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ANTI-EPIDEMIC ARCHITECTURE STRATEGIES "COVID 19 AN ENTRANCE TO THE DESIGN OF A PREVENTIVE ARCHITECTURAL PRODUCT"

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Abstract

Despite the development of medicine, architecture is one of the most important methods of preserving human life from environmental and climatic conditions as well as human threats, including epidemics, especially during the escalation of the seriousness of the COVID-19 pandemic in the world. Accordingly, the research problem was represented by the following: There is a lack of knowledge about anti-epidemic architecture strategies, characteristics and its standards to reach an architectural product that supports the quality and continuity of social life, The aim of the research was to reveal the role of epidemics in formation the architectural product. the research approach is analysing to clarify anti-epidemiological architecture through building a knowledge framework, then a comprehensive theoretical framework extracted from architectural propositions to be embodied in its final form in Three main vocabulary, namely: "anti-epidemic architecture strategies, anti-epidemic architecture characteristics, standards of evaluation anti-epidemic architecture". It has been applied to the elected projects to clarify the extent to which these indicators have been achieved and to reach conclusions that explained architects are more inclined towards technology strategies to anti-epidemic than urban and architectural strategies, while transformation is the dominant characteristic in architectural product preventive compared to mobility and adaptation.

Keywords: Anti-epidemic architecture strategies, Anti-epidemiological architecture, Characteristics, Epidemic, Standards of evaluation.

1. Introduction

An epidemic is an outbreak of a disease that spreads quickly and affects many individuals at the same time, if it spreads to other countries or continents, it may be termed a pandemic such as COVID-19. Several studies have dealt with the concept of epidemics in architecture, but they have not addressed in terms of its strategies, characteristics, and evaluation standards. Accordingly, the research problem was represented by the following: There is a lack of knowledge about anti-epidemic architecture strategies, characteristics and its standards to reach an architectural product that supports the quality and continuity of social life, the aim of the research was to reveal the role of epidemics in formation the architectural product, this topic is guideline of how design healthy architectural environment. In order to solve the research problem, divide his structure into three axes. The first: It includes building the knowledge framework of anti-epidemic architecture. The second focused on building the theoretical framework through analysis of the literature and previous studies. third: it deals with the elected projects for the purpose of application.

2. The Knowledge Framework of the Research

The axis discusses anti-epidemiological architecture through four main areas, namely: Its definition, principles, patterns, and applications.

2.1. Anti-epidemiological architecture

The interpretation of epidemiological architecture includes two possibilities: First, it is the process of designing spatial buffer buildings according to strategies, characteristics and standards that achieve health security from epidemics and limit their spread before people can return to society. Secondly, the process of converting either underused or abandoned buildings or temporarily unused buildings into places to house people in a quarantine [1]. The research focuses on the first definition, which means it strategy based on the integration of the architectural product in treatment and prevention.

2.2. Principles of anti-epidemic architecture

Anti-epidemic architecture has three main principles, namely:

- Providing the basic functions for epidemic prevention and control: Include natural ventilation, indoor disinfection, waste management, changing the room function when necessary to medical rooms for isolation.
- Reducing the risk of infection and preventing cross-infection: The building itself must also “isolate” the virus by controlling the exhaust flow of kitchens and bathrooms and putting in place effective watertight seals to reduce the risk of virus transmission through sewage pipes, conditioning system by zones. These architectural features - the smooth surfaces of the architecture, streamlined forms, a rejection of ornamentation, and disavowing clutter where dust could linger and become vectors of disease.
- Protecting the health of occupants: Use green building materials with an anti-bacterial function to reduce the risk of disease, the broad implementation of automated touchless technologies - such as "voice-activated elevators, hands-free light switches" [2, 3].

These principles sense the existence of potential dangers that threaten human life, regardless of their type or size, and work on their own to treat or quarantine them until that time. therefore, a set of anti-virus strategies were adopted, as shown in the following examples:

- CURA Project in Italy: The hospital's design was based on transitions from shipping containers to intensive care units as well as MOBILE PPS (Personal Protective Space) that a space where doctors can treat patients in a protective space.
- Vegetable market in Indonesia: The design of the market is based on the concept of social distancing, as the spaces are divided in sequence manner as a strategy to limit the spread of the virus [4] as shown in Fig. 1.

