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THE EFFECT OF SHELL AND ACTIVE SYSTEMS ON THE PERFORMANCE INTEGRATION OF SUSTAINABLE AIRPORT BUILDINGS

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Abstract
Structural systems are a source of architectural creativity throughout history. They are also a motive for the development of materials, construction methods, and digital processors, which provided the possibilities for designers to create distinctive architectural products. The present study tackles the influence of the technology of shell and active construction systems on contemporary architectural production in general and airport buildings in particular in terms of performance and achieving sustainability.

The Significance of the Present Study
It is due to the need to shed light on the methods of shell and active construction, identify its features and the stages of its development in light of the different architectural currents, and to test the efficiency of its functional, formal, environmental, and economic performance, with the aim of adapting this experience so that its advantages can be taken and applied in developing performance of the facilities in Iraq so that they achieve the standards of functional and formal performance and environmental sustainability and become more capable of responding to all developments and changes.

The Objectives
The present study aims to clarify the concepts related to the two types of structural systems, and how to achieve performance integration, analyze the relationship between these systems and architectural production, and build a theoretical framework that combines the main and sub-paragraphs and apply them to a number of projects represented in sustainable global airport buildings that are distinguished in the field of structural systems technology within its temporal and spatial context.

The Results; The shell and active structures in airport buildings achieved their goal, which is integrated performance by achieving functional, environmental, structural, economic and expressive performance alike at high rates. By achieving this percentage, it can be considered

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that it achieves the principle of sustainability through its integration with other design systems in airport buildings.

Keywords: Shell facilities, suspended facilities, integrated performance, sustainable airports, integrated airports

Introduction

The building and construction sector has witnessed many developments in construction materials and systems, which reflect the image of civilized development, especially in the field of sustainable architecture as a need or necessity to confront environmental problems. The applications of modern structural methods have appeared in a limited way in the Iraqi architecture, which negatively affected the flexibility of architecture towards the functional and formal changes resulting from scientific and technical progress. Architects have realized, to varying degrees, the importance of structural knowledge, especially in light of the rapid development in construction techniques, and the importance of familiarity with structural knowledge. It requires an ability to understand the development, the mechanism of work of construction systems, their requirements, the extent of their influence on the architectural solution, and the proper architectural use of them. The problem appeared in "weak local knowledge related to the importance of performance integration of both shell and active types of construction systems and the possibility of achieving sustainability through them in airport buildings." Technology has always been associated with globalization, but modern trends confirm the possibility of technology to achieve the characteristic of place and locality. The present study assumes that the technology of shell and active systems has the ability to achieve creativity and integration with sustainable local architectural production." The descriptive and analytical approach is adopted by extracting the criteria adopted in Analyzing the integrated performance and sustainability of buildings in general and airport buildings in particular, determining the hierarchy of their effective indicators according to their importance, reviewing the conditions of the shell and active construction systems in the selected models for international and Arab projects and diagnosing the extent to which they achieve these standards in an attempt to come up with different standards and present them in the form of evaluation results to enhance the local experience, enrich knowledge, and diversify the local production with non-traditional types of construction systems.

Integrated performance; The concept of integration refers to the harmonious relationship between the parts to form a single whole. In the field of architecture, it is the process of integration between the systems and parts through the overlapping and participation of the functions of the systems with each other to reach the positive effect, increase efficiency, shorten time in design and construction, and rationalize the materials used in each part of the building (Ali and Armstrong, 2010). Rush's viewpoints tackled the theory and definition of integration through the possibility of dividing the building into four main systems, including the structural system, the internal spaces, the external cover, and the services. By placing each group on the corner of a three-dimensional pyramid, this geometric expansion of this idea generates a dual, triple and quadruple union according to the five levels of integration, separate, contiguous, connected, intertwined, and unified (Shaheen, 2013). The goals of integration are to reduce

time and materials And the space used in the building and the increase in the events that can occur inside it, which results in balance. Among the advantages of integration are the reduction of time and effort, the reduction of space, energy and cost, the increase in building performance, and the enhancement of teamwork among staff. (Bachman) identifies three patterns for the integration of buildings, namely: physical integration in the method of participation and coordination between systems and structural components in space. Visual integration occurs in the method of participation between structural components in order to collect and create the form of the dominant forces, where the integration of performance is in the method of participation and coordination between systems and structural components of function. The main goal of designing integrated building systems is to eliminate redundant resources, which are generally obtained through strategic combinations of distributed systems in concert with common standards of space, form, or function (Bachman, 2003).

