Flexibility in sustainable architecture output Resistance to epidemics

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Abstract. The research deals with the concept of sustainable architecture beyond pandemic diseases. As there is a motivation to reduce the number of occupants of buildings and reconsider the space arrangement at the level of corridors and internal and external spaces as well as focus on natural factors such as ventilation and insolation. Also, the death of a group of architects due to Corona virus will motivate them to form an architectural product that is friendly to the natural environment. Thus, the aim of the research was to uncover the interrelationship between flexibility and epidemics and the role of each one to shape a sustainable architectural output. Accordingly, the research problem was to explore the role of Flexibility in Sustainable epidemic-resistant design. The research approach is to clarify the foundations of epidemic-resistant architecture as well as its characteristics and standards by building a knowledge framework, then a comprehensive theoretical framework from architectural literatures to be embodied in its final form in three main vocabulary, namely: foundations of epidemic-resistant architecture, characteristics of sustainable flexible architecture, and the standard for social spacing architecture. It has been applied to elected projects to clarify the extent to which these indicators have been achieved and to reach the conclusions, which made clear that flexibility and resisting architectural output is the extent of its ability to survive in the face of disasters and epidemics, and this is an ideal time to rethink how to develop new design standards and address existing structures to achieve the sustainability.

1. Introduction
Flexibility is the ease of changing the architectural product to suit the new epidemiological requirements, which gives it the characteristic of resistance to limit the spread of the pandemic. Several studies have examined the concept of Epidemiological architecture. However, they did not address foundations of epidemic-resistant architecture, characteristics of sustainable flexible architecture, as well as the standard for social spacing architecture. Accordingly, the research problem is represented in: (exploring the role of Flexibility in Sustainable epidemic-resistant design). Thus, the aim of the research was to uncover the interrelationship between flexibility and epidemics and the role of each in shaping sustainable architectural output. For the purpose of solving the research problem, the research methodology was divided into four sections. Firstly, it includes building the knowledge framework for Flexibility in Sustainable epidemic-resistant design. Secondly, it is focused on building the theoretical framework through analysis of the literature and previous studies. Thirdly, it deals with the elected projects for the purpose of application. Lastly, it includes putting forward conclusions and recommendations.

2. Knowledge Framework:
The axis discusses Flexibility of sustainable and epidemic-resistant architectural output through three main areas, such as stages development of the flexibility throughout history, types, and approaches.
2.1 The stages of development of the flexibility of the architectural product throughout history:
Flexibility is the architectural field that is concerned with the continuity of the building’s work despite changing functional requirements, by reconfiguring it so that it can continue to meet the new requirements [1]. A comparison can be made between the flexibility of the architectural output in each of the classical, modern and sustainable architecture in the Table 1 as follows:

| Comparison              | Flexibility in classical architecture | Flexibility in modern architecture | Flexibility in sustainable architecture |
|-------------------------|---------------------------------------|-----------------------------------|----------------------------------------|
| Define                  | It is means "Architectural structures that withstand the adversities of time and nature". | Creating flexible structures and spaces with innovative technologies to accommodate disturbances. | The capacity of a system, output or person to absorb or withstand change, maintaining its core purpose in the face of dynamic circumstances. In other terms, it denotes a building’s ability to self-organize and adapt. |
| Mechanisms              | - Unity meaning that "shapes integral to a building’s making". -Reconstructing shapes to achieve innovation. | -Prefabrication & standardization in the architectural product design. - Reuse of existing structures for contemporary needs modern. | - Repetition to the large scales of urbanism, planning and architecture. - Sustainable adaptation to foreseeable changes in the environment. - Reconfiguring Architectural productions while it is also adapted to change, In addition transformability. |
| Goals                   | It has been employed to examine the physical Output of the architecture and the histories that envelop them. | It has been employed to to perpetually create newer, grander and more efficient structures. In addition to Building Repair and Urban Renewal. | It has been employed to address wide-ranging challenges in architectural practice, from sustainability to urban crisis management in the wake of catastrophic events. |

It is clear from the above that the flexibility of multiple mechanisms, including: "Unity, Reconstructing, Prefabrication, standardization, Reuse, Repetition, Sustainable adaptation, Reconfiguring and transformability", In line with the requirements of the changing human need.

2.2 Types of Flexibility in Design Sustainable epidemic-resistant:
Flexibility in epidemic resistant Sustainable design has two major types:
- *Internal flexibility*: related to a change in the functions of the spaces or their shape by means of a physical intervention for the purposes of quarantine.
- *External flexibility*: related to adding a new additional mass to the building for introducing new function Like expanding hospitals according to the epidemiological situation [2].

It is noted from the above, the type of flexibility in the architectural product is related to several factors, such as structural and technical constants, and social and epidemiological variables.
2.3 Approaches of Flexibility in Design Sustainable epidemic-resistant:

Flexibility in design has two major approaches:

- **Open building approach**: Open building approach was first articulated by Habraken (1972). and mean "Design open spaces without determining the interior layout to achieve adaptability with epidemiological cases".

- **Extendable core design or the grow approach**: design allow users to make some modifications to their building according to their future needs by adding a space or replacing it with another and use moving partitions to reduce the spread of epidemics through social distancing, and these modifications will be conditioned to cost, need & time [3]. (see Figure 1)

![Figure 1: Approaches of Flexibility in Design Sustainable epidemic-resistant, [3].](image)

It is noted from the above, Flexibility in Sustainable design epidemic resistant has two major approaches the Open building approach and the grow approach; and despite the fact that the previous literature provides a knowledge base and an appropriate field that can be invested to build a theoretical framework, it has not clarified it yet in terms of a Foundations of epidemic-resistant flexible architecture, Characteristics and Standard for social spacing architecture; this will be done in the second section of the research in order to challenge main and secondary indicators as well as the value of the possible measure.

