Budownictwo i Architektura 24(1) 2025, 97-112

DOI: 10.35784/bud-arch.6493
Received: 16.09.2024; Revised: 11.12.2024;
Accepted: 13.12.2024; Available online: 31.03.2025

Orginal Article

Factors affecting the cost of dynamic architecture in the design phase

Lamiaa Mohamed Said Elsherif[1,2,*], Eman N. Shaqour[2], Abdullah Badawy Mohammed[1], Sherif Mohamed Sabry El Attar[1]

[1] *Architecture Department; Faculty of Engineering; Fayoum University; Fayoum, Egypt;*
lamiaelsherif91@gmail.com, *lamiaa.mohamed@nub.edu.eg*, ORCID: *0009-0004-6723-0238*
Abg00@fayoum.edu.eg, ORCID: 0000-0002-5145-5756
sma00@fayoum.edu.eg, ORCID: 0000-0002-4600-1362
[2] *Architecture Department, Faculty of Engineering, Nahda University (NUB), Beni-Suef, Egypt;*
eman.shaqoor@nub.edu.eg, ORCID: *0000-0003-2669-1893*

Abstract: In this study, the authors examine all aspects of moving surfaces in buildings, such as formation, colour, size, texture, and lighting. We also investigate the actual movement patterns in architecture (rigid elements, deformable elements, soft and flexible elements, elastic elements, pneumatic forms), the definition of movement and dynamic architecture, and the types of movement directions in dynamic buildings (static movement, dynamic movement). Additionally, we analyse the factors affecting the cost of dynamic buildings during the design phase, including the selection of the type of movement for the space, interactive movement systems, and movement patterns. Furthermore, we examine the cost impact of the design phase through questionnaire analysis, assessing the influence of selecting the type of movement for the space, interactive movement systems, and movement patterns on cost. The results indicate that the selection of all types of movement within a space is one of the most significant factors affecting cost, highlighting the importance of choosing interactive movement systems due to their impact on overall expenses.

Keywords: dynamic architecture, kinetic, movement in buildings, construction project management, economic feasibility, cost

1. Introduction

Recently, computer applications have had a significant impact on the culture and science of architecture, introducing new dimensions to design. The integration of architecture and information space through computational tools has enabled the creation of countless design alternatives. The influence of computers and their applications extends beyond the development of construction technology, as new technologies and building materials have also emerged. Computers have enhanced the efficiency and speed of manufacturing processes for these materials, ensuring high quality. Extensive research has been conducted on computer science and its impact on the concept of responsive architecture and the super-surface. This approach seeks to modify the surface and form of architectural spaces to adapt to various factors, such as changing weather conditions, wind intensity, and high temperatures. It also allows for adaptation in terms of colour, shape, and surface properties, whether through natural or mechanical means. These advancements in building materials and technology have significantly influenced architectural design processes, leading to the emergence of new architectural trends under the concept of mechanical architecture. These include topological architecture, parametric architecture, non-Euclidean architecture (NURB), bubble architecture, and super-surface architecture, all of which fall under the broader concept of digital architecture. In this study, we present an economic analysis of dynamic architecture, focusing on the financial return of its implementation in buildings [1].

Many buildings lack the capability and flexibility to fully meet users' needs, as they are static structures incapable of continuous adaptation and transformation to accommodate evolving requirements. This lack of dynamism, adaptability, and responsiveness creates economic challenges in the design phase. Additionally, construction projects often fail to deliver tangible financial returns. Therefore, this study aims to establish a methodology for dynamic construction projects during the design phase [2].

1.1. Theoretical basis of dynamic architecture

A comprehensive literature review will be conducted to define the theoretical foundations of: Movement patterns within the architectural domain; The concept and defining characteristics of dynamic architecture; The design principles underpinning dynamic architectural systems [3].

1.1.1. Moving surfaces

There are common aspects of moving surfaces, which can be categorised based on formation, colour, size, texture, lighting, movement mechanisms, and causes of movement.

1.1.2. Actual movement patterns in architecture

In architecture, rigid bodies (static buildings) are more prevalent and are typically connected by movable joints to create dynamic elements (movable buildings). Flexible bodies are also utilised in moving elements on a small scale, but their use in load-bearing applications is relatively rare. Apart from buildings designed with inherent flexibility, and considering that motion is a branch of mechanics, actual movement patterns in architecture can be classified into five types:

- rigid elements;
- deformable elements;
- soft and flexible elements;
- elastic elements;
- pneumatic forms [3,4].

1.1.3. Movement and dynamic architecture

Movement encompasses every interaction, transition, or transformation of an element into a form it previously did not possess, or the transition of an element from one state to another while maintaining its inherent characteristics.

1.1.4. Movement (dynamics)

A study of different concepts of movement and spatial dynamics has shown that movement arises from specific influencing factors. It is indicative of both the individual components and the overall design. Movement is part of an integrated system that can be divided into several subcomponents, with spatial movement representing changes within a single element. It results from a series of coordinated motions subject to a specific design approach that governs the components and elements of the structure [4].