The economic effect of integration is in covering wide range with relatively low costs and a high speed of implementation through pre-manufacturing of the parts of the outer shell. As for functional efficiency and high flexibility, they are achieved when the outer shell includes all the activities and remains constant when there is a need for any change inside to keep pace with the expansion of And the development of operational systems for buildings, and the adoption of the tectonic system as a structural and expressive language to express the building environment and express design ideas at the level of the part and the level of the whole. Software has a role in the integration of design and physical, visual and functional compatibility between building systems through the benefits included in each stage such as cooperation between the work team, data sharing, time and cost scheduling, accuracy of information, reduction of clashes, accurate recording of building performance, optimal use of management and maintenance guarantee. It consists of three phases, including the BIM planning and design phase to develop design, coordination, cooperation, data sharing, time and cost scheduling, flow analysis, and identification of space and service facilities requirements, the construction phase (BAM) for construction planning, material procurement, cost estimation, reduction of miscommunication, accuracy of information, reduction of clashes, and quality management, and operation stage BOOM Accurate recording of the building's origin, management of use, management of warranty and maintenance, and provision of a model continuous management of the building.

Modern roofing methods for buildings with wide ranges; There are many types of roofing methods for wide ranges, but the focus will be on only two types of structural systems, which are shell and active, because of their distinguished aesthetic and environmental influence, speed of construction implementation in an economical manner, and their rare local use through defining each type and stating Their types, building materials used in them, their advantages and disadvantages, and the functions that are compatible with them.

A. Thin Surface Structure Systems with effective surface

It is a thin shell of reinforced concrete in most cases. It is formed in such a way that it acquires a self-shearing moment. The shell structures are among the best fixed concrete structures,

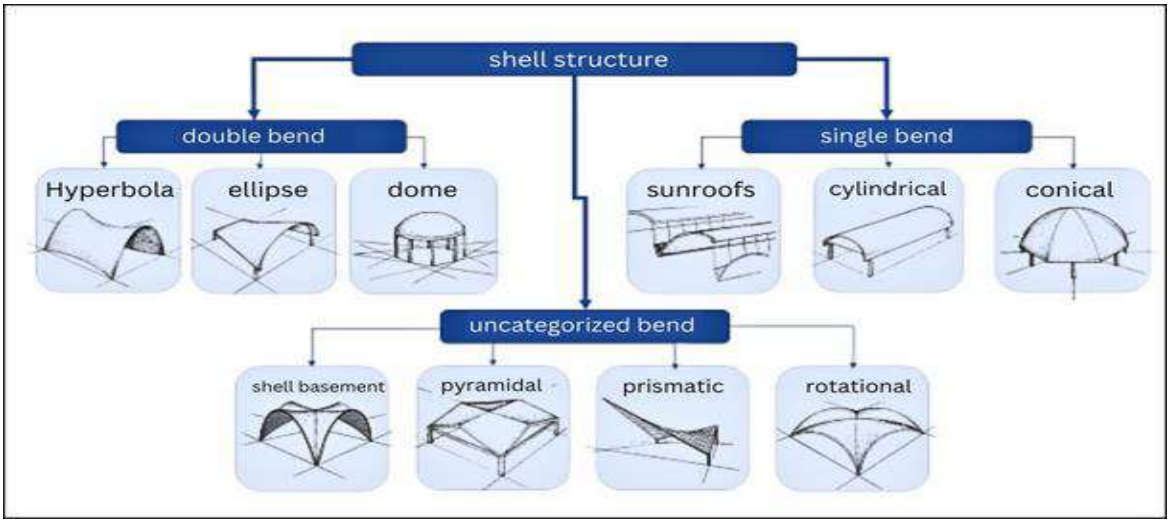
which are light in weight and more expressive of the structure, whether from the inside or the outside (Sacco, 1999). The emergence of materials such as Concrete reinforced with iron, fibers, composite materials, and reinforced polymers led to enhance the field of crustal sheathing technology. With the development of prefabrication and the need to recycle materials, the potential for shell systems applications has increased further, in addition to its mechanical advantages such as durability, stability, high strength, and its very high aesthetic value in various architectural designs. Despite these advantages and potential applications, many practicing engineers and architects are not fully aware of the aspects of their behavior and design (Farshad, 1992). These structural systems are suitable for specific and non-traditional purposes and are characterized by dazzling implementation and high resistance, as loads and stresses are distributed in the space in the three directions and not In one direction. It is required that the thickness of the surface be very small in relation to the other dimensions irrigated for the roof. It is not used to carry anything except its own weight, wind loads, and light live loads for maintenance only. This type is suitable for theaters, airports, and conference halls, as they are open and often not internally divided (Sherief, 2013).