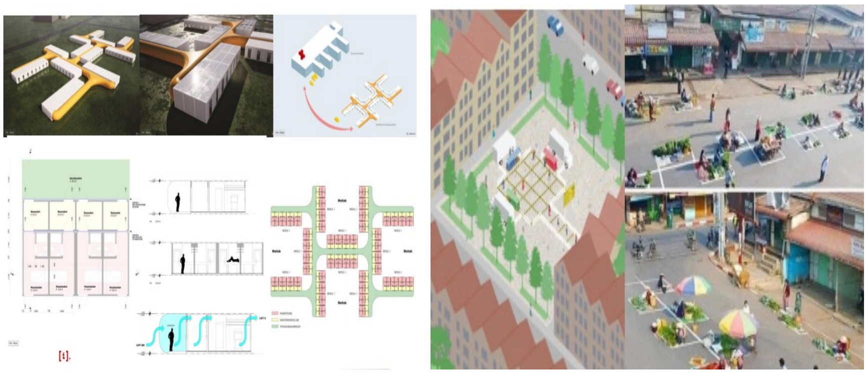

Fig. 1. CURA and vegetable market projects [4].

2.3. Anti-epidemic architecture patterns

Anti-epidemic architecture is classified into three patterns:

- Existing health buildings pattern (hospitals): The COVID-19 pandemic has revealed on the importance of increasing the number of beds in hospitals. Explaining several mechanisms, including design a room with negative air pressure, design an Airborne Infection Isolation Room (AIIR), reuse corridors in critical situations.
- Alternative buildings pattern: It will require rapid physical and operational adjustments, include Hotel rooms, its need to be rehabilitated where Isolating the ground floor from the rest of the building while the elevator determines the access of caregivers only, and hotel corridors are 5 or 6 feet wide this means a hotel with 24 rooms on a floor may be able to support only 10 to 12 patients provided that they are equipped with HEPA filter machines. Homes, it's used to quarantine people with stable non-dangerous conditions, if it is used for critical cases, a high-efficiency temporary filter machine HEPA is required to purify the air surrounding the patient's bed.
- Erecting temporary structures pattern: It is concerned with building alternative sites quickly such as tent hospitals such measures were possible because of advanced planning and the flexibility in build [5] as shown in Fig. 2.

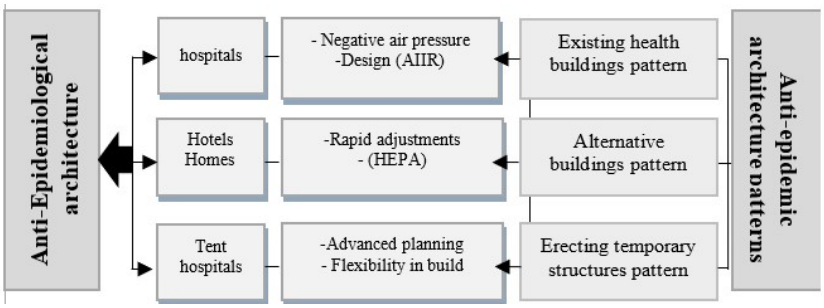

Fig. 2. Anti-epidemic architecture patterns.

2.4. Applications anti-epidemiological architecture:

Building with new methods to combat the disease has been effective in mitigating the spread of the disease, as is the case with sanitation and water infrastructure which helped reduce transmission of some diseases. Especially that planned housing fights disease. Also, infectious diseases are one of the engines of housing reform and the era of regeneration, where the overcrowded living conditions in housing have become considered "fever nests" and "lung masses" due to the high rates of the population infected with tuberculosis [6], we will demonstrate two practical examples of epidemic-fighting architecture as shown in Table 1.

Table 1. Applications of anti-epidemiological architecture.

