توجه كبير في النطاق الأكاديمي وفي مراسم التصميم المعماري لتبني الاستدامة كعنصر أساسي في التصميم المعماري في الجامعات السعودية، .إضافة إلى أن الطلبة وأساتذة العمارة على حد سواء يعتبرون الاستدامة حاجة أساسية في التصميم المعماري ولا يعتبرونها حركة معمارية.