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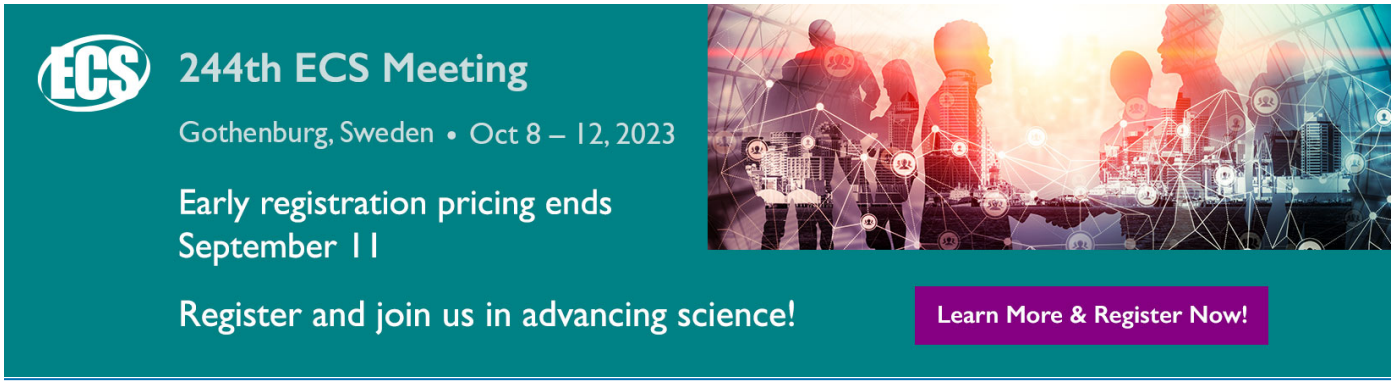

Risks of Innovation in the Architectural Design Process in Egypt: An Investigative Study

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Abstract. Achieving sustainability in construction projects is becoming an increasing priority worldwide. Being one of the crucial phases of the construction process, the design process plays a major role in achieving the goals of sustainability. Adopting innovative design solutions is a promising way of enhancing the sustainable performance of buildings. However, the implementation of innovative solutions is risky and needs to be managed carefully to avoid failure. Due to the increasing number of construction projects being developed in Egypt and because of the need to achieve the Sustainable Development Strategy (SDS) 2030, adopting innovative solutions became an essence. Accordingly, this research aims to investigate the risks associated with innovative solutions during the design process. In order to achieve this aim, a research methodology consisted of literature review and case studies was designed to achieve three objectives. First, to build a comprehensive background about the research topic including the concepts of sustainability, innovation and innovation risks, and the design process. Second, depict the relationship between innovation risks, the architectural innovation aspects, architectural design process and sustainability aspects. Final, present and analyze three case studies to explore the innovation management strategies adopted to overcome the risks associated with the adopted innovation solution.

Keywords: Innovation, Risks, Sustainability, Architectural Design Process, Egypt.

1. Introduction

Egypt, as a developing country, faces social, economic, and environmental challenges, and meeting the goals of the country's Sustainable Development Strategy (SDS) by 2030 is critical. The successful implementation of the strategy is essential for addressing crucial issues such as poverty, inequality, and resource depletion [1&2]. In the design and construction industries, there is an increasing need and calls for achieving sustainability. This is duo to the fact that buildings are among the largest consumers of energy and resources. Buildings are responsible for 39% of global carbon emissions, 50% of global material use, and 73% of global electricity consumption [3]. Therefore, there is a need to adopt innovative approaches that enable the design team and construction professionals to achieve the client requirements in a sustainable manner. Egypt is one of many countries that developed building sustainability rating systems, frameworks, codes, and regulations to move towards a sustainable built [1]. However, many challenges block the way such as the complexity and multidisciplinary nature of the concept of sustainability on one hand. On the other hand, the fragmented nature of the design process and ongoing technological advances make it hard to achieve the expected targets [4]. Subsequently, the traditional design approach is no longer sufficient to deal with these challenges. Innovation can be an effective solution to overcome the barriers that arise with developing sustainable built environment. Developing new sustainable building technologies, introducing innovative green and smart materials, applying creative waste reduction processes, and creating novel delivery systems are examples showing how innovation is a crucial ingredient to move towards a sustainable built environment [5]. However, Innovative solutions and techniques, especially in the construction industry, are associated with risks

that stand against their implementation. Addressing these risks and applying innovative techniques at an early stage of the project life cycle increases the probability of success towards achieving sustainability objectives in construction [6]. Therefore, this research aims to investigate the risks associated with innovative solutions and build a relationship between these risks, architectural innovation aspects, architectural design process and sustainability.