	The Lovell Health House in Los Angeles	**Villa Savoye in Paris**
Definition	It is the gleaming, all-white modernist house is bathed in sunlight and has floor-to-ceiling windows throughout. Its architect - Richard Neutra designed it in the late 1920s for Philip Lovell, His house is designed for a healthy lifestyle and takes its signs from buildings designed to treat tuberculosis.	The Villa Savoye, an influential modernist house, design by Le Corbusier that viewed light and air as being medicinal, and it is smart home can read your temperature and it knows you can't go out Depending on the symptoms of the disease.
Philosophy	Use the built environment or space to control epidemic spread, in this project, TB treatment is provided by design, including large windows, balconies and flat surfaces that do not collect dust, white paint, and dry air ventilation.	It's depended on Quarantine, it's almost like an algorithm of adding space and time and preventing something from encountering us immediately, it means the activation of a technical program to detect epidemiological obstacles in the community to reduce them by Architectural Design & urban.
Picture		

Although the previous literature provides a knowledge base and a suitable area to invest in building a theoretical framework, strategies anti-epidemic architecture has not been clarified; So, the need arose for his study, and this will be done in the second axis.

3. Building the Theoretical Framework

This topic deals with the presentation of a set of previous studies to extract the vocabulary of the main and secondary theoretical framework and its possible values. The previous studies are outlined in Table 2.

Table 2. Outlining of the literature reviewed.

	The Cognitive subtraction of the study
[7]	The study showed the strategies of anti-epidemic architecture: • spaces purposefully design, we need designers to question the long-term implications of the spatial decisions we are making now to help in the prevention, containment, and treatment of infectious disease, including COVID-19. • Design rapid temporary structures as a medical clinic. • Design surface antimicrobial and to reduce the porosity of fabrics to prevent the spread of pathogens, where Studies are showing that coronavirus is more stable on plastic and steel (up to three days) than on porous fabrics like cotton, leather, and even cardboard (less than 24 hours). • Design isolation units, ventilation systems, windows, and filters [7].
[8]	The study explains a set of strategies to control epidemics: • Elastic City. It can open its borders to everyone in moments of peace and prosperity, and this city itself should be able to close its borders and divide it into small, isolated, self-reliant groups during times of health emergency. • Distributed Urbanism. The city is distributed among its inhabitants across time and space. City areas are made available only to certain people at certain times of the day, and on certain days of the week or month. In this way contact and pollution can be reduced. Flexible City is concerned with the distribution and proximity of the place. Whereas "Distributed Urbanism" is more concerned with time. • Urban Clusters. If we divide the city into self-reliant groups, the area of each cluster for entry or exit may be closed, but within each of them, life can continue to close to normal. • Balconies. It is a tool to communicate with the outside world and create a sense of society while preserving social spaces. • Green Roofs. Accessible green roofs should be an option in every building to provide a distributed natural space for social life mainly protected from the outside. This can help to expand the space available for families that share narrow urban living conditions and can help people's psychological life.[8]
[9]	The study discussed the characteristics of epidemic-resistant architecture: 1. flexibility: A space formation property to accommodate possible future changes. It includes three sub characteristics, namely**:** Transformation, refer to buildings are capable to change their shape, area, appearance through the physical alteration of their structural components, external shell, or internal surfaces, according to environmental or epidemiological conditions based on the technological systems which are divided into: input, processing, and output (IPO) devices**.** Mobility, refer to buildings that can physically move from one place to another. Its usefulness lies in Relief of the sick or injured in disasters **.**Adaptation, refer to buildings that can accommodate various functions specified by users' activities in critical situations. 2. Responsive: an efficient building model conversion Characteristic that responds to Environmental and epidemiological conditions. It is composed of

	intelligent frames, structures, and skins. The response could be a change in the building shape and its physical characteristics by simulating bionic performances of consumers and natural systems. It includes several mechanisms, including adaptive shape, interactive technological systems [9].
[10]	The study clarified epidemic control technologies as "it is preparedness for what is forecasted as an unpreventable event of disease emergence leading to a pandemic", and the study focused on the technological aspects of disinfection of interior spaces using disinfection devices, early warning techniques, surveillance, and Sentinels issue signs of an invisible threat as an infection control strategy. While it has been proven that preparedness has transformative effects on the hospital, the hospital spaces are divided into three categories, "contaminated area, clean area, and sharp area", each of which requires "a specific set of personal protective equipment as well as surfaces and pressure [10].
[11]	The study discussed the standards of evaluating isolation facilities: • Basic infrastructure requirements • Ventilation: Single pass ventilation for each room or isolation area • Accessibility considerations: (proximity to the hospital, parking lots, easy access to food and medical supplies) • Space requirements: (Multiple rooms for patients, Clinical staff areas, waste and pollution laundry area, laundry facilities, Meal preparation, Accessible bathroom • Social support resources such as Television and internet • Mechanisms for communication, including telephone (for monitoring, reporting of symptoms and communicating with family • mental health and other psychological support services [11].