Characteristics of shell structures; Shell construction systems, with the variety of classifications, have achieved architectural success in projects with large ranges and different types of spaces in order to achieve the formative relationships of space such as extension, continuity, and containment. They are light in weight and economical in the materials used. Their structure is flexible and solid in its architectural formations, which gives freedom in designing the shapes of the facilities, whether in the horizontal or vertical section. Resistance to powers through its outer shell is another characteristic of these structures. They also have the ability to bear unbalanced loads. If damage occurs at some point, no collapse occurs due to the powers stored inside. There is a considerable ease of making large openings for natural lighting in the shell surface structure. They are resistant to fire, rain water, and temperature change.

Disadvantages of shell structures; They require high skill in design and construction. There are large and difficult computational factors required by the design. Shell concrete surfaces are difficult to treat for the purpose of architectural effect in the structure. The shell shape can interfere with the basic functions of the structure, as it is difficult to change the shape of the shell.

Shell structures can be classified into several types:

1. Single-curvature shell structures; Their surface consists of only one curve and has several shapes, such as a cylinder and a cone.
2. For double-bending shell structures; These shell ceilings consist of two curved surfaces and have different shapes such as domes, hyperbolas, and ellipses.
3. Unclassified shell structures with curvature; They are double surfaces resulting from the movement of a straight line on two vertical curves located in two parallel lines that differ in shape and height.



B. Structural systems with an effective vector called Active Structural Systems

Active structures are structural facilities that rely on tensile forces to form the structural structure and achieve stability for the structure. Cable and tent structures have similar covering behavior in terms of the powers applied to them during the construction process. This type of facility began to be used since ancient times and witnessed a clear development on the structural, functional, and aesthetic levels. Active structural systems at the present time are considered the most widely used structural systems in covering wide ranges in buildings, whether they are main or joint with other structural structures, such as their use in glass facades or entrance awnings. The active structural systems attracted the attention of architects, especially in the second half of the twentieth century (Sebestyen, 2003). The tensioned active structural systems consist of the main load-bearing element, the peripheral support, the vertical support elements, and the covering layers.

Characteristics of active structures; Cable structures are characterized by several advantages due to their various shapes and flexibility, which made them spread widely. Among these advantages are (Sebestyen, 2003):

They cover wide ranges. They give the least possible space for the vertical elements that support the building. Thus, it is possible to take advantage of the total area of the floors. There is a possibility of modifying and changing the divisions of the internal space even after the completion of the construction of the building. It is possible to reach various and free formations in the facades because they are not linked to the structural elements. Their weight is light when compared to the other structural systems. They have the ability to withstand the external powers applied to them, such as wind powers and others.

Defects of active installations; Despite the high flexibility of the cable systems, some defects are noticed, including their lack of stability in all circumstances and the difficulty of stopping wind vibrations. Their shape changes with the change of the loads placed on it, which makes its use accurate in terms of choosing the appropriate function for the structure.