2. Research Objectives and Methodology

To accomplish these aims, a research methodology consists of literature review and case studies was designed to achieve three objectives.

- Building comprehensive background through reviewing the concepts of sustainability, innovation and innovation risks, and the design process.
- Depicting the relationship between innovation risks, the architectural innovation aspects, architectural design process and sustainability aspects.
- Presenting and analyzing three case studies to explore the innovation management strategies adopted to overcome the risks associated with the adopted innovation solution.

3. Literature Review

3.1 Sustainability

Sustainability is the development that meets the needs of the present with-out compromising the ability of future generations to meet their own needs. It is the ability to develop and progress with the condition of preserving and utilize natural resource efficiently. The main three pillar of sustainability are environmental, social, and economic pillars. The environmental aspect focuses on protecting the natural resources and physical environment. The social aspect is concerned with providing healthy and safe lives to achieve human prosperity. The economic aspect deals with achieving economic growth without affecting the other two factors [7,8].

Figure 1. Aspects of Sustainability [9].

The interaction between social and environmental aspects generated a new aspect, which revolves around the right of all individuals to have a fair share of the natural resources of the environment. The economic–social aspect focuses on delivering economic sustainability without compromising society needs through promoting business ethics, ensuring fair trade and preserving workers' rights. Finally, the environmental-economic aspect focuses on achieving environmental objectives of sustainability in an economic way through reducing unnecessary costs, efficient use of energy and natural resources, and offering subsidies and incentives for encouraging research centres and construction organisations to develop creative solutions to achieve economical sustainable environment [4&9], see figure (1).

3.2 Innovation

Innovation is a complex and debatable term that has various definitions. Jacobs and Snijders [10] defined innovation as invention that adds value. The Department of Trade and Industry of UK [11] defined it as the successful implementation of new ideas. A more sophisticated and business-oriented definition by Pillar [12] who defined innovation as the creation, introduction and successful diffusion of products, service, system, processes or even business models, which are new from perspective of the particular

organization and/or user. Drucker [13] defined innovation as a tool that embrace and utilize change to improve business. In conclusion, the definitions have two characteristics of innovation in common. First, innovation has to offer a degree of novelty and second, it must add value.

3.2.1 The 4Ps framework of Innovation

For an organization to embrace innovation, it must explore the four main spaces of innovation: person, process, product, and press. The first space focuses on the human factor in achieving innovation and how encouraging new ideas, willingness to take risks, resiliency to uncertainties is essential to achieve innovation [14]. The second space is concerned with the process itself and how to reach desired output most efficiently. The third space is the product and how to create innovative output that is characterized by novelty, elegancy, genesis, and relevancy [6,14,15]. The fourth space is the press, or the paradigm and it is concerned with organizational culture as it focuses on enhancing the working environment and embraces the management support to achieve internal organizational innovation [14,15].

3.2.2 Degrees of Innovation

Throughout the history of innovations, market demand and advance in technology are the main contributors to great innovative ideas. These two factors also define the diverse types of innovation: incremental, disruptive, architectural, and radical. Incremental innovation is the most common type in the organization as it focuses on how existing processes, products and services can be better and more efficient [5,6,15]. Disruptive innovation depends on utilizing modern technologies or solutions to an existing market or problem. It is called disruptive because most often this innovation gets mature with time and overshadows the traditional exiting methods.

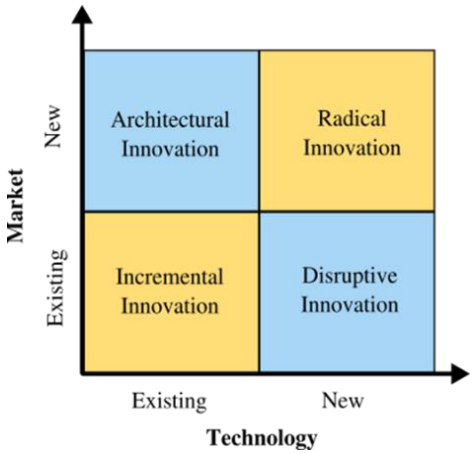


Figure 2. Degrees of Innovation [16].

Architectural innovation is the reconfiguration of existing components in a new and novel way [15]. Finally, radical innovation is the hardest and rarest but has the greatest impact. It utilizes modern technologies to create new market opportunities [5,15], see figure (2).

