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The Impact of Appropriate kinetic Architecture Technology on User Needs (Physical – Nonphysical) in Houses

ABSTRACT
In discussing the changing of user needs (physical - nonphysical) in houses, it's essential to acknowledge that the shift towards sustainable and flexible living spaces reflects a response to changing .The discourse on architectural work extends beyond physical functionality to encompass the emotional and psychological well-being of users (nonphysical function). This approach to architecture underscores a profound understanding of the positive impact that well-designed living spaces can have on our daily experiences and interactions within our homes. The concept of kinetic houses, with their dynamic and adaptable design , has a profound impact on users' needs and spaces' experiences. By exploring the kinetic design, researcher try to uncover how these designs can respond to changing user needs in real-time, offering flexibility, customization, and enhanced functionality. Therefore, the research presents analysis of kinetic examples of houses , well-known for success , that shows the importance of kinetic architecture to fulfill user needs .
DOI :

1.1 Problem

Shortage of traditional buildings to fulfill changing user needs, both physical and non-physical in houses.

1.2 Target

Studying the impact of Appropriate kinetic Architecture Technology concepts on user needs in houses focusing on the fulfilling of user's needs, both physical and non-physical.

2 Introduction

Why kinetic architecture? Its use is aimed at meeting the needs (Physical - Non Physical) of users in a constantly evolving world. Kinetic architecture is used to adapt to the needs (Physical - Non Physical) of users that continuously evolve over time and as user space constraints arise during the implementation of activation. Mobility in buildings is therefore a solution to meet the changing needs of users and a goal to change the static state in buildings.

In Fig.1, the shaded area refers to users' needs, while the outer black line is the building. When a building is designed, it is designed to meet the needs of a given era or time, and over time it is possible that the fixed spaces does not meet the needs of the users for which it is designed. Therefore, we can resort to comprehensive design (Space fits all), but for more flexibility, we find that kinetic design corresponds to constantly changing needs; it allows the asset to be changed and adapted to their needs, not abandoned .

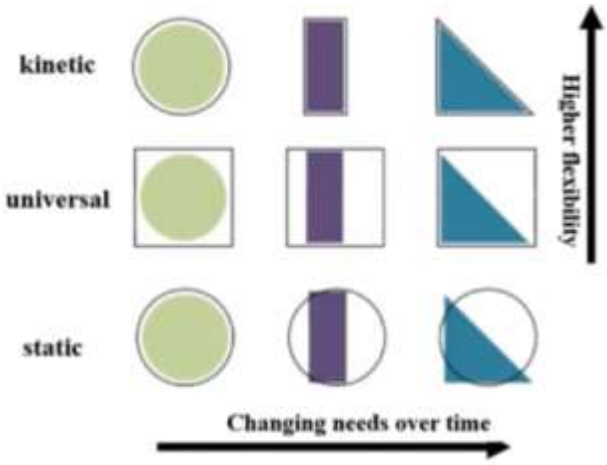


Figure "1" :
Explains the problem of changing needs over time
Source: Zuk 1970. Kinetic Architecture, New York, Van Nostrand Reinhold Company.

3 Theoretical Approach

This section deals with the identification of the main information of the concept of kinetic architecture and its components.

3.1 Types of movement

Term kinetic architecture refers to the concept of buildings design produced by physical movement. The physical movement types, in architecture , is classified into four basic types , Fig.2 :

- **Sliding Movement** : Changes the position of moving elements while its direction remains the same.
- **Rotation Movement** : Changes the direction of the moving elements while remaining in the same position around a rotation central (vertical or horizontal) axis.
- **Hinged (Open – Close) Movement**: Change the direction of the moving elements while remaining in the same position.
- **Folded Movement** : This motion consists of several elements connected to each other that can be folded together to take less space than vacuum compactly.

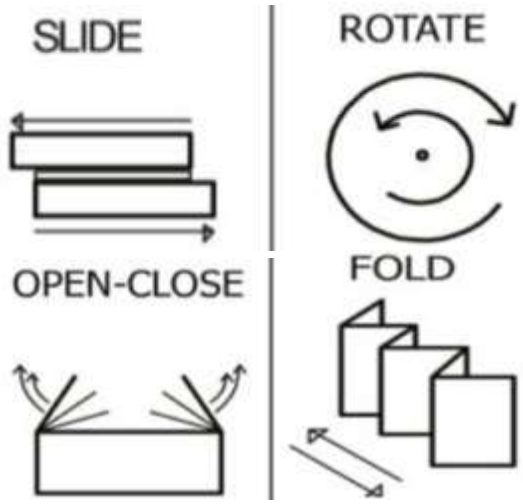


Figure "2":
The physical movement types.
Source: Başar, ,C. 2014. Examination of Space Movements in Physical, Topological and Experiential Contexts, Master Thesis, Istanbul Technical University, Istanbul, Turkey.