These facilities are divided into several sections:

1. Cable Or Tension System

2. Membranes System, which is divided into:
A. Tent System
B. Inflated System

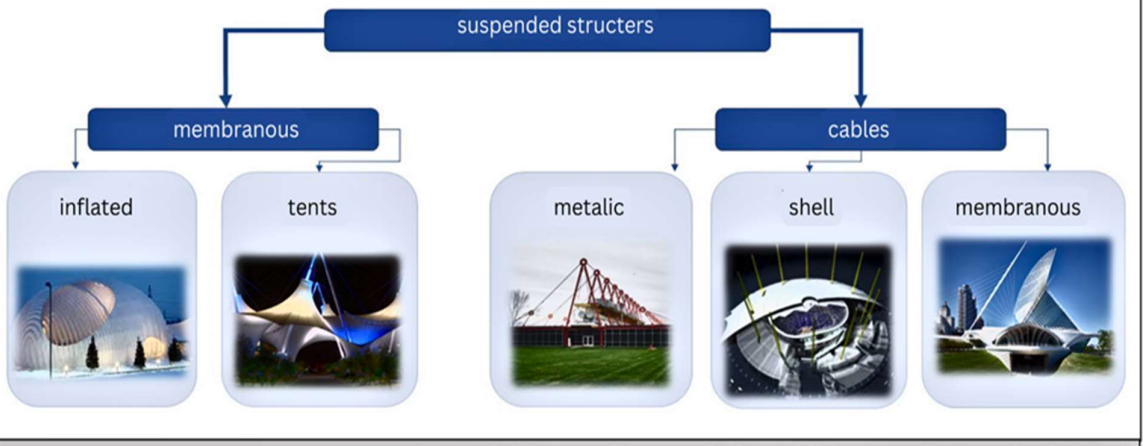


Figure (2) Types of Suspended Establishments (Researcher's Work)

Why airports?

A. The importance of airports and their role in the city

Airports are some of the most important and complex buildings of the past 100 years, with no competition in function, size, and form. The history of the airport is the history of the twentieth century itself. It tells the story of modernity represented in space, speed, light, and flight (Blow, 1991). The distinguished architectural form of airports is a reflection of successful functional solutions and human architectural values on a human scale that reflect and serve the prevailing values and specificities in the region in a way that achieves the principle of organic integration with the environment. In order to achieve the principle of organic integration with the environment. The result is buildings with high functional performance and expressive forms that serve the desired goal, which is to provide a convenient, comfortable, and efficient place for air travelers. The airport itself is among the newly developed architecture and the result of the industrial revolution. Research is continuing to reach a philosophy and theory that frame and draw the features of this type of architecture. Sustainable passenger stations can be defined as those in which sustainability principles are applied with basic considerations of design patterns, as well as movement and flexibility considerations, within an approach that integrates environmental, social, and economic aspects.

Airport terminal construction systems

The vast majority of airport buildings depends on deep constructional systems due to the complexity of operational and kinetic systems inside the buildings of travelers and the high flexibility of many traveling activities to absorb large numbers of travelers at the same time make the use of a giant construction system with wide scopes one of the most important planning and design requirements for contemporary airport buildings. Therefore, the design

factors for the construction systems that characterize the current generation of airport buildings are:

Design for flexibility and scalability

1. Ease of use for travelers
2. Safety and security through design, control, and electronic means
3. An environmentally friendly approach in the selection of materials and means of providing construction services
4. Organizing travelers and gathers them into separate groups ready for flights

These functions are related to each other and exchange roles among themselves (Edwards, 2005). The distinctive and unique structural design of the terminal building plays a major role in the success of the airport project as a whole. Improvements are made to the elements of the structural system, which must be economical and implemented in a responsive manner to meet the expected requirements to achieve the objectives of the project (Englot, 1998).

There are other factors affecting the selection of construction systems in airport buildings, namely the economic influence of airports: traffic intensity, social and cultural influence, expressive and aesthetic influence, technical influence, and the effect of external and internal powers on the structural system (Arslan and Sorguc, 2003).

Integration of design building systems and their relationship to the structural system in airport buildings

Building integration in general is the orderly distribution of the HVAC system, structural system, lighting, outer envelope and other assemblies of the facility for the purpose of reducing energy, material and time consumption, to satisfy detailed performance specifications (Xing, 2001). Light shell and suspended structures are being developed to allow future expansion of airport terminal facilities by designing structural support systems to handle potential additional loads. Depending on the architect's design goal, the structural components can be left exposed as part of the aesthetic quality of the architecture (Brown, 2010). There are several examples of performance integration between two main systems and their sub-systems in terms of performance. To limit the scope of the present study, the structural system and its relationship to other systems is discussed.