1.1.5. Dynamic architecture

Dynamic architecture is an emerging concept in the field of architecture that utilises dynamic movement to usher in a new era of architectural design, redefining design methodologies and offering a forward-looking vision for architectural structures (Fig. 1) [4].

dynamic movement (dynamic movement static dynamic (static movement)

Fig. 1. Types of movement directions in dynamic buildings. *Source*: [5,6]

1.1.6. Types of dynamism (types of movement)

There are two types of dynamism: static dynamism (static movement) and dynamic dynamism (dynamic movement).

1.1.7. Types of movement directions in dynamic buildings

Movement in dynamic buildings can be categorised into two types: static movement and dynamic movement.

- *Static movement*: This occurs through the spatial progression of spaces and blocks in a manner that aligns with the functional dynamics within the building. This type of movement creates an illusion of motion through various techniques, such as: perceptual illusion of movement, control of external lighting; modification of the building's external texture; addition or removal of building elements [7,8]
- *Dynamic movement*: This involves the actual movement of building components in the X, Y, or Z directions.

Dynamics result from changes over time and the incorporation of the fourth dimension – time – into the design process. The design becomes four-dimensional (length, width, height, and time), enabling the building to rotate around its axis and change its façade and appearance. Dynamic movement appears in buildings in several forms, as evidenced by the movement of various building components, including the movement of furniture, water elements, openings, coverings, floors, certain floors of the building, and the building as a whole [7,8].

Construction and building projects, at various stages (design, execution, and operation), are influenced by several factors that can either positively or negatively impact the total project cost. Similarly, dynamic construction projects are also affected by a range of such factors [9].

1.2. Factors affecting the cost of dynamic buildings during the design phase

The design stage is the fundamental phase that influences the cost of dynamic building projects. At this stage, the type of movement, interactive kinetic systems, and movement patterns to be applied in the design of dynamic buildings are determined [10,11].

1.2.1. Selecting the type of movement for the space

There is a direct relationship between movement, space, and the type of space, as well as its interaction with movement. Flexibility in architecture can be categorised into four characteristics, as defined by architect Kronenburg: interaction, adaptation, transformation, and movement. The primary objective of selecting the type of movement is to maximise its benefits and utilise it effectively to serve architectural spaces, thereby extending the lifespan of the building. Ultimately, this contributes to reducing the overall cost of dynamic construction projects [12,13].

Table 1. Selecting the type of movement for the space

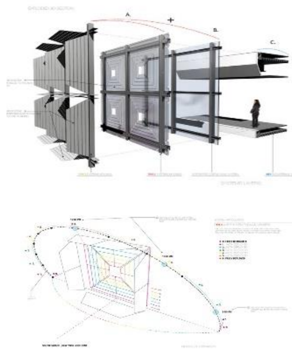
Mov. type	Description	Example	Figures
Changing Space	Adding a new function to the space and creating multiple configurations within it.	Multi-use furniture: In small spaces, using multi-functional furniture is an effective solution that optimises limited space to perform multiple functions [14].	 Fig. 2. Multi-use furniture. *Source*: [15]
Adjusting space	Modifying the space according to user needs and environmental and lighting conditions to enhance the quality of the interior space.	Kinetic roof: The central square of the Msheireb project in the heart of Doha, Qatar, features a kinetic roof that can be converted into a covered area, protecting users from surrounding climatic conditions [16].	 Fig. 3. Kinetic Roof -Msheireb Downtown, Doha, Qatar, 2008. *Source*: [17]
Connecting Space	Connecting spaces and openings to modify their size and maximise spatial efficiency.	Olympic Medals Plaza (Hoberman Arch): This structure comprises 96 transparent panels, connected with screws in a fixed arrangement, which can be opened and closed to activate the space, allowing users to follow Olympic ceremonies [18].	 Fig. 4. Olympic Medals Plaza, China, 2002. *Source*: [19]
Moving Space	Completely relocating a space to achieve maximum functionality.	Sliding House: The building's roof and walls move in a linear motion using an electric motor hidden within the wall, enabling optimal use of sunlight throughout the day [20].	 Fig. 5. Sliding House, England, 2009. *Source*: [21]

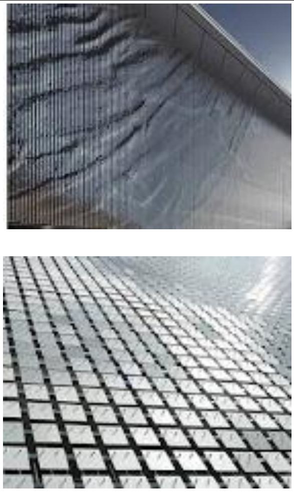
Mov. type	Description	Example	Figures
Creating Space	Adjusting the size of spaces by expanding when additional space is required or contracting when space is not in use.	Muvbox: A mobile restaurant that can be opened to accommodate additional visitors and closed when not needed [22].	 Fig. 6. MuvBox shipping container café, Canada. *Source*: [23]

1.2.2. Selecting interactive movement systems

Kinetic systems in building envelopes have evolved to respond and adapt to various environmental influences, such as sunlight, wind, sound, and even human movement. These systems can change their state without the need for human intervention and revert to their original form without deformation once the external influence ceases [24].