3.2 Kinetic architecture components

kinetic architecture consists of five elements:

- Structure.
- Connections.
- Motors.
- Materials.
- Control Mechanism .

4 Kinetic Houses analysis

This section analyzes three international cases , well-known for success , focusing on the fulfilling of user needs, both physical and non-physical, by using appropriate kinetic architecture technology concepts

4.1 Sharifi-ha House (Rotation Movement)

The house is located in the north of the Iranian capital Tehran, designed for a family of four persons. The home is represented both the traditional and contemporary housing of Tehran in term of adaptability to various summer and winter climatic seasons, Fig.3.

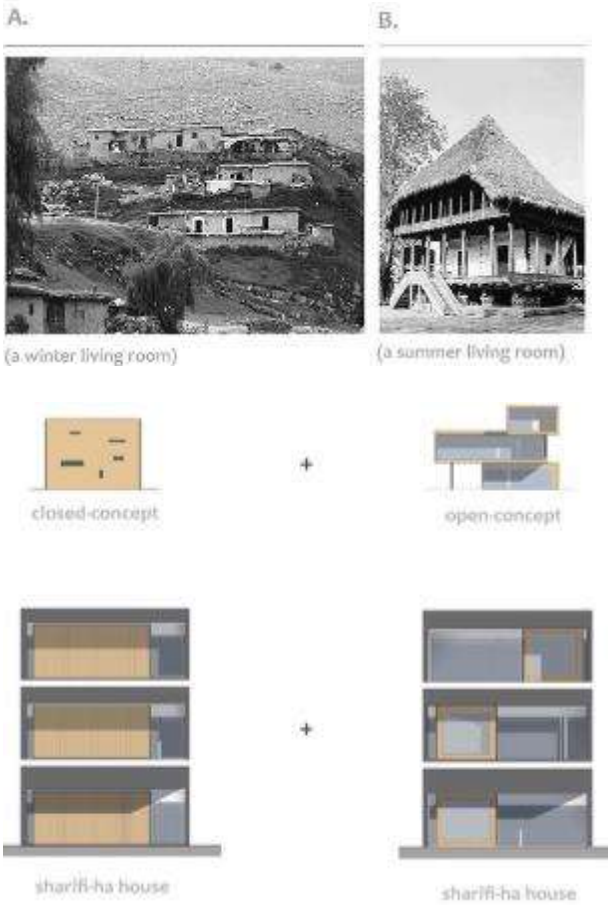


Figure "3":
House Designed to be in line with the culture of the summer and winter Iran's houses and the ability of adapt to climate seasons.
Source:https://www.archdaily.com/522344/sharifi-ha-house-nextoffice

The elevation of the house , like the lot of urban plots , with a remarkably narrow width compared to their depth therefore the designers resorted to the idea of transforming the 2D elevation into a 3D by the movement of the building and the possibility of rotating three 90-degree rooms on the first, second and third floor that allow the closure and

opening of the building and its connection to the street according to the needs of the inhabitants, Fig.4.

Figure "4":
Transforming the 2D elevation into a 3D by the rotation movement 90-degree of three rooms
Source:https://www.archdaily.com/522344/sharifi-ha-house-nextoffice

The house consists of seven floors and has a central vacuum starting from the first separating two blocks where the central vacuum ensures a good flow of light throughout the house when the rooms are closed on the front end .The three kinetic rooms have a dining room on the first floor, a guest room on the second floor, and a home office on the third floor, each with a door from the side that allows access to the balcony when opened and access to the house when closed.

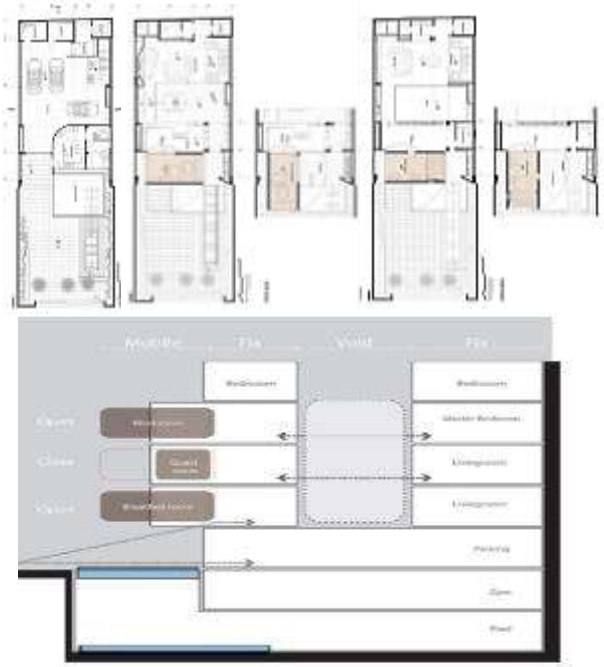


Figure "5": Ground (room and a garage) , first & second floor plans components - Building section consists of seven floors and has a central vacuum.
Source: https://architizer.com/projects/sharifi-ha-house-1/

4.1.1 kinetic Analysis.