A. Integration of the structural system with the internal space system; Human comfort in the internal space is achieved through the integration of the structural system with the system of internal space and the availability of shell and active facilities. There is a possibility of defining the space or creating units or expressing movement and the creation of ceiling openings to enter sunlight and remove smoke. The systems that can be used for construction are suitable for each climate to improve the quality of the internal environment.

B. Integration of the structural system with the outer envelope system; Choosing the structural systems for the building's outer envelopes is one of the methods used to achieve the distinctive architectural form and high functional performance for the airport building. This is provided by shell and active facilities that are characterized by flexibility and speed of implementation.

C. Integration of the structural system with the mechanical system; The integration of the structural and mechanical systems as a technological concept can be achieved through balance and harmony between the functions of the building and the mechanical systems inside it. This is what shell and active facilities can achieve. HVAC air conditioning systems and other technical services are integrated with it. Natural and artificial light may become a decisive factor in the design. Lighting elements are integrated into the structural system through overlapping and supplying service pipes within the system.

Functional, structural, expressive, environmental, and economic performance integration analysis of shell and active systems in airport buildings

Integrated airport buildings have a very high level of connection between form and structural system. This connection is necessary to achieve performance goals, which are as follows:

A. Functional performance; It is possible to achieve the integration of functional and structural shell and active systems in airports through a balance between the functions of the building and the different systems and matching the goal to obtain a comfortable and productive internal environment and save time and energy through design and facilities and reduce procedures and ease of access.

B. Structural Performance; It is a very essential aspect of the overall performance of the building as the primary objective of the building design is to provide the safety of passengers and property. Structural shell and active systems for airport buildings are large and complex structures that create a dynamic architectural form, simulate the aerodynamic shapes of aircraft, and sometimes provide an integrated flexible space for events in the airport building.

C. Expressive Performance; The symbolic expressive function represents the specialty of the airport building and could be perceived as a means of expression and presentation of meanings and ideas invented by the engineer or designer through the introduction of theoretical functional concepts in the models of airport buildings. The structural shell and active systems played a major role in creating the architectural form that carries its own expression as a result of the cultural background, which is mixed with special values and meanings that have a local specialty and are compatible with the zeitgeist.

D. Environmental Performance; Evaluating the environmental performance of airports revolves around two important areas, including human comfort and environmental performance. The facility and light are both indispensable and interdependent elements of architecture. The shell and active installations may control the locations of light entry into the building, its quantity and quality, and the need for daylight that inevitably determines the structural shape and details. The influence of the green physical environment of the airport is strong on the psychological responses of visitors, emotional responses, and their behaviors.

E. Economic performance; The shell and active structures reduce costs by reducing the materials used due to their small thickness, beside the possibility of recycling the raw materials used in their manufacture, in addition to saving energy by introducing daylight and natural ventilation.

The theoretical framework indicators

A measuring ruler can be extracted from the theoretical framework to evaluate the integration in building systems with the shell or active system in airport buildings, in addition to evaluating performance by coming up with several measurable performance standards, in an attempt to make what is not quantitative a quantitative evaluation indicator that can be measured, and to reach quantitative results. Through statistical methods. A questionnaire based on specific impressions of the users of those airports is to be developed by the airport staff to obtain some common results when analyzing and evaluating and indicating the extent of their effectiveness and the amount of what has been achieved in each respondent while maintaining their commitment to local solutions.

Description of the selected projects

A. Changi Jewel Airport in Singapore; It is one of the most beautiful airports in the world. It was designed by Safadie Architects. It won the best airport in the world for six consecutive years. The idea of designing the station has been design to really embody nature through a wide garden covered with a glass shell ring dome that allows direct light to pass through it. This station connects the four buildings of the airport together with a lively atmosphere and various activities. It was designed to simulate nature and embody the identity of Singapore in terms of the massive urban development in the country.

B. Hamad International Airport in Doha / Qatar; It is considered the largest airport in the region and won the first place as the best airport in the world for 2022. It overlooks the Arabian Gulf. It was designed by Hok Studio. The sea waves were embodied in its shell structural system in the roof of the building with the introduction of Sufficient amount of light through the ceiling openings to rationalize energy consumption and better guide the occupants in the building.