The vocabulary of the main and secondary theoretical framework and possible values can be crystallized as it was extracted from the knowledge framework and previous literature, as shown in Table 3.

Table 3. Explains the main and secondary vocabulary of the theoretical framework.

Main Vocabulary		Secondary vocabulary and possible values		Symbol	Reference
Anti-epidemic architecture strategies	Physical strategies x.1.1	Urban strategies	Elastic city	X.1.1.1	[8]
			Distributed Urbanism	X.1.1.2	
			Urban Clusters	X.1.1.3	
		Architectural strategies	Spaces purposefully design	X.1.1.4	[7]
			Balconies design	X.1.1.5	
			Green Roofs design	X.1.1.6	
			Design of rapid temporary structures	X.1.1.7	
			Smooth surfaces design	X.1.1.8	
			Green antimicrobial surface design	X.1.1.9	
	Technology strategies	Disinfection techniques		X.1.2.1	[10]
		Early warning techniques		X.1.2.2	
		Surveillance techniques		X.1.2.3	
		Voice-activated elevators techniques		X.1.2.4	
		Hands-free light switches techniques		X.1.2.5	

		Filter Machine Design (HEPA)		X.1.2.6	
Anti-epidemic architecture characteristic X.2	Flexibility X.2.1	Transformation	Isolating spaces	X.2.1.1	[9]
			Reuse corridors	X.2.1.2	
			Subdivision of spaces: "contaminated & clean"	X.2.1.3	
		Mobility	Tent hospitals	X.2.1.4	
			Alternative buildings: (Hotel, Office, Home.)	X.2.1.5	
			Isolation units design	X.2.1.6	
		Adaptation	Negative air pressure space design	X.2.1.7	
			Airborne Infection Isolation Room design	X.2.1.8	
	Responsive X.2.2	Electronic systems simulation		X.2.2.1	
		Natural systems simulation		X.2.2.2	
Standards of evaluation anti-epidemic architecture X.3	Basic infrastructure requirements			X.3.1	[11]
	Ventilation systems X.3.2	Single pass ventilation		X.3.2.1	
		Non - recirculating ventilation		X.3.2.2	
		Conditioning system by zones		X.3.2.3	
	Access considerations X.3.3	Proximity to the hospital		X.3.3.1	
		Parking places		X.3.3.3	
		Easy access to medical supplies		X.3.3.3	
	Space Requirements X.3.4	Multiple rooms for patients		X.3.4.1	
		Clinical areas		X.3.4.3	
		Contaminated waste area		X.3.4.3	
		Laundry facilities		X.3.4.4	
		Multiple bathroom		X.3.4.5	
	Social support resource			X.3.5	
	Mechanisms for communication			X.3.6	
	psychological support services			X.3.7	

It is clear from the above, the existence of three main vocabulary of research:

- Anti-epidemic architecture strategies X.1: When architectural spaces are conceptualized and designed with a clear goal, such space can promote or aid the inhibition of infectious diseases. Whether it is urban or architectural strategies such as design for social distancing depending on the elasticity of the walls, and design to enhance natural ventilation by design approach (open-end corridor and courtyard) increases ventilation rate thereby reducing the risk of infection significantly, in addition to design with adaptive finishing materials shows that coronavirus is steadier on plastic and steel (up to 3 days) than on spongy fabrics like cotton, even cardboard (<24 h), while the same strain of the virus only survives for (4) hours on copper surfaces. Thus, specify copper-infused, or plated materials for frequently touched surfaces such as staircase handrails, balcony rails [12].