- **kinetic Element**

The building has three blocks of 90 degree rotational motion in 1th , 2nd and 3rd floors .

- **Type of movement**

Axial (pivotal) rotational movement.

- **Movement Reasons**

The three blocks move to adapt to different climate seasons to realize the idea of winter and summer homes in Tehran , provide diversity and change in user vision , flexibility in fulfillment functions and increasing terrace space.

- **Kinetic components**

1. Structure

Light skeleton structure system (Bending Moment B.M. structure system) of steel columns and beams installed by a screws and connected to a concrete frame of the building. The structure's design and calculation also took into account the prevention of structural deformation that controls potential vibrations in rotating blocks and thus the stability and balance of structure , Fig.6 .

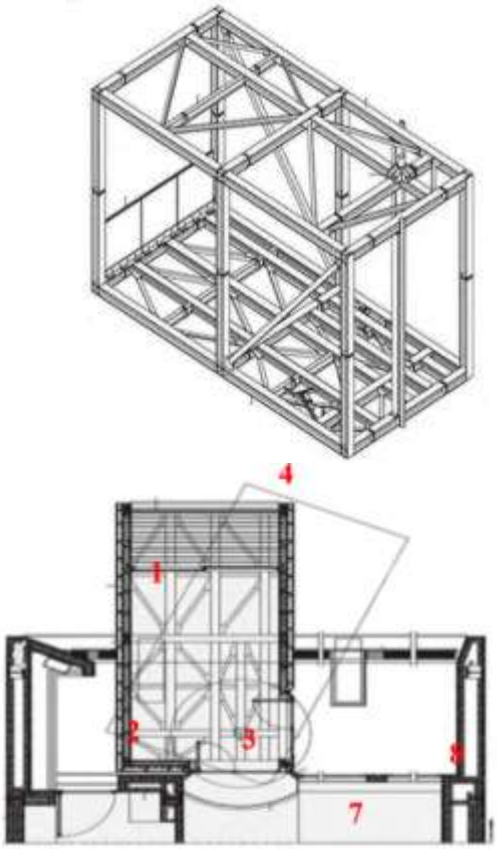


Figure "6": Structural system components and its connection to the building concrete structure
Source:
https://www.archdaily.com/522344/sharifi-ha-house-nextoffice

2. **Connections**

The rotation movement spin by roller bearings and central wedges orbiting the motion axis.

3. **Materials**

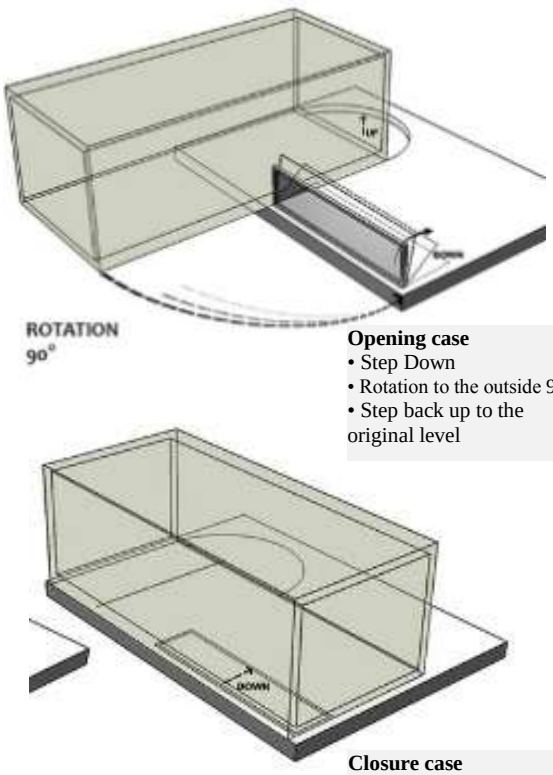
Steel in moving blocks , reinforced concrete RC in building , wood cladding as outer casing for moving blocks and polystyrene in insulation.

4. **Motors**

Blocks move by electric motors that represent the movement source.