Table 2. Selecting interactive movement systems

Mov. system	Example	Description	Figures
Interactive with the sun (light, heat, energy)	Light: These systems regulate interior lighting levels, particularly in museums and galleries. Additionally, some systems consider solar heat control to enhance thermal comfort and reduce energy consumption for lighting and cooling. Heat: Designed to maximise solar heat absorption in winter and minimise heat gain in summer, this system adapts by altering the thermal-physical properties of the moving elements. Energy: Unlike conventional power generation systems, these systems integrate mobile photovoltaic panels into the building envelope, making them a functional part of the structure rather than an independent system.	Helio Trace Helio Trace is an administrative building located in New York, USA, designed by architect Hoberman. The kinetic system integrated into the building envelope was developed to increase daylight exposure by up to 81% while simultaneously reducing the effects of solar heat gain for occupants. This system follows the path of the sun throughout the day and year, using a three-layer structure to achieve maximum adaptability. It incorporates panels that track optimal solar energy, commonly referred to as heliotropic sun-tracking systems [25].	 Fig. 7. HelioTrace Façade System. *Source*: [26]

Mov. system	Example	Description	Figures
Interactive with wind movement (to provide natural ventilation and generate wind energy)	These systems are designed to be compatible with wind flow and can be categorised into two types: those responsive to natural ventilation and those responsive to wind energy. Their locomotive behaviour is influenced by air exchange, indoor thermal comfort, and air quality. Responsive systems providing natural ventilation The kinetic process associated with natural ventilation involves the introduction of outside air – accounting for factors such as temperature, humidity, dust, and odours – into the indoor environment to enhance air quality and comfort. Responsive systems generating wind energy Similar to Building-Integrated Photovoltaics (BIPV), small-scale wind turbines can be incorporated into the building envelope. These wind-responsive kinetic systems function as an integrated part of the structure rather than as independent wind energy systems.	Brisbane Airport parking building The design concept of this building revolves around a kinetic façade spanning 5,000 square metres for the airport's new domestic parking facility. The façade appears to undulate and move as wind flows behind 250,000 aluminium panels, creating a dynamic and visually unique structure. This movement also generates complex patterns of light and shadow on the walls and floor as sunlight interacts with the kinetic façade [27].	 Fig. 8. Actuated tensegrity prototyps2003. *Source*: [28]
Interactive with sound	Inspired by the natural phenomenon of plants responding to external stimuli, designer Natasa Sljivancanin developed an intelligent kinetic building system that adapts to changing environmental conditions. In collaboration with Cornell University, Sljivancanin designed a sound-responsive wall composed of cellular components that open and close in reaction to various stimuli, absorbing sound and emitting light. Additional potential triggers include light, proximity to people, and touch.	Hypo Surface by dECOi Architects & MIT: Sound responsive wall: The Sonomorph cells consist of aluminium outer panels and glass-reinforced plastic inner panels. They are mounted on a simple steel wire mesh with standard hardware and incorporate various sensory devices, servo motors, and LEDs for interactive functionality. During the day, the polished aluminium shells of the cells shimmer in the sunlight, while at night, they emit a subtle, colourful glow [29].	 Fig. 9. Sonomorph sound-responsive wall. *Source*: [30]

Mov. system	Example	Description	Figures
Interactive with human	It is a powerful new medium that evokes curiosity and excitement in people of all ages. This physically interactive system integrates sound and motion, combining generative sound and movement logic with light and image projection.	A flexible architectural surface, such as a display composed of small pneumatically controlled metal panels, reacts in real time to electronic inputs. This enables the screen to generate highly expressive, precisely detailed, and seemingly organic movements [31].	 Fig. 10. HypoSurface by dECOi Architects & MIT. *Source*: [32]

1.2.3. Selecting movement patterns

The kinetic patterns of buildings that respond to varying conditions are determined through interaction with different types and design components of kinetic building systems, as well as their evaluation. This process fosters a new level of integration between architectural design and implementation. For designers, understanding movement patterns enables the anticipation of achieving the highest degree of continuity between the current design and the intended outcomes.

The primary objective of developing kinetic buildings is to comprehend the complexities involved in designing and selecting various types of kinetic responses, using both physical tools and digital technology. Kinetic patterns are based on commonly applied principles in architecture and construction [33].

Table 3. Selecting movement patterns

Mov. pattern	Description	Example	Figures
Wave	Commonly utilised in functional elements such as interface control or aesthetics, the pulley system is one of the most prevalent mechanisms. However, its application in architecture is rare, particularly in buildings with kinetic façades.	Nordic Embassies Analysing complex movement mechanisms helps determine their potential for integration as effective components in developing interfaces, aiming to achieve interaction through movement transformations such as rotation and sliding [34].	 Fig. 11. Nordic Embassies *Source*: [35]
Inflate & Deflate	It incorporates more flexible components instead of rigid materials, aiming to reduce mechanical friction and forces while facilitating movement. This design enhances contraction in response to opening and closing actions.	Media ICT Kinetic façades with flexible material surfaces that respond to external lighting and heating conditions are constructed using lightweight ETFE airbags, which inflate and deflate based on internal air volume [36].	 Fig. 12. Media ICT. *Source*: [37]