3.2.3 Innovation in architecture

Contrary to popular belief, the concept of innovation in architecture is not new. It dates back to the Egyptians and Romans, who mastered the use of available resources to create spectacular structures. With the beginning of the industrial revolution, the introduction of new materials such as steel and reinforced concrete, as well as developing inventions such as elevators, aided in shaping radical evolution in architecture [17]. Because of social, economic, and environmental reasons, innovation has gotten a lot of attention over the last two centuries. Buildings are no longer used as social shelters to protect humans. They have a significant impact on their lifestyle, health, and well-being. Economically, rising demand for construction projects causes buildings to cost more today than ever before.

Environmentally, the deterioration of resources around the world necessitates their rationalization [2]. As a result, there is a growing recognition that innovation can address these new challenges. There are various areas of architectural innovation. It could be in the project design, the design thinking process, or the way the project was delivered. The successful implementation of innovation in one area necessitates an integrated approach in which the other areas are addressed to gain the greatest benefit for the firm. Akamija [18] classifies the main factors that influence the incorporation of innovation in architecture as shown in figure 3 and table 1.

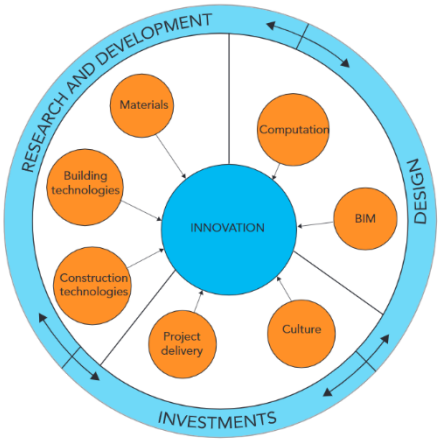


Figure 3. Architectural Innovation Aspects [18].

Table 1. Architectural Innovation Aspects [18].

Advanced material	These are materials with enhanced properties or that are smart and responsive to external stimuli. Materials innovation can be incremental, such as improvements in thermal performance or structure properties of concrete and metals, or radical, such as self-healing materials and nanomaterials.
Building technologies	Building technologies encompass advances in building services such as the façade system, HVAC system, firefighting system, and lighting system. It entails automating all of these systems with sensors and controls to ensure efficiency.
Construction technologies	It is the assembly of building components through advanced techniques such as prefabrication, robotics, and automation.
Project delivery	It is the process that determines how the project is going to be executed. Innovative project delivery such as integrated project delivery (IPD) allows maximum collaboration and quality.
Culture	Innovation can be implemented in the culture of firms and organizations through their strategies, values, the ways of engaging clients, and the way of how they distinguish themselves form other competitors.
Computation	It is the integration of computation in the design process such as using building information modeling (BIM), structural analysis, and environmental analysis.

3.3 Risks of innovation

Innovation is essential ingredient for achieving sustainability [19]. However, it adds additional risks and uncertainties to projects which increase the possibility of their failure [20]. Literature review has identified risks of innovation. Salter & Gann [21] identified 11 barriers of innovation in the design process. On top of the list is lack of time, cost, and lack of interest of project stakeholders. In addition, internal risks related to firms such as the limited understanding of the benefits of innovation, the uncertainty of results and outcome, and the lack of experience and knowledge act as a barrier [22]. Moreover, the lack of interdisciplinary teams and poor communication are contributors to failure of innovation [23]. Table 2 identified risks to innovation in architectural design process. In conclusion, risks of innovation can be categorized into technical risks, financial risks, institutional risks, and schedule risks.

Table 2. Risks of innovation in the design process.

NO.	Risks	Author(s)
R1	Inadequate available design time or failure to deliver on time	[21,24]
R2	Unanticipated Cost of innovation	[21,22,24]
R3	Inadequate top management commitment	[25]
R4	Lack of interest among suppliers within the supply chain	[21,23]
R5	Lack of interest or demand among clients	[21,22]
R6	Too many projects ongoing concurrently	[21]
R7	Lack of organisational skills and expertise	[21, 22]
R8	Difficulty to access information	[21]
R9	Long administrative procedures in organisations	
R10	Lack of co-ordination among different organisational engineering disciplines	
R11	Inability to get feedback from end-users	
R12	Manufacturing technologies or development issues	[22,23]
R13	Uncertain economic return	[22]
R14	Government Bureaucracy	
R15	Lack of belief in value of innovation	[26]
R16	Limited ambition of project participants	
R17	Lack of long-term performance data	[18]
R18	Failing to meet technical criteria	[24]
R19	Lack of client acceptance and marketing risks	[23]
R20	Competitors risks	
R21	Poor organization and project management skills	
R22	Lack of collaboration & communication between multidisciplinary project teams	[27]
R23	Company image and reputation damage	
R24	Lack of access to fund	[28]
R25	Limited organizational resources	
R26	Lack of maintenance strategy	
R27	Organisational culture and resistance to change	[18]
R28	Lack of long-term strategies	
R29	Incomplete codes and standards of innovation	[29]
R30	Lack of quality assessment tools	