5. **Control Mechanisms**

Moving process of the rotating begins with the downward moving step so that the mass can easily rotate, after the rotation of the block at an existing angle, the step begins to return to the top of the same original level of the slab. The terraces are designed with a folding handrails that leans up or down while rotating blocks, to accommodate the changeable, Fig.7 .



Opening case
- Step Down
- Rotation to the outside 90
- Step back up to the original level

Closure case
- Handrail go down.
- Step Down
- Rotation to the outside 90
- Step back up to the original level

Figure "7": Control mechanisms of rotating rooms when closing and opening.
Source:[*https://www.archdaily.com/522344/sharifi-ha-house-nextoffice*](https://www.archdaily.com/522344/sharifi-ha-house-nextoffice)

4.1.2 Analysis of the most important User's Needs (Physical - Non Physical) that positively influenced by kinetic Architecture Technology concepts .

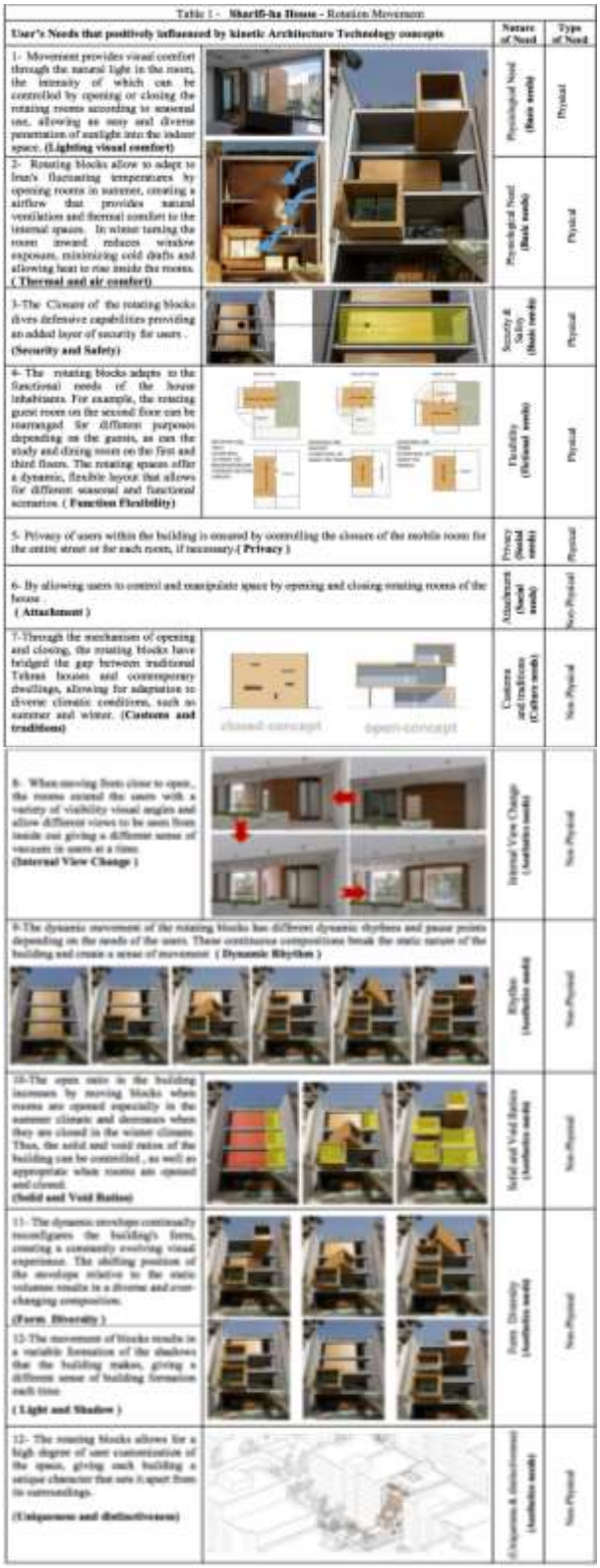


Table .1 Analysis - Sharifi-ha House, focusing on the fulfilling of user's needs by using kinetic Architecture Technology concepts.
Source: Researcher

4.2 Sliding House by DRMM (Sliding Movement)

Sliding House located in East Anglia and the site provided a blend of undulating English countryside and cultivated Dutch farmland, yet its development was restricted by rigorous local regulations governing rural areas. The designer and owner (to retire to, grow food, entertain and enjoy the landscape) appreciated the country houses as the designer took into account strict local planning standards for rural development , Fig.8 .

Figure "8": Site of Sliding house, fixed house and glass house
Source: *https://drmmstudio.com/project/sliding-house/*

The Sliding House is a seemingly simple linear building, sliced into three parts: house, garage and guest annexe. The house has a sliding outer shell that can tie different shapes together to create different containers the house can be extended in the future by adding a swimming pool. As it moves, the sliding element creates changing outdoor living areas between fixed elements as well as changing views, lighting conditions and a sense of structure within the home , Fig.9 .