C. New Beijing Daxing Airport / China; The new airport, designed by architect Zuha Hadid, is the largest single building in the world. It includes one terminal and four runways. The airport obtained the LEED platinum certificate in sustainable development. The design of the airport is based on the principle of traditional Chinese architecture in connecting the different spaces in one common courtyard, which reduces the time of the traveler to reach the gates and helps in reducing the carbon footprint by not using internal trains. It depends on the shell roof to provide Energy, introduce light through manipulators of various

shapes and sizes, and provide an internal area that is free of columns to facilitate the guidance of passengers.

D. New Istanbul International Airport / Turkey; It is considered the largest airport in the world and the winner of the international LEED gold award in sustainable green buildings. It was designed by Nordic and Grimshow Architects. It is a modern and highly efficient airport. Its active construction system embodies the cultural and artistic influences of Istanbul, such as the huge recurring domes that create an open space and clear sight lines, in addition to the introduction of natural light through the glass domes in the ceiling.

E. Incheon International Airport in Seoul / South Korea; Incheon Airport is one of the largest airports in South Korea. It is classified as the best and busiest transit airport in the world. It was designed by architect Gensler and implemented by Hyundai E&C. The design of the station embodies the legendary phoenix, which symbolizes Movement and balance in Korea. The shell roof of the glass windows covers the station, and it allows light to penetrate and improve the internal environment by using natural plants and improving energy efficiency through solar cells integrated into the structural system.

F. Marrakesh Menara International Airport / Morocco; It is considered one of the most beautiful airports in the world and the best in the continent of Africa. It is designed by the Moroccan architect Abdulhilu. The last station is considered a jewel in the Moroccan style due to the geometric patterns, decorations, and glass ceilings in the form of a shell dome, which gives the airport a welcoming And optimistic environment. The dome is made of pyramids, which are photovoltaic units that help in generating energy, which gives the airport the characteristic of sustainability, so the building has obtained the ISO environmental quality certificate. The active system also worked to support the ceiling and to obtain large scopes and wide areas that are free of columns. Therefore, the airport is an example of the successful marriage between traditional Islamic architecture and modern technologies in architecture.

Indicators of the theoretical framework

Table (1) Applying main and sub-paragraphs of integration in the shell and active facilities of sustainable airport buildings, and evaluating and measuring their variables

Main paragraphs	Sub-paragraphs	Possible values	Codification	Selected projects						Total values	Percentages
				A	B	C	D	E	F		
Functional integration of shell and active structures	Functional performance	Availability of safety requirements	Z-1	**4**	**5**	**5**	**5**	**4**	**4**	27	90%
		Providing a flexible space for events and the possibility of expansion and internal division	Z-2	**5**	**4**	**5**	**5**	**4**	**4**	27	90%
	Environmental performance	**Conserving energy and enhancing human spatial experience**	Z-3	**5**	**4**	**5**	**5**	**4**	**5**	28	93%
		Air purification and the possibility of indoor cultivation due to the availability of natural light	Z-4	**5**	**3**	**5**	**4**	**5**	**4**	26	87%
	Economic performance	**Reducing costs by reducing used materials and the possibility of recycling them**	Z-5	**5**	**4**	**3**	**5**	**4**	**4**	25	83%
		Saving energy for the possibility of entering daylight and natural ventilation	Z-6	**5**	**5**	**5**	**5**	**5**	**4**	29	97%
	Constructional performance	**Stability and constancy, enhancing the safety of travelers and property, and resisting weather conditions, fire, and earthquakes**	Z-7	**4**	**5**	**5**	**3**	**5**	**4**	26	87%

		Ease of disassembly, installation, expansion or shrinkage of spaces	Z-8	**3**	**4**	**2**	**5**	**4**	**3**	21	70%
	Expressive performance	**Express local architectural symbols and values and the community's cultural heritage**	Z-9	**3**	**4**	**4**	**5**	**5**	**5**	26	87%
		Expressing the zeitgeist through materials and construction methods	Z-10	**5**	**5**	**5**	**4**	**4**	**5**	28	93%
	Evaluation ratio for the main paragraph Z for each project			**88 %**	**86 %**	**88 %**	**92 %**	**88 %**	**84 %**		