Mov. pattern	Description	Example	Figures
Sliding	A type of movement associated with malleable structures, enabling the creation of responsive systems. These systems can adapt their locomotor function through suspended responsive structures, such as scissor mechanisms.	Origami pavilion Inspired by origami techniques, the final form comprises two "flower" modules joined together to create a portal structure resembling a Japanese torii diagram [38].	 Fig. 13. Origami pavilion. *Source*: [39]
Contracting & Expanding	Developing facilities that enable designers to effectively identify and address problems in interactive architectural design.	Interactive Wall by Hyperbody An interactive wall that conveys its state through commonly used methods, including internal movement, light, and sound [38].	 Fig. 14. Interactive Wall by Hyperbody. *Source*: [40]
Transformable	The response obtained from kinematic transformations through prototypes provides valuable insights into the effectiveness of control systems when integrated with the enclosure, as well as the role of materials in their development.	Cafe and open-air restaurant in Amsterdam Designed by architect De Architekten Cie, this structure features a kinetic system with an independent frame that continuously transforms and evolves its patterns. This dynamic architectural element regulates light, heat gain, ventilation, airflow, privacy, and visibility [39].	 Fig. 15. Cafe-restaurant openair, Amsterdam by de Architekten Cie. *Source*: [41]

1.3. Materials and methods

The research is based on a quantitative analysis using a questionnaire consisting of three parts. The first part collects general data about the respondents, the second part examines their sources of information on dynamic architecture, and the third part focuses on study-specific questions, divided into three key phases: the design phase, the execution phase, and the operation phase. This research specifically focuses on the design phase.

The study follows a two-part structure to achieve its objectives. The first part adopts a theoretical approach to identify and extract the factors influencing the cost of dynamic buildings based on previous studies. The second part employs a survey-based questionnaire to determine and assess the factors affecting the economic cost of buildings during the design phase, both positively and negatively, as shown in Fig. 16 [42].

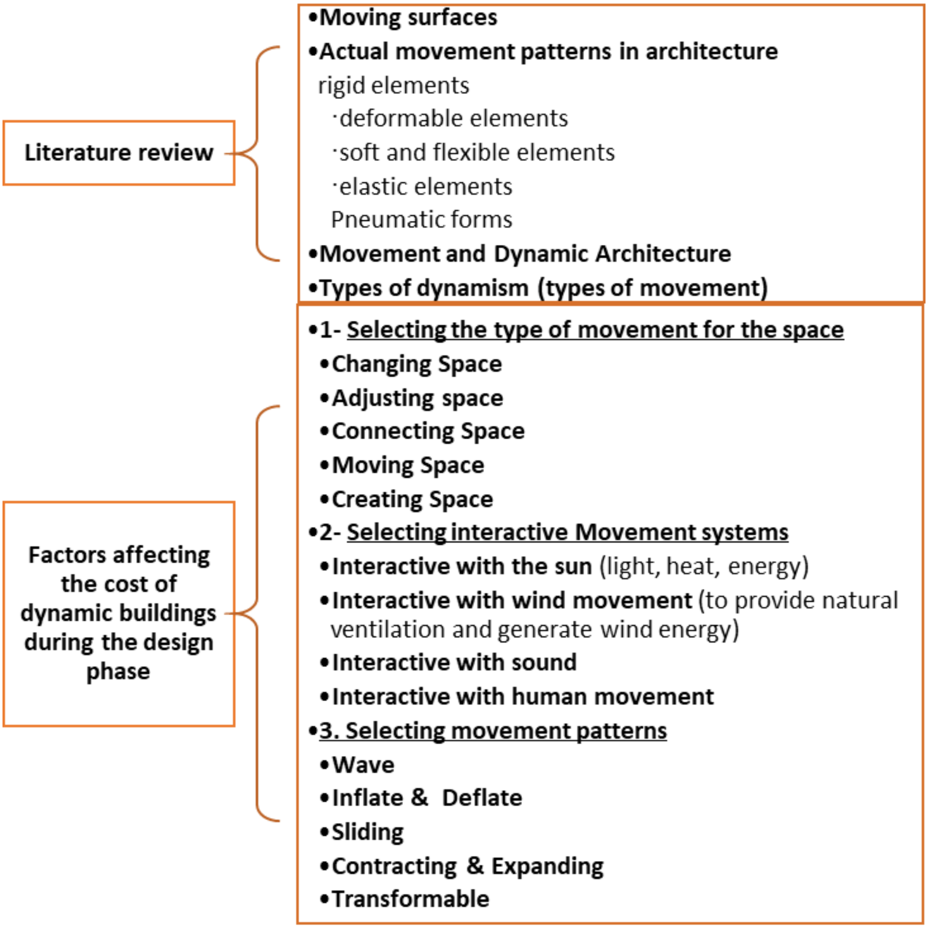


Fig. 16. Data and methods of the research. *Source*: own study

A structured questionnaire was administered to a group of 79 architecture experts to identify the key cost determinants in dynamic building construction and to develop quantitative metrics and descriptors. The questionnaire focused on variables influencing the cost of dynamic building projects across their design, execution, and operational phases [43,44].

- Type of questionnaire: A closed-ended questionnaire.
- Before being presented to architectural specialists, the questionnaire was reviewed by experts in dynamic architecture to gather feedback and make necessary modifications to its design.
- The questionnaire was designed in both electronic and paper formats.
- A pre-test was conducted on a small sample in what is known as a pilot study.
- The validity and reliability percentage was 95.7%, indicating a high level of credibility and quality.
- Linearity of relationships and data continuity were ensured when calculating correlation and regression scales.
- Software used: IBM SPSS Statistics 25 program and Microsoft Excel.