Figure "9":Outdoor spaces of the sliding house and sheltered terrace when the roof canopy is extended over it.
Source: *https://drmmstudio.com/project/sliding-house/*

The design comprises three conventional building forms with unconventional detailing and exceptional performance. A 28-meter-long building, adhering to the maximum permitted dimensions, is divided into three distinct programs: a 16-meter house, a 5-meter garage, and a 7-meter guest annexe. The garage is offset to create a courtyard. Each building features a unique finish: a red rubber membrane, glass, and red and black stained larch , Fig.10.

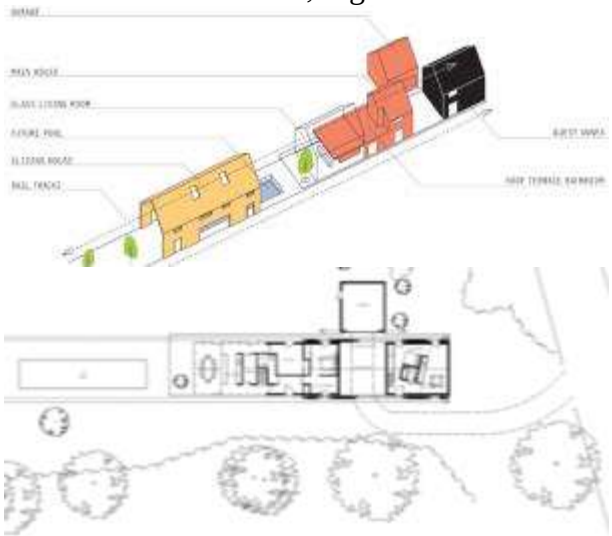


Figure "10": Parts of the sliding house
Source: *https://www.dezeen.com*

4.2.1 kinetic Analysis.

- **kinetic Element**

House has a 20-tonne mobile (sliding) roof/wall enclosure which traverses the site on liner railway tracks.

- **Type of movement**

Linear sliding motion along the building's components , Fig.11.

Figure "11": Type of movement of the sliding house (Linear sliding motion)
Source: *https://www.themodernhouse.com/past-sales/sliding-house/*

- **Movement Reasons**

Sliding House offers radically variable spaces, sunlight and views through its innovative, responsive design. Adjust the cooling and heating loads of the house by seasons casing a different shaded spaces between the building's component parts Controls the level of user privacy depending on the need.

- **Kinetic components**

1. **Structure**

The sliding roof structure is a steel frame (Binding Moment B.M. structure system) with timber infill.

2. **Connections**

Sliding roof travels through sliding linear links (sliding and roller bearings) along iron rails hidden in the cover wall .

3. **Materials**

Steel for the sliding enclosure to capitalize on its durability and lightness, while timber, insulation, and untreated pine were utilized to promote sustainability .

4. **Motors**

Movement is powered by hidden electric motors embedded in wall thickness has a pair of DC car batteries which are charged by power supply or solar photovoltaic panels.

5. **Control Mechanisms**

External casing control automatic remote control moves on rail tracks that can be extended in the future.

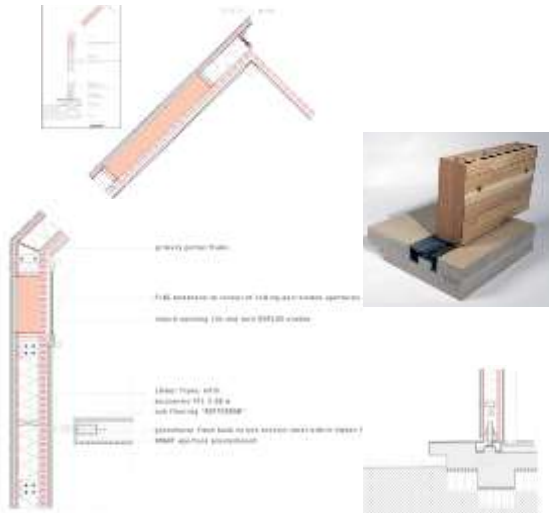


Figure "12": Sliding cover structure system and construction materials
Source:https://www.dezeen.com/2009/01/19/sliding-house-by-drmm-2/

Figure"13":Motor control mechanisms& batteries
Source:*https://drmmstudio.com/project/sliding-house/*

4.2.2 Analysis of the most important User's Needs (Physical - Non Physical) that positively influenced by kinetic Architecture Technology concepts .