The results of the application of the main paragraph of performance integration in sustainable airport buildings indicate the following:

First; Functional performance; The results of the application of this paragraph show the similarity of the results in achieving functional performance by reaching the desired goal of obtaining a comfortable and productive environment by 90%. Functional performance was achieved in saving time and energy through design through integrated design technologies, on which most modern designs in sustainable airports relied. The results also show high superiority of the facilities in reducing customs procedures, ease of access, openness, and wide spaces, in addition to defining the way, providing a flexible space for events and the possibility of expansion and internal division through the construction systems of those stations.

Second; Environmental Performance; The results of the application show that the paragraph of environmental performance achieved a high percentage of (93%) in most of the selected projects in terms of the quality of environmental services, energy conservation, the enhancement of human spatial experience, the quality of the internal environment, and compliance with the concepts of sustainable green architecture. It also obtained (87%) in the possibility of air purification by indoor cultivation due to the availability of natural light.

Third; Economic Performance; The results of the paragraph economic performance also show a clear disparity through studying the appropriateness of the costs spent on construction and the strategy that was developed by the beneficiary. The result is (83%). Most projects required special designs and implementation methods. They were not subject to pre-standard manufacturing. They also require qualified and specialized manpower in this field. As for the site and investment, the shell and active construction systems played their role in achieving the quantitative and qualitative benefit of the project by (97%) for all the selected projects by providing energy for the possibility of introducing daylight and natural ventilation.

Fourth; Structural performance; The paragraph of structural performance achieved (87%) for the physical safety of the building, stability, enhancing the safety of travelers and property, and resistance to weather conditions, fire, and earthquakes. The result is (70%) for the efficiency and effectiveness of the structural elements of the shell and active systems and the ease of dismantling, installation and expansion Or reduction of space.

Fifth; Expressive performance; All samples could achieve the expressive performance paragraph by (87%) through matching the goal of building design and the embodiment of the shell and active structures of the architectural idea in different forms of their assembly and through realizing the internal and external form through the elements of those facilities, in addition to expressing Local architectural symbols and values and the cultural heritage of the community. The result is (93%) in expressing the zeitgeist through materials and methods of construction.

Through the evaluation ratio of the main item Z for each project, most projects were able to achieve very good rates in achieving integrated performance.

Conclusions

1. The integration process in design and implementation is an approach to integrating people, systems, business facilities, and practices in a process that collaboratively harnesses the talents and visions of all participants to improve project results, increase benefit to the developer, reduce waste, and maximize efficiency through the stages of design, manufacturing, construction, operation, and even maintenance. All sustainable projects within the core aspects of architecture design have the potential to intelligently conserve energy and enhance the human spatial experience.

2. Structures with long ranges, including shell and active structures, are the most appropriate in terms of functional flexibility by achieving open and wide spaces to meet functional needs, ease and smooth movement, and the possibility of dividing them into multiple shapes and sizes without being restricted to certain dimensions. Most of the research samples with shell and active systems have achieved patterns of integration even if there is a discrepancy in some samples due to differences in integration methods between building systems. Integration in airport planning and design is supported by certain programs used to express the airport environment and achieve economic and functional efficiency, flexibility, flow analysis, and identification of service requirements, which facilitated the design process to the extreme.

3. The shell and active structures in airport buildings have achieved their goal, which is the integrated performance by achieving functional, environmental, structural, economic, and expressive performance alike at high rates. By achieving this percentage, it can be considered that it achieves the principle of sustainability through its integration with other design systems in airport buildings. It also has a significant influence on the sustainability of airport buildings due to the availability of low-tech solutions, distinguished functional operation, and improving the quality of the internal environment by saving energy and resources. In this way, it can be considered that the shell and active structures meet the requirements of sustainability in buildings through the fulfillment of the functional and kinetic requirements, the requirements

of security and safety, the safety of use, sustainable environmental design, and the achievement of the desired economic efficiency from the design.

4. The results proved the validity of the hypothesis, considering that the shell and active structures achieve integrated performance in varying proportions and according to the nature of the material used in the construction.

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