- A five-point Likert scale was used, followed by the creation of a frequency distribution table for study variables. This table was used for statistical analysis to obtain weighted arithmetic means and standard deviations. The researcher also applied a hypothetical arithmetic mean of 3 as a criterion for measuring and evaluating cost-related data. After statistical processing and analysis, the weighted arithmetic means and standard deviations for the respondents' answers were obtained.
- The analysis was conducted through the following steps: Analyze → Descriptive → Frequencies → Mean.
- Specialists are architects who specialise in the field of architecture.
- A group of specialists in the field of architecture who have prior knowledge either through study, research, or work in the field of dynamic architecture..
- They are a group of specialists in the field of architecture who have prior knowledge either through study, research, or work in the field of dynamic architecture.
- A percentage of them have worked on such dynamic projects, while another percentage have worked on other large projects. For the most part, they have studied and conducted research specifically in the field of dynamic architecture.

Data analysis was performed using IBM SPSS Statistics 25 to ensure the reliability of the findings, as illustrated in Fig. 17. Subsequently, the processed data were transferred to Microsoft Excel for organisational purposes, as shown in Fig. 17 [45,46].

Simple regression study in the design phase

Descriptive Statistics

	Mean	Std. Deviation	N
y	3.7912	.71366	79
DESIGN	3.8286	.71164	79

Correlations

		y	DESIGN
Pearson Correlation	y	1.000	.926
	DESIGN	.926	1.000
Sig. (1-tailed)	y	.	.000
	DESIGN	.000	.
N	y	79	79
	DESIGN	79	79

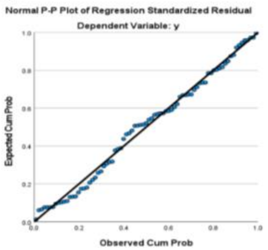
Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	DESIGN[b]	.	Enter

a. Dependent Variable: y

b. All requested variables entered.

Access to the linear equation for simple regression in the design phase



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.926[a]	.857	.855	.27168

a. Predictors: (Constant), DESIGN

b. Dependent Variable: y

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.042	1	34.042	461.201	.000[b]
	Residual	5.684	77	.074		
	Total	39.726	78			

a. Dependent Variable: y

b. Predictors: (Constant), DESIGN

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.237	.168		1.408	.163
	DESIGN	.928	.043	.926	21.476	.000

a. Dependent Variable: y

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.6179	4.8786	3.7912	.66064	79
Residual	-.61220-	.73867	.00000	.26994	79
Std. Predicted Value	-3.290-	1.646	.000	1.000	79
Std. Residual	-2.253-	2.719	.000	.994	79

a. Dependent Variable: y

Fig. 17. To enhance the reliability of the data, the questionnaire was analysed during the Design phase using IBM SPSS Statistics 25. *Source*: own study

2. Research results

After analysing the questionnaire, the following results were reached.

2.1. Cost impact analysis of the design phase: questionnaire results

The frequency of responses to the five design phase questions in the following order (Contacting a specialist with a track record and the costs of submitting his financial dues, Selecting the type of movement for the space (changing space - adjusting space - connecting space - moving space - creating space), Selecting interactive movement systems, selecting movement patterns, and the owner's role in making design decisions) was analysed. The mean was calculated to determine the overall cost impact during the Design phase, as shown in Fig. 18.

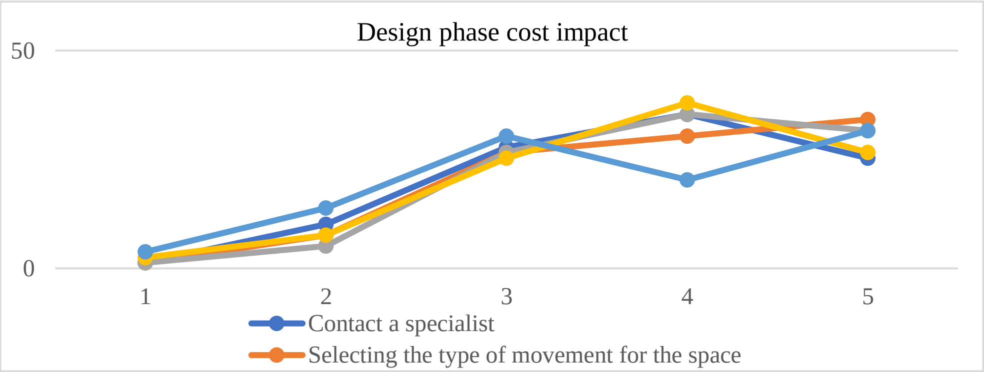


Fig. 18. Design phase cost impact assessment: analysis of questionnaire results. *Source*: own study

A critical curve analysis using a five-point Likert scale was conducted to assess the impact of various factors on Design costs. The results indicate that selecting interactive movement systems has the most significant influence (mean = 3.9114), followed by selecting the type of movement for the space (mean = 3.8861), then selecting movement patterns (mean = 3.3671), followed by contacting a specialist (mean = 3.3671), and the owner's role in making design decisions (mean = 3.6203). This indicates that the selection of all types of movement in space is one of the most important factors affecting the cost.

2.2. Selecting the type of movement for the space and its impact on cost

The questionnaire was conducted on the five types of movement shown in Tab. 1, in the following order: changing space, adjusting space, connecting space, moving space, and creating space, as shown in Fig. 19.