Table 2 - **Sliding House by DRMM -** Sliding Movement

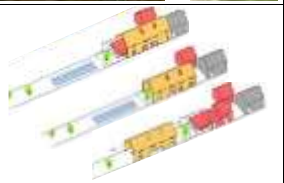
User's Needs that positively influenced by kinetic Architecture Technology concepts		**Nature of Need**	**Type of Need**
1-The sliding roof/wall offers visual comfort by act as a solar shading device, acting as a sunshade between the building's three sections. It can dynamically adjust to shade specific areas or allow sunlight to penetrate the spaces as needed." **(Lighting visual comfort)**		Physiological Need **(Basic needs)**	Physical
2- The sliding envelope is used to regulate the heating and cooling loads of the building according to weather conditions. When it moves to enclose the main building, the annex, and the glass conservatory, it forms an insulating shell for the spaces. **(Thermal and air Comfort)**		Physiological Need **(Basic needs)**	Physical
3-The sliding envelope offer defensive capabilities when closed providing an added layer of security for users specially for the glass part . **(Security and Safety)**		Security & Safety **(Basic needs)**	Physical
4-The concept sliding envelope (roof/wall) that can be partially or fully closed enhances the human need for containment within his house. **(Containment)**		Containment **(Social needs)**	Non-Physical
5- The sliding envelope adapts to various functional needs, seamlessly integrating with the static building. It can slide over the glazed living room, creating covered spaces and open-plan living areas. Additionally, it can extend to form a covered garage or serve as a pool cover, with the potential for future poolside extensions. **(Function Flexibility)**		Flexibility **(Fictional needs)**	Physical
6-The system allows for customized privacy levels as movable envelope provides privacy by covering selected areas of the building, shielding them from view. **(Privacy)**		Privacy **(Social needs)**	Physical
7-The ability of users to customize the space experience through the sliding envelope (roof/wall) operations cultivates a deeper sense of connection with the house . **(Attachment)**		Attachment (Social needs)	Non-Physical
8- The design serves as a symbol of using latest kinetic architecture technology that fulfilled the user needs with respect to the context located in a quiet and landscaped English countryside and cultivated Dutch farmland .(**Symbolism**)		Symbolism (Culture needs)	Non-Physical
9-The dynamic envelope's movements along its tracks, passing through the giant annex, main building, and glass house, exhibit varying dynamic rhythms and pause points according to user needs. These continuous configurations disrupt the static nature of the building, creating a sense of movement . **(Dynamic Rhythm)**		Rhythm (Aesthetics needs)	Non-Physical
10- The design offers a unique spatial experience through the dynamic ratios between solid and void. The sliding envelope increases the building's permeability as it moves to reveal the interstitial spaces between volumes. This allows for dynamic control over the building's openness and enclosure, adapting to the occupants' changing needs . **(Solid and Void Ratios)**		Solid and Void Ratios (Aesthetics needs)	Non-Physical
11- The dynamic envelope continually reconfigures the building's form, creating a constantly evolving visual experience. The shifting position of the envelope relative to the static volumes results in a diverse and ever-changing composition. **(Form Diversity)**		Form Diversity (Aesthetics needs)	Non-Physical
12- The sliding movement produces dynamic shifts in the building's daylighting and shadow patterns, resulting in a constantly evolving visual experience, and this movement creates a visually rich variable interplay when using artificial light . **(Light and Shadow)**		Light & Shadow (Aesthetics needs)	Non-Physical

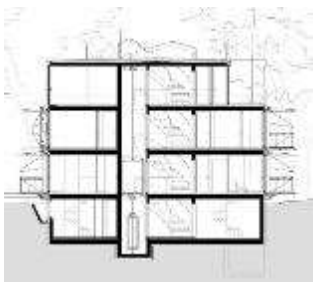
Table .2 Analysis of Sliding House by DRMM, focusing on the fulfilling of user's needs by using kinetic Architecture Technology concepts .
Source: Researcher

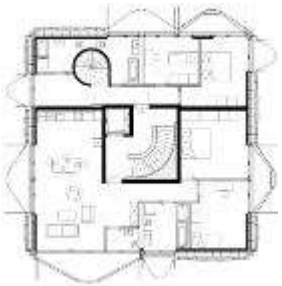
4.3 Ballet Mécanique House (Hinged Open – Close Movement)

The project is located within a residential enclave in the heart of Zurich, proximate to a lake and in close proximity to the Heidi Weber Museum, a dedicated repository of Le Corbusier's oeuvre. A salient feature of the site is its garden , characterized by an unexpected diversity of flora, including spontaneous vegetation, architectural elements, and trees possessing sculptural qualities. A primary design constraint (challenge) was the preservation of the existing arboreal canopy.