- Anti-epidemic architecture characteristics X.2: A healing design approach that could be implemented in the post-pandemic era in building, its addition security layers through trying to reshape our flexibility physical spaces across transformation, mobility, and adaptation to reduce the spread of epidemics.
- Standards of evaluation anti-epidemic architecture X.3: Design of quarantine buildings for infected persons or probable of covid-19 disease to reduce the spread of epidemic. whether it's existing health buildings (hospitals), or alternative buildings (temporary structures). It must be including several criteria including basic infrastructure requirements, single pass ventilation, conditioning system by zones, space requirements such as multiple rooms for patients and bathrooms in addition to psychological support services [13]. Note the following Fig. 3.

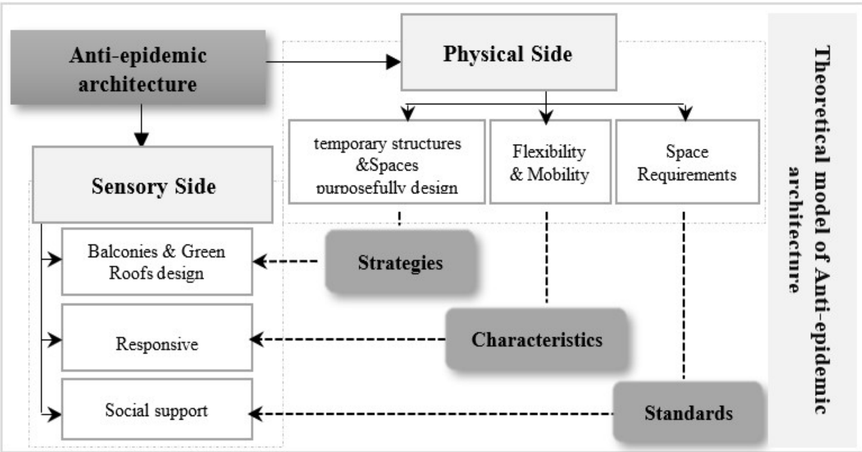

Fig. 3. Sides of anti-epidemic architecture physical and sensory.

The practical study requires submitting to a qualitative measurement, where all vocabulary will be measured anti-epidemic architecture strategies in the elected projects, depending on symbol (1) to indicate verification and symbol (0) for non-verification, as shown in Table 4 and Fig. 6.

4. Applications

4.1. Application to samples

To verifying the research hypothesis that came in the following form: "Epidemics have an impact on the designer by directing him towards specific strategies, characteristics or standards in anti-epidemic architecture", the criteria for selecting projects included several aspects, the most important of which are:

- The selected projects belong to different spatial contexts, and they have the information base and the necessary plans to describe and analyse them, which enhances the desired results of the research.
- The selected projects belong to the same period, which witnessed the spread of many epidemics as SARS and COVID-19, therefore it relied on strategies, characteristics, and anti-epidemic standards.

4.1.1. Bee’ah headquarters in Sharjah

An environmental office building in Sharjah designed by Zaha Hadid, it is design from a series of decentralized sand dunes to antibacterial brass doorknobs to limit the spread of epidemics where form has always followed fear of infection. Also, it has been design “contactless pathways”, this means that employees rarely have to touch the roof with their hands to move through the building, elevators can be called from a smartphone, while office doors open automatically with motion sensors that form an invincible shield against this invisible enemy. Finally, the area of office furniture has been increased from 1.4m to 1.8m and more because people will not want to sit close to each other [14] as shown in Fig. 4:

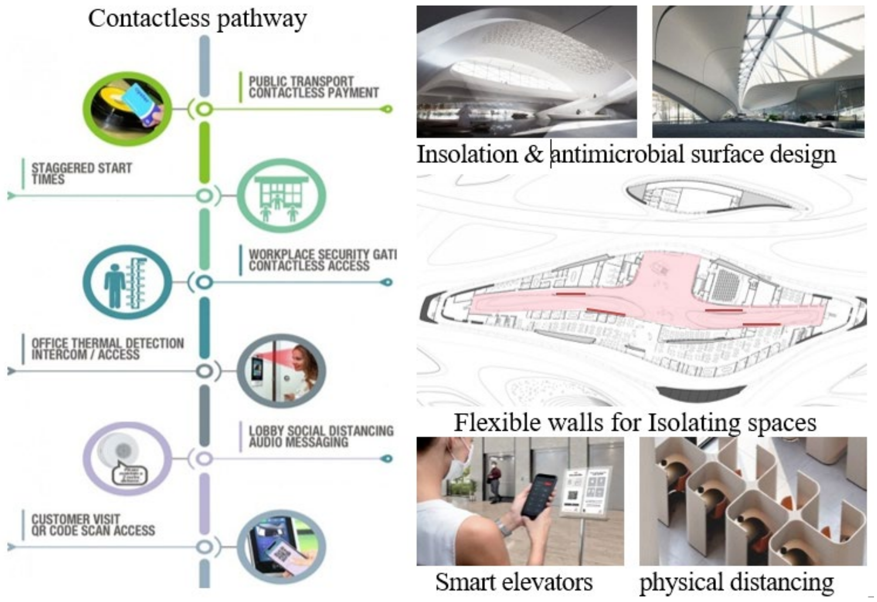

Fig. 4. Bee’ah Headquarters [14].

4.1.2. Cyber house life in Russian

Russian architects designed a house project that includes an internal disinfection system with the ability to protect its interior in extreme emergencies, and the area of the house is 1370 square meters and can fit 6 to 10 people in the event of a disaster. It is made with heavy-duty steel and integrated radiation and microbiological protection systems. as well as the protection system is similar to the laboratory room system, where people enter the house through a "sterilization corridor", and each is sprayed with sterilization materials to remove dust or animal pathogens such as coronavirus. It also contains an independent heat pump that controls home temperature, and the walls of the house are tilted to keep out intruders for more safety [15] as shown in Fig. 5.

4.2. Analyzing and discussing the results

The paragraph explains the most important indications of the results of the application on the selected samples:

- Results of (anti-epidemic architecture strategies - X.1): Their percentage is (37.5%), the indicators achieved (X.1.1.4-X.1.1.5-X.1.1.8-X.1.1.9-X.1.2.1-X.1.2.2-X.1.2.3) (100%) in the projects, and the percentage of verification of indicators decreased (X.1.1.1-X.1.1.2-X.1.1.3-X.1.1.6-X.1.2.4-X.1.2.5) to (50%) in projects, while the existence of the indicators (X.1.1.7-X.1.2.6) was not achieved.
- Results of (anti-epidemic architecture characteristics - X.2): Its percentage (25%), the indicators achieved (X.2.1.1-X.2.2.1) (100%) in the projects, in addition to the decrease in the ratio of the indicators (X.2.1.2-X.2.1.3-X.2.1.6) to (50%) only, and finally the existence of the indicators (X.2.1.4-X.2.1.5-X.2.1.7-X.2.1.8-X.2.2.2) was not achieved.
- Results of (standards of evaluation anti-epidemic architecture -X.3): Its ratio is (37.5%), the indicators achieved (X.3.1-X.3.2.1-X.3.2.2-X.3.2.3-X.3.3.2-X.3.4.5-X.3.5-X.3.6) with a percentage (100%) in the projects, and the ratio of verification of the four indicators decreased (X.3.3.3-X.3.4.1-X.3.4.2-X.3.4) to (50%), while the existence of the indicators (X.3.3.1-X.3.4.3-X.3.7) was not achieved, as shown in Table 4 and Fig. 6.