3.4 The architectural design process

The design process is a research-based, problem solving and iterative process. It plays a major role towards delivering sustainable projects that meet the client needs and end-user requirements within time, cost and quality standards. Moreover, the decisions made during this process have impacts on the project's performance throughout its life cycle. There are essential factors that affect the design decision making process such as project site, programme, type of client, a few to name. These factors make each project unique [30,31]. According to RIBA work plan, the design phase is divided into 5 stages [32].

- **Strategic Definition:** This is a pre-design phase at which all requirements of the client are defined and fulfilled through initiating construction project. As a result, a business case is developed including a preliminary review of project budget and project risks.
- **Preparatory and briefing:** at this stage, the requirements of the client are translated into a project brief in which the project programme, project outcomes, spatial requirements and feasibility studies are included.
- **Concept design:** The architectural concept is developed in this stage and approved by the client. The concept must be adjusted until it aligns with the project brief and cost plan. Feedback from the project stakeholder is essential at this stage to avoid design changes during further development.

- **Spatial coordination:** This stage introduces different engineering disciplines to the design process. Structure engineer, HVAC engineer, electrical engineer, and specialist work together with the architect to integrate architectural and engineering information.
- **Technical design:** The last phase of the design process that prepares the design for execution. Subcontractors and specialists are integrated in the design process to develop architectural and engineering technical drawings.

Table (3) shows the relationship between risks, architectural innovation aspects, architectural design process and sustainability.

Table 3. Relationship between risks, architectural innovation aspects, architectural design process and sustainability.

Risk	Architectural Innovation Aspects							Architectural design process					Sustainability		
	Culture	Project Delivery	Building Technology	Construction Technologies	Materials	Computation	BIM	Strategic definition	Preparation and briefing	Concept design	Spatial coordination	Technical design	Environmental	Social	Economical
R1		X		X		X	X				X				X
R2	X	X	X	X	X	X	X				X				X
R3	X	X				X	X	X					X	X	X
R4		X	X	X	X			X	X						X
R5	X	X	X	X	X	X		X					X	X	X
R6		X									X				
R7	X			X		X	X				X		X		
R8	X			X		X	X		X				X		X
R9	X														X
R10	X	X		X			X				X	X	X		X
R11		X							X	X			X	X	X
R12			X		X						X	X	X		X
R13	X		X		X			X	X	X					X
R14			X					X	X						
R15	X	X		X	X	X				X	X	X		X	
R16	X													X	
R17								X	X					X	
R18			X		X	X				X	X	X	X	X	X
R19			X			X					X	X	X		X
R20									X	X					
R21	X			X											
R22				X		X					X	X	X		X
R23	X			X		X				X	X	X	X	X	X
R24	X			X		X				X	X	X	X		X
R25	X					X									X
R26			X		X						X	X	X		X
R27			X	X						X	X	X	X	X	X
R28			X									X	X	X	X
R29	X	X	X	X	X					X					X
R30	X	X											X		

4. Case Studies

4.1 Definition and Selection Criteria

A case study is a research approach used to describe and analyse a particular topic, phenomena, event, or project to discover factors, structures, forms, and orders of interaction between the players in the scenario, or to assess work performance or development progress [33]. Three case studies are presented to explore the role of innovation strategies adopted towards overcoming the risk that hinder the implementation of innovation in the architectural design process. The case studies selection criteria were based on the nature of the selected projects, data availability, date of construction, degree of success, and location. All of the case studies featured construction projects that were faced different degree success in overcoming risks of innovation. Because this topic received scant attention in construction literature, few case studies were published, the availability of data was a major factor in selecting the case studies. Finally, the case studies were chosen from France and United Arab Emirates and the learned lessons of the case studies will aid in overcoming the risks of innovation in Egypt. Table (4) explains the research idea through a practical application to the cases studies to illustrate the concept of the idea. These case studies were analysed and compared through investigating (1) the architectural innovation aspect used, (2) the degree of achieving the desired sustainable goals, (3) the degree of innovation, (4) the risks of innovation, (5) learned lessons (recommended innovation management strategies to implement).