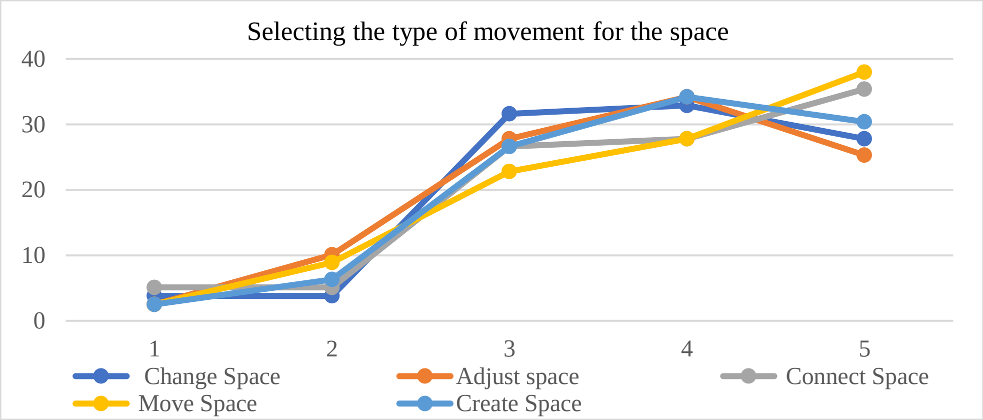


Fig. 19. Selecting the type of movement for the space: analysis of questionnaire results. *Source*: own study

The critical curve demonstrates the relationship between the frequency and cost ratios of the indicator and its overall cost impact. Using a Likert scale, the mean values converge between 3.8987 and 3.6962. This indicates that the selection of all types of movement in space is one of the most important indicators affecting the cost.

2.3. Selecting interactive movement systems and their impact on cost

The questionnaire was conducted on the four types of interactive movement systems shown in Tab. 2, in the following order: interactive with the sun (light, heat, energy), interactive with wind movement (to provide natural ventilation and generate wind energy), interactive with sound, and interactive with human movement, as shown in Fig. 20.

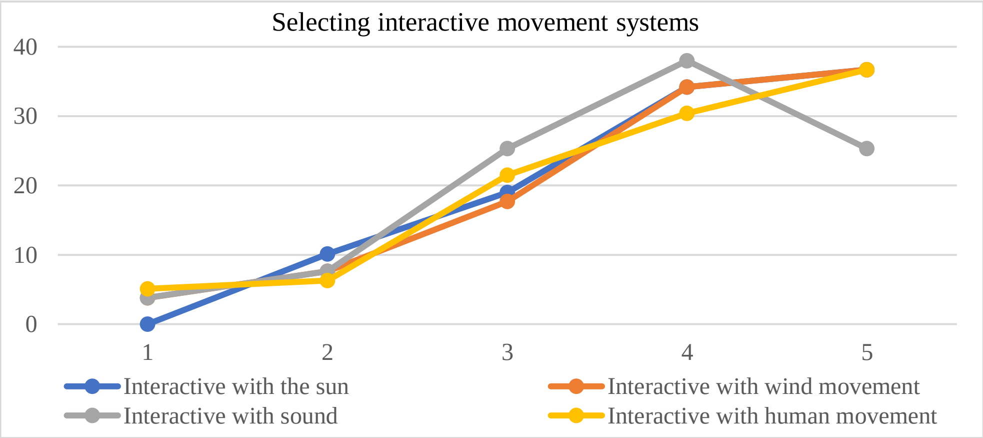


Fig. 20. Selecting interactive movement systems: analysis of questionnaire results. *Source*: own study

Using a Likert scale, the mean values converge between 3.9747 and 3.7342. This indicates the importance of selecting interactive movement systems for their role in affecting the cost.

2.4. Selecting movement patterns and their impact on cost

The questionnaire was conducted on the five patterns of movement shown in Tab. 3, in the following order: wave, inflate and deflate, sliding, contracting and expanding, and transformable. Mean values also converged between 3.962 and 3.7468. This indicates the importance of selecting movement patterns for their role in affecting the cost, as shown in Fig. 21.

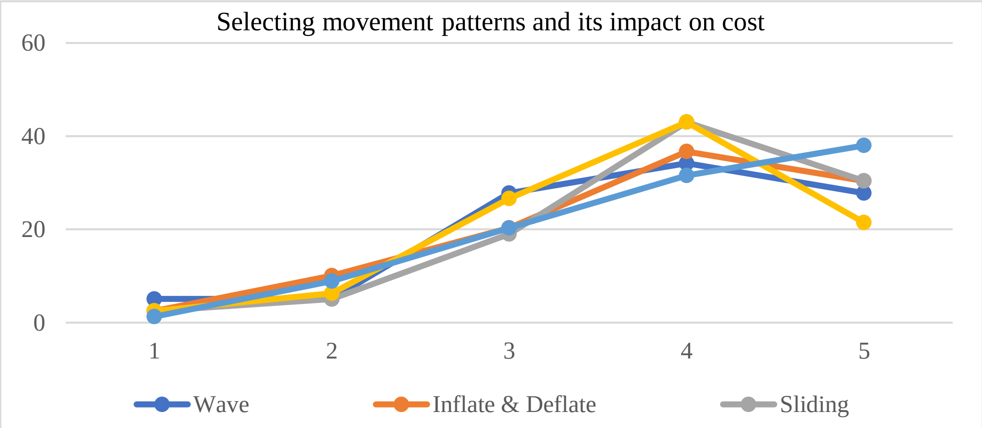


Fig. 21. Selecting movement patterns and their impact on cost: analysis of questionnaire results. *Source*: own study