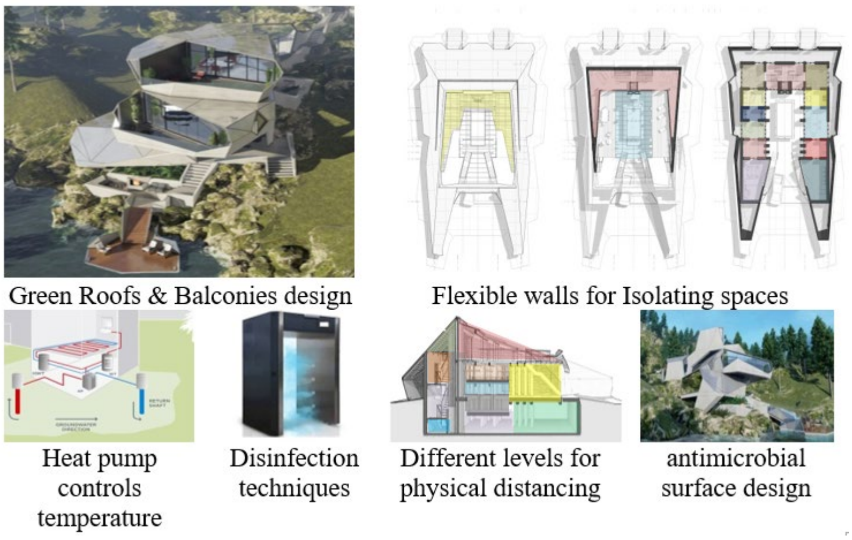

Fig. 5. Cyber house life [15].

Table 4. Project analysis (A, B).

Symbol	X.1.1.1	X.1.1.2	X.1.1.3	X.1.1.4	X.1.1.5	X.1.1.6	X.1.1.7	X.1.1.8	X.1.1.9	X.1.2.1	X.1.2.2	X.1.2.3	X.1.2.4	X.1.2.5	X.1.2.6	X.2.1.1	X.2.1.2	X.2.1.3	X.2.1.4	X.2.1.5
A	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	0
B	0	0	0	1	1	1	0	1	1	1	1	1	0	0	0	1	0	1	0	0
Total	50%	50%	50%	100%	100%	50%	0%	100%	100%	100%	100%	100%	50%	50%	0%	100%	50%	50%	0%	0%

Symbol	X.2.1.6	X.2.1.7	X.2.1.8	X.2.2.1	X.2.2.2	X.3.1	X.3.2.1	X.3.2.2	X.3.2.3	X.3.3.1	X.3.3.2	X.3.3.3	X.3.4.1	X.3.4.2	X.3.4.3	X.3.4.4	X.3.4.5	X.3.5	X.3.6	X.3.7
A	0	0	0	1	0	1	1	1	1	0	1	0	1	1	0	0	1	1	1	0
B	1	0	0	1	0	1	1	1	1	0	1	1	0	0	0	1	1	1	1	0
Total	50%	0%	0%	100%	0%	100%	100%	100%	100%	0%	100%	50%	50%	50%	0%	50%	100%	100%	100%	0%

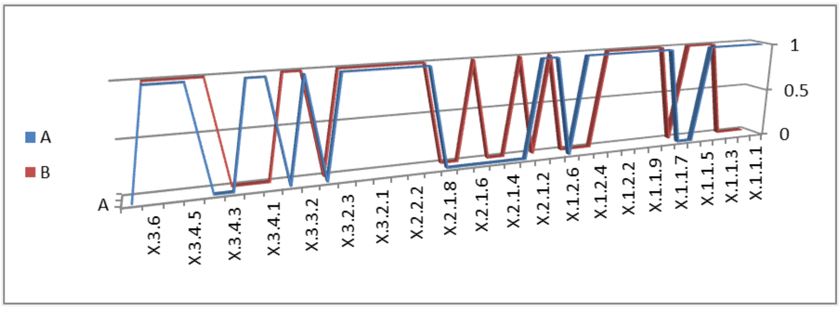

Fig. 6. The percentages of the vocabulary verification of the theoretical framework in the elected projects.

5. Conclusions

This paragraph deals with the most prominent conclusions that have been reached through the theoretical and practical sides, which are as follows:

- The relationship between the influencer (epidemics) and the affected (the community) is a direct (positive), while the relationship between (design) and the (epidemic) Is an inverse relationship, the higher the rate of preventive response through the strategies and characteristics as well as the design standards for anti-epidemic architecture, the lower the percentage of epidemics in the community.
- Epidemics affect the formation of architectural products: In terms of form, the design of balconies and roof garden is maintaining human contact despite the spacing, while functionally determining the level of flexibility in dividing spaces through the design of partitions and the different levels in buildings.
- The relationship between the strategies of the anti-epidemic architecture and their characteristics is associative, where spaces design linked with flexibility characteristic, while linked temporary structures with Responsive characteristic in addition to correlation balconies and green roofs design with adaptation as a strategy to reduce the spread of epidemics.
- The results of the application showed that architects are more inclined towards technology strategies to anti-epidemic than urban and architectural strategies, despite their limited effectiveness and high cost.
- Transformation is the dominant characteristic in architectural product anti-epidemics compared to mobility and adaptation, while the response characteristic is created in buildings that are not resistant epidemic in emergencies.
- The standards for evaluating anti-epidemic architecture are based on two sides, one for space and the other for the occupant.