4.2 Case Study 1: Arab World Institution, France

Arab World Institution is a well-known building with its unique adaptive façade system. The conceptual design was done by the French architect Jean Novel in 1981 after winning the design competition of the building. What makes the design special is not only the dynamic façade that responds automatically to the external environment allowing a suitable amount of light to the interior of the building, but also, the social aspect behind the design. The façade design is inspired by the traditional Arabian mashrabia. However, only after three years of the opening of the building, serious functional problems started to emerge in the innovative façade system, and within six years the system stopped completely. It is stated that the main reason for the failure of such innovation is related directly to the design process [34, 35].

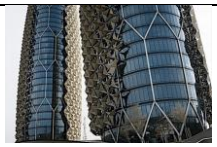
4.3 Case Study 2: Louvre Museum, UAE

The Louvre Museum in Abu Dhabi is a masterpiece created through the collaboration of the UAE and the French governments in 2007. The main innovative feature of the building is the dome which is considered the largest in the world. Its function is to create a microclimate beneath it and to stand against the burning sun of Abu Dhabi. As a result, the heat gain is ceased to 72%. The museum achieved a Three Pearl Design Rating Certificate, and it is targeting the silver LEED status. Subsequently, this case study managed successfully to overcome risks of innovation and to achieve sustainable values through implementing innovation management strategies [36,37,38].

4.4 Case Study 3: Al-Bahr Towers, UAE

The Al Bahr Towers are twin towers in the financial centre of Abu Dhabi. The towers are listed among the “Innovative 20” tall buildings, in addition to winning the 2012 Council for Tall Buildings & Urban Habitat’s Innovation Award. The project deserves these awards as it introduced an innovative adaptive façade system that controls the amount of light and heat entering the building [40]. However, it is stated that this innovation is still far away from adding sustainable values to the project. In conclusion, this case study clearly shows the difficulties and the risks associated with innovations and concludes different innovation management strategies [39] (see table 4).

Table 4. Case Studies Analysis.

	Case Study 1	**Case study 2**	**Case Study 3**
Name	Arab world institute	Louvre Museum	Al Bahr Towers
			
Location	Paris, France	Abu Dhabi, UAE	Abu Dhabi, UAE
The architectural innovation aspect used	Building technology, Adaptive façade system	Construction technology, Dome structure system	Building technology, Adaptive façade system
Degree of achieving the desired sustainable goals	Failed	Succeeded	Failed
Degree of innovation	Modular	Radical	Modular
Risks of innovation	• High maintenance cost • Fail to meet the technical criteria • Low economic return	• Technical issues • Tight project delivery schedule • Complex manufacturing technologies • Lack of information	• High initial cost • Complex manufacturing technologies • Lack of quality assessment tool • Lack of soft-landing process and post occupancy evaluation
Learned lessons (Recommended innovation management strategies to implement)	This case study failed to overcome the risks of innovation and the following strategies are recommended: • Developing an early-stage, performance-based design approach • Integrating whole life cycle assessments in the design process [34,35]	This case study succeeded to overcome the risks of innovation due to implementing the following strategies: • Developing simulations and computational tests • Creating Large scale mockups • Mitigating risks through partnerships • Using a Design-Build project delivery process [36,37,38]	This case study succeeded to overcome the risks of innovation but failed to achieve its sustainable goal and the following strategies are recommended: • Applying design assessment tests • Developing performance criteria • Using BIM to enhance the team collaboration • Engaging the construction expertise [39,40]

5. Conclusion and Recommendations

Because the adoption of innovative design solutions is a promising way of enhancing the sustainable performance of buildings, innovation in different architectural aspects is gaining increasing attention from the design and construction community. However, risks associated with these aspects, such as higher cost and technological complexity, indicate that risk management strategies need to be developed for encouraging the adoption of innovation in buildings development. During this research, the literature review identified 30 risks that affect the implementation of innovative solution during the design process. In addition, a relationship matrix was developed to relate these risks with the architectural innovation aspects, the design process, and their impact on achieving sustainability objectives. Moreover, 3 case studies were presented and analyzed to explore the innovation management strategies adopted to overcome the risks associated with the adopted innovation solution. Based on that, the research recommends developing an innovation management framework to overcome the risks that hinder the implementation of innovative approaches in the design process.

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