3. Conclusions

Motion or dynamism is the continuous change in the body relative to a fixed point, and it has a force and speed that can change. Formation, colour, size, texture, lighting, and movement mechanisms are common features in moving surfaces. Dynamic architecture is that which depends on dynamic movement resulting from the passage of time and the incorporation of the fourth dimension into the design. Dynamics in buildings can either be: static dynamics, by controlling the external lighting of the building or the external texture of the building, or moving dynamics (dynamic movement or movement of building parts). Construction and building projects in their various phases (design, execution, operation). The most important factors affecting the cost of dynamic buildings in the design phase are selecting the type of movement for the space (changing space, adjusting space, connecting space, moving space, creating space), selecting interactive movement systems (interactive with the sun, interactive with the movement of the wind to provide natural ventilation and generate wind energy, interactive with sound, interactive with human movement), and selecting movement patterns (wave, inflate and deflate, sliding, contracting and expanding, transformable). Factors affecting the cost of dynamic buildings during the design phase include selecting the type of movement for the space, selecting interactive movement systems, and selecting movement patterns.

The highest mean value was recorded for selecting interactive movement systems. The mean values of responses to the questions on the cost impact of the design phase converge between 3.9114 and 3.6203. This indicates that they are very close together and all have a significant impact on the cost. This means that each of the following factors has a great impact on the cost in dynamic buildings during the design phase: selecting the type of movement for the space (changing space, adjusting space, connecting space, moving space, creating space), selecting interactive movement systems (interactive with the sun, interactive with wind movement to provide natural ventilation and generate wind energy, interactive with sound, interactive with human movement), and selecting movement patterns (wave, inflate and deflate, sliding, contracting and expanding, transformable).

The most influential of the above factors is selecting movement patterns, as it is the primary determinant, and the design is initially determined by choosing it.

References

[1] Linn C., *Kinetic architecture: design for active envelopes*, Images publishing, 2014.

[2] Vazquez E., Correa D., Poppinga S. "A review of and taxonomy for elastic kinetic building envelopes", *Journal of Building Engineering*, vol. 82, (2023), 108227. https://doi.org/10.1016/j.jobe.2023.108227

[3] Elkhayat Y. O., "Interactive movement in kinetic architecture", *JES. Journal of Engineering Sciences*, vol. 42(3), (2014), 816-845. https://doi.org/10.21608/jesaun.2014.115027

[4] Mohammed A. B., "The concept of dynamism and movement in architecture", *Journal of Engineering and Applied Science*, vol. 66(1), (2019), 47-69.

[5] Shanghai - Qizhong Forest Sports City Arena (15,000). Available: https://www.pinterest.com/pin/519039925774911423/ [Accessed: 11 Nov 2024]

[6] Habitat '67, building, Montreal, Quebec Canada. Available: https://www.britannica.com/biography/Moshe-Safdie [Accessed: 11 Nov 2024]

[7] Kolarevic B., Parlac V., *Building dynamics: exploring architecture of change*, Routledge, 2015.

[8] Mohamed Sherif L. M. S., Meselhy M. S., El Atar S., "Evaluating the performance of global models applying dynamic architecture", *Journal of Al-Azhar University Engineering Sector*, vol. 15(54), (2020), 416-427. https://doi.org/10.21608/auej.2020.73163

[9] Schumacher M., Vogt M. M., Krumme L. A. C., *New move: Architecture in motion-new dynamic components and elements*, Birkhäuser., 2019.

[10] Ching F. D., *Architecture: Form, space, and order*, John Wiley & Sons, 2023.

[11] Cho Y., Karmann C., Andersen M., "Dynamism in the context of views out: A literature review", *Building and Environment*, vol. 244, (2023), 110767. https://doi.org/10.1016/j.buildenv.2023.110767

[12] Nicoletti V., Arezzo D., Carbonari S., Gara F., "Dynamic monitoring of buildings as a diagnostic tool during construction phases", *Journal of Building Engineering*, vol. 46, (2022), 103764. https://doi.org/10.1016/j.jobe.2021.103764

[13] Negendahl K., "Building performance simulation in the early design stage: An introduction to integrated dynamic models", *Automation in Construction*, vol. 54, (2015), 39-53. https://doi.org/10.1016/j.autcon.2015.03.002

[14] Mustafa Ali Labib A., "Space-saving and multiple using furniture", *International Journal of Design and Fashion Studies*, 2(1), (2019) 18-21. https://doi.org/10.21608/ijdfs.2019.180019

[15] *Multipurpose furniture*, Available: https://n9.cl/pjtjkf. [Accessed: 11 Nov 2024]

[16] Al-Fadala E., Fadli F., "Smart city applications: Promoting comfort, health and well-being through Sustainable Smart Urban Design (S2UD) in Msheireb downtown", in IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT), 2020, pp. 254-261. IEEE.