Figure"14": Location of Ballet Mécanique
Source:*https://www.archdaily.com/909097/ballet-mechanique-manuel-herz-architects*

Project is a residential building with dynamic facades that can transform into balconies. The building consists of three floors, five residential apartments, in addition to a penthouse floor, studio floors & a basement.





Figure"15": Section reveals a composition of three floors above ground and one basement level. - First plan.
Source: https://www.dezeen.com

4.3.1 kinetic Analysis.

- **kinetic Element**

The dynamic element is represented by metal panels (Shutters) on the facade. On all four sides, the walls open up on two levels to form balconies and colored sunshades.

- **Type of movement**

Articulated – Hinged - movement (open-close) as needed .

- **Movement Reasons**

Panels forming balconies for residential units, while also serving as sunshades for shading . The panels allow users to adjust the level of privacy according to their needs .

Figure“16”: Hinged movement panels (shutters) on the facade (open-close) as needed .
Source: https://www.archdaily.com :

- **Kinetic components**

1. **Structure**

The movable panels are composed of rigid steel cantilever beams (Binding moment B.M. structure system) secured to the facade by hinged joints . Fig .17

Figure“17”: Structure System of movable panels are composed of rigid steel cantilever beams covered with aluminum sheets
Source:https://www.luechingermeyer.ch/en/project/ballet-mecanique-mehrfamilienhaus-lindenstrasse-21-zuerich/

2. **Connections**

The panels are equipped with hinged connection joints that facilitate their articulation (opening and closing).

3. **Materials**

Lightweight steel beams forms the skeleton of the movable panels covered with aluminum sheets and aluminum railings for balcony slabs.

4. **Motors**

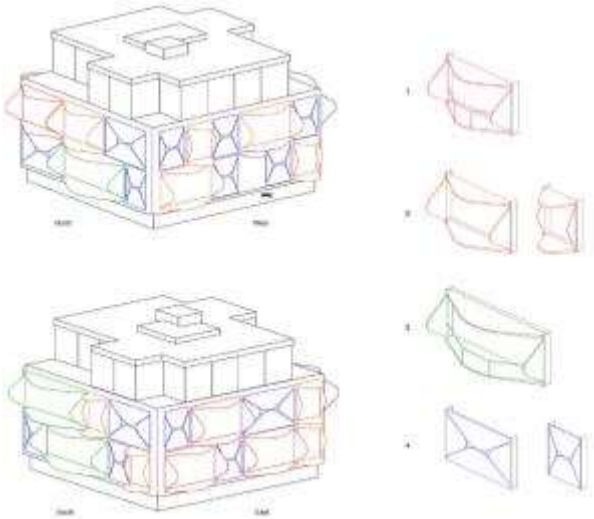
The movement is actuated by electric motors concealed within the building's structure, and motor control ensures remarkably smooth and synchronized motion.

5. **Control Mechanisms**

The balconies are equipped with an automated mechanism located directly in front of the living rooms of each residential unit. The sliding mechanism of balconies railings ensures user safety at all times, as the railing must be extended before accessing the balcony and cannot be retracted until the railing is pulled back, guaranteeing that the balcony is unoccupied.

Balcony slabs, canopies, shutters as well as the necessary railings are part of the

mechanization of the “Ballet”. According to the user’s needs, these elements can be optionally closed and partially or fully opened until the accessibility of the balconies is achieved . Fig .18



Figure“18”: Movable panels can be adjusted to four different positions: fully closed, in motion, partially open, or fully open
Source:https://www.archdaily.com/909097/ballet-mechanique-manuel-herz-architects

4.3.2 Analysis of the most important User’s Needs (Physical - Non Physical) that positively influenced by kinetic Architecture Technology concepts .

Table 3 - **Ballet Mécanique House** - Hinged movement (open-close)

User's Needs Description		Nature of Need	Type of Need
1-The building offers visual comfort by dynamically adapting natural light levels within the spaces. The use of operable panels allows for precise control of sunlight penetration, catering to the varying needs of different seasons and occupants. offers (**Lighting visual comfort**)		Physiological Need (Basic needs)	Physical
2-The movable panels enable users to adapt to varying temperatures by allowing them to be closed during winter to retain heat and opened during summer to provide ventilation and shade. As such, the panels function as dynamic sunshades that meet the changing needs of users. (**Thermal and air Comfort**)		Physiological Need (Basic needs)	Physical
3-The movable, steel constructed, panels offer defensive capabilities when closed, providing an added layer of security for users and the sliding handrail mechanism incorporates a safety feature that prevents the balcony from closing unless the handrail is fully retracted, ensuring that the space is unoccupied. **(Security and Safety)**		Security & Safety (Basic needs)	Physical
4-The concept of movable panels that can be partially or fully closed enhances the human need for containment within the home, providing a sense of security and privacy . (**Containment**)		Containment (Social needs)	Non-Physical
5-The system's adaptability (movable panels) enables the transformation of small panels into stationary balconies for bedrooms. **(Flexibility in adapting to different functions)**		Flexibility (Technical needs)	Physical
6-The system allows for customized privacy levels by enabling users to fully or individually close of the movable panels. (**Privacy**)		Privacy (Social needs)	Physical
7-The ability of users to customize the space experience through movable panel operations cultivates a deeper sense of connection and affiliation with the building. (**Attachment**)		Attachment (Social needs)	Non-Physical