Abbreviations

AIIR	Airborne Infection Isolation Room
HEPA	High efficiency particulate air
PPS	Personal Protective Space
SARS	Severe Acute Respiratory Syndrome

References

1. Jacobs, K. (in press). The architecture of quarantine is no longer a thing of the past. *The Journal of The American Institute of Architects*.
2. World Green Building Council. (2020). The contribution of green buildings in the fight against COVID-19. Retrieved March 14, 2021 from https://www.worldgbc.org/news-media/contribution-green-buildings-fight-against-covid-19.
3. Chang, V. (2020). The post pandemic style. Retrieved April 19, 2020, From https://slate.com/business/2020/04/coronavirus-architecture-1918-flu-cholera- modernism.html
4. Al-Yousif, I.J.K.; and Albawi, A. (2020). Architectures are unified at time of the epidemic: Anti-virus architecture between the epidemic thought and its image. *Iraqi Journal of Architecture and Planning*, 4(13), 2-10.
5. Hercules, W.J; Anderson, D.; and Sansom, M. (in Press). architecture is a critical ingredient of pandemic medicine. *The Journal of the American Institute of Architects.*
6. Budds, D. (2020). Design in the age of pandemics. Retrieved Mar 17, 2000, from https://www.curbed.com/2020/3/17/21178962/design-pandemics-coronavirus-quarantine
7. Murphy, M. (2020). The role of architecture in fighting a pandemic. Retrieved April 6, 2000, from https://www.bostonglobe.com/2020/04/06/opinion/role-architecture-fighting-pandemic.
8. Albretch, B. (2020). Pandemics & Architecture Retrieved October 23, 2021, From https://www.cafx.dk/post/pandemics-architecture.
9. Elmokadem, A.; Eleinen, O.M.A.; Aly, R.H.; and Ezz-Eldien, D.A. (2019). Flexibility and sustainability in architectural design concept. *International Journal of Innovative Research in Science, Engineering and Technology*, 8(6), 6795-6803.
10. Lynteris, C.; and Poleykett, B. (2018). The anthropology of epidemic control: Technologies and materialities. *Medical Anthropology*, 37(6), 433-441.
11. CDC (2005). *Public health guidance for community-level preparedness and response to severe acute respiratory syndrome (SARS) version 2 appendix d3: Guidelines for evaluating homes and facilities for isolation and quarantine*, Centers for Disease Control and Prevention, United States of America.
12. Emmanuel, U.; Osondu, E.D.; and Kalu, K.C. (2020). Architectural design strategies for infection prevention and control (IPC) in health-care facilities: Towards curbing the spread of Covid-19. *Journal of Environmental Health Science and Engineering*, 18(2), 1699-1707.
13. Megahed, N.A.; and Ghoneim, E.M. (2020). Antivirus-built environment: Lessons learned from Covid-19 pandemic. *Sustainable Cities and Society*, 61, 102350.
14. Wainwright, O. (2020). Smart lifts lonely workers no towers or tourists: Architecture after coronavirus. Retrieved April 13, 2020, from https://www.theguardian.com/artanddesign/2020/apr/13/smart-lifts-lonely-workers-no-towers-architecture-after-covid-19-coronavirus
15. Canales, K. (2020). Take a look at the cybertruck-inspired, post-apocalyptic bunker designed to protect against a nuclear threat, zombie invasion, or viral outbreak. Retrieved March 23, 2020, From https://www.businessinsider.com /coronavirus-doomsday-bunker-cyber-house-life-tesla-modern-house-lair-2020-3.