[17] *Msheireb Projects*. Available: https://land-slide.net/msheireb-projects/ [Accessed: 11 Nov 2024]

[18] Traganou J., *Designing the Olympics: Representation, participation, contestation*, 2016, Routledge.

[19] *Hoberman Arch at the Salt Lake 2002 Olympic Cauldron Park*, Available: https://commons.wikimedia.org/wiki/File:HobermanArchLit.JPG [Accessed: 11 Nov 2024]

[20] Janowski M., "Kinetic House. Mobility in shaping the function and form of the contemporary house", *Architectus*, 3(67), (2021), 93-102. https://doi.org/10.37190/arc210309

[21] *HobermanArchLit*. https://n9.cl/xafivk [Accessed: 11 Nov 2024]

[22] Cerrahoglu M., Maden F. "A review on portable structures", in Conference: International Symposium of Architecture, Technology and Innovation (ATI 2020), 2020

[23] *MuvBox shipping container café -Canada*. https://varnum.org/olympics/medals.htm [Accessed: 11 Nov 2024]

[24] Guccione A. A., Neville B. T., George S. Z., "Optimization of movement: a dynamical systems approach to movement systems as emergent phenomena", *Physical Therapy*, 99(1), (2019), 3-9. https://doi.org/10.1093/ptj/pzy116

[25] Hosseini S. M., Mohammadi M., Guerra-Santin O., "Interactive kinetic façade: Improving visual comfort based on dynamic daylight and occupant's positions by 2D and 3D shape changes", *Building and Environment*, 165, (2019), 106396. https://doi.org/10.1016/j.buildenv.2019.106396

[26] *The 3D section for Helio Trace Centre window unit by SOM/ABI/Permasteelisa*, https://www.researchgate.net/figure/The-3D-section-for-Helio-Trace-Centre-window-unit-by-SOM-ABI-Permasteelisa-2010-14_fig2_305896048 [Accessed: 11 Nov 2024].

[27] Gschwend R., "The development of public art and its future passive, active and interactive past, present and future", *In Arts*, vol. 4(3), (2015), 93-100. https://doi.org/10.3390/arts4030093

[28] *Brisbane Airport Parking Garage*, Courtesy of UAP. https://parametric-architecture.com/what-is-kinetic-architecture/ [Accessed: 11 Nov 2024]

[29] Waseef A., El-Mowafy B. N., "Towards a new classification for responsive kinetic facades", in Proceedings of the Memaryat International Conference 'MIC, 2017.

[30] *Sonomorph, Sound-responsive wall.* https://transmaterial.net/sonomorph// [Accessed: 11 Nov 2024]

[31] Chang J. R., "From interactive to intra-active body: towards a new organic digital architecture. *A+ BE| Architecture and the Built Environment*, vol. 1, (2018), 47-80.

[32] *Hyposurface...wood textile*, http://tiffyyang.blogspot.com/2010/04/hyposurface.html [Accessed: 11 Nov 2024]

[33] Atef E., Megahed N., Elgheznawy D., Nashaat B., "Adaptive office buildings: improving functional flexibility in response to shifting needs using kinetic technology", *Architectural Engineering and Design Management*, vol. 20(4), (2024), 946–971. https://doi.org/10.1080/17452007.2024.2328119

[34] Silvestrin-Racine V., *Understanding the transition of ambassadors: The cases of the five nordic countries*. Master's thesis, University of Agder, 2021. https://trepo.tuni.fi/handle/10024/132717

[35] *Nordic Embassies in Berlin*, https://en.wikipedia.org/wiki/Nordic_Embassies_%28Berlin%29# [Accessed: 11 Nov 2024]

[36] Gutiérrez-Martín A., Pinedo-González R., Gil-Puente C., "ICT and Media competencies of teachers. Convergence towards an integrated MIL-ICT model", Comunicar, 30(70), (2022), 19–30. https://doi.org/10.3916/C70-2022-02

[37] *Media-ICT building, Barcelona*, https://www.ruiz-geli.com/projects/built/media-tic [Accessed: 11 Nov 2024]

[38] Meryem A. K., "Origami design in digital design methods: a pavilion example", *Space & Form/Przestrzeń i Forma*, vol. 58, (2024), 7–20. http://dx.doi.org/10.21005/pif.2024.58.B-01

[39] *Origami pavilion*. https://talfriedman.com/origami-pavilion [Accessed: 11 Nov 2024]

[40] *InteractiveWall*. https://www.festo.com/rep/en_corp/assets/pdf/InteractiveWall_en.pdf [Accessed: 11 Nov 2024]

[41] *Architecture Board.* https://architectureboard.wordpress.com/2017/04/28/cafe-restaurante/ [Accessed: 11 Nov 2024]

[42] Stefanowitsch A., *Corpus linguistics: A guide to the methodology*, Language Science Press, 2020.

[43] Patten M., *Questionnaire research: A practical guide*, Routledge, 2016.

[44] Falissard B., *Analysis of questionnaire data with R*, Boca Raton, FL: CRC Press, 2012, p. 269..

[45] George D., Mallery P., *IBM SPSS statistics 26 step by step: A simple guide and reference*, Routledge., 2019.

[46] Sah A. N., *Data analysis using microsoft excel*, Excel Books India, 2009.