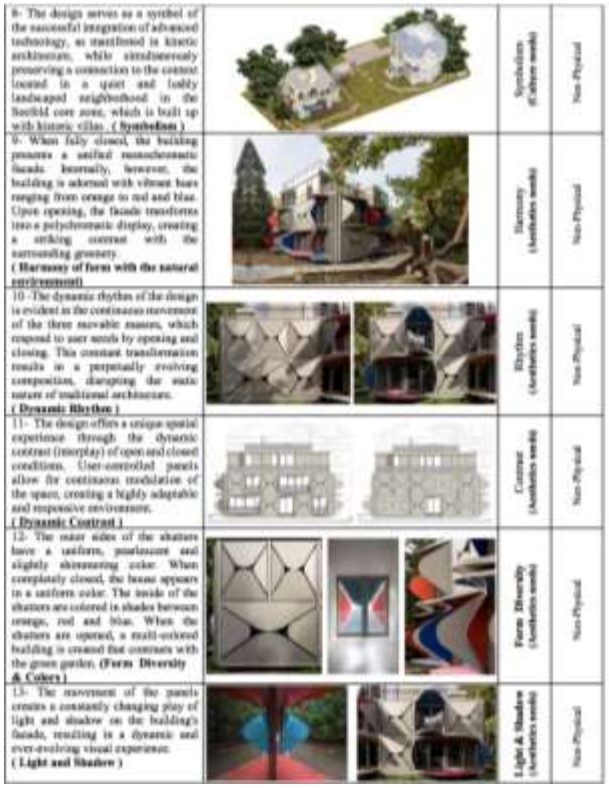


Table .3 Analysis of Ballet Mécanique House, focusing on the fulfilling of user's needs by using kinetic Architecture Technology concepts.
Source: Researcher.

5. Results of the Case Studies Analysis.

Table .4 presents analysis results of appropriate kinetic Architecture Technology and its impact on the fulfilling of user needs (Physical - Non Physical) for the three case studies [**Sharifi-ha - Sliding House by DRMM - Ballet Mécanique**].

Table 4 – Results of the case studies analysis of movement impact on users' needs

Building Name			**Sharifi-ha House**	**Sliding House by DRMM**	**Ballet Mécanique House**
Building picture					
Movement type			**Rotation Movement**	**Sliding Movement**	**Hinged movement (open-close)**
User Needs	Basic needs	**Physiological needs** *1- Lighting visual comfort 2- Thermal and air comfort*	✓	✓	✓
		Type of Need	*Physical*	*Physical*	*Physical*
		Security and Safety	✓	✓	✓
		Type of Need	*Physical*	*Physical*	*Physical*
	Functional needs (Flexibility)		✓	✓	✓
		Type of Need	*Physical*	*Physical*	*Physical*
	Social needs	**Containment**	×	✓	✓
		Type of Need	×	*Non - Physical*	*Non - Physical*
		Privacy	✓	✓	✓
		Type of Need	*Physical*	*Physical*	*Physical*
		Attachment	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
	Culture needs	**Symbolism**	×	✓	✓
		Type of Need	×	*Non - Physical*	*Non - Physical*
		Customs and traditions	✓	×	×
		Type of Need	*Non - Physical*	×	×
	Aesthetics needs	**Dynamic Rhythm**	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
		Uniqueness & distinctiveness	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
		Form Diversity	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
		Solid and Void Ratios	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
		Internal View Change	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*
		Light & Shadow	✓	✓	✓
		Type of Need	*Non - Physical*	*Non - Physical*	*Non - Physical*

6. Conclusion

The study sought to demonstrate the significant important and potential of appropriate kinetic Architecture Technology in fulfillment the changing of user needs of houses. Through an analysis diverse case studies of kinetic houses, the study has pinpointed five core user needs (Basic, Functional, Social , Culture and Aesthetics needs) that can be adequately fulfilled by existing appropriate kinetic architecture technologies can effectively meet on both physical and non-physical (psychological) levels. Consequently, kinetic architecture, equipped with available and appropriate technologies, emerges as a promising solution to accommodate the dynamic requirements of residential users.

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