3. Building the theoretical framework:

This axis deals with the presentation of a set of previous studies to extract the main and secondary theoretical vocabulary terms and their possible values, as shown in Table 2. According to Table 2, 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. The practical study requires submitting to a qualitative measurement, where all the vocabulary will be measured in an attempt to reach an integrated picture of Flexibility in sustainable architecture output Resistant to epidemics, relying on code (1) to indicate verification and symbol (0) to indicate lack of verification as shown in Table 4 and Figure 4.
Table 2: Explains the previous literature. (researchers).

| Study Year | Vocabulary                          | The cognitive subtraction of the study                                                                 |
|------------|------------------------------------|--------------------------------------------------------------------------------------------------------|
| 2020       | Urban approaches, Architecture     | The study clarified the foundations of epidemiological architecture through two approaches:            |
|            | approaches                         | - Urban approaches                                                                                 |
|            |                                    | - Architecture approaches                                                                          |
| 2019       | Classification, Modular system     | The study clarified the criteria for the social spacing architecture to prevent epidemics, including:  |
|            |                                    | - Classification                                                                                    |
|            |                                    | - Modular system                                                                                   |
| 2016       | Natural ventilation, Sunlight      | The study clarified the foundations of epidemic-resistant architecture, including:                    |
|            | design                              | - Natural ventilation                                                                               |
|            |                                    | - Sunlight design                                                                                   |
| 2015       | Variability, Modular System        | The study discussed sustainable flexible architecture in two aspects, namely:                         |
|            |                                    | - Variability                                                                                      |
|            |                                    | - Modular System                                                                                   |
| 2013       | Transformation, Interaction,       | The study showed three characteristics of flexible epidemic architecture:                            |
|            | Mobility                            | - Transformation                                                                                    |
|            |                                    | - Interaction                                                                                      |
|            |                                    | - Mobility                                                                                        |
| 2018       | Adaptable, Flexibility             | The study demonstrated two characteristics of resilient epidemic architecture:                      |
|            |                                    | - Adaptable                                                                                        |
|            |                                    | - Flexibility                                                                                     |

- Megahel, 2020.
- Acharya, 2013
- Nazarian, 2015
- FarokhiFiroozi, 2019
- Khai, 2016.
Table 3: Explains the main and secondary vocabulary of the theoretical framework, (researchers).

| Key vocabulary | Secondary Vocabulary | Possible Values | Symbol |
|----------------|----------------------|----------------|--------|
| Urban approaches | Expanding horizontally | X.1.1.1 | |
| Fewer density cities | X.1.1.2 | |
| Decentralization | X.1.1.3 | |
| Urban farming | X.1.1.4 | |
| Urban renewal | X.1.1.5 | |
| Architecture approaches | Self-sufficient strategies | X.1.1.1 | |
| Refocusing on green spaces | X.1.2.2 | |
| Low-rise buildings | X.1.2.3 | |
| Natural ventilation | X.1.2.4 | |
| Sunlight design | X.1.2.5 | |
| Foundations of epidemic-resistant architecture X.1 | |
| Adaptable | physically separating | X.2.1.1 | |
| prefabrication | X.2.1.2 | |
| reduce intra-system interactions | X.2.1.3 | |
| use interchangeable system components | X.2.1.4 | |
| Changeable in the function of the space | X.2.2.1 | |
| changes in the load carried by the systems of the building | X.2.2.2 | |
| changes in the Users | X.2.2.3 | |
| Variability replaceable | X.2.3.1 | |
| reusable | X.2.3.2 | |
| recyclable | X.2.3.3 | |
| Maintenance & modernization | X.2.3.4 | |
| Characteristics of sustainable flexible architecture X.2 | |
| Shape Transformation | X.2.4.1 | |
| Space Transformation | X.2.4.2 | |
| Sensor systems design | X.2.5.1 | |
| Control systems design | X.2.5.2 | |
| Isolation units | X.2.6.1 | |
| Tent hospitals | X.2.6.2 | |
| Classification | sliding partitions | X.3.1.1 | |
| mobile platforms | X.3.1.2 | |
| Modular system | Organizing Space | X.3.2.1 | |
| Non - Hierarchical space | X.3.2.2 | |
| Holism | X.3.2.3 | |

4. Application.
4.1 Application to samples:
For the purpose of verifying the research hypothesis, which came in the following form: "Epidemiology influences a designer by directing it towards the foundations of epidemic-resistant architecture, its characteristics, Social spacing standards", the application will be to architectural samples within different spatial contexts to clarify the lasting effect of epidemics on it despite changing times.

4.1.1. Huoshenshan Hospital. A makeshift hospital for novel coronavirus patients in suburban Wuhan, the hospital was quickly built because of its modular structure and Prefabricated units. The total area of Hospital is 60,000m², where the area of the new-built isolation area is 34000 m² with an uninsulated area of 25000 m² and the last is an area transformed from the existing buildings that were used as a sanatorium for workers and employees, and the hospital has 419 suites and 1000 beds including 30 intensive care wards. The hospital was characterized by two main characteristics, namely: Classification, Where the hospital classified into three zones and two channels, meaning dividing areas into clean, semi-polluted and polluted areas, as well as creating two separate channels for medical staff and patients to walk through. Interaction, in each room in the hospital there are two beds and a box with a glass window to facilitate interaction between the patient and the medical staff in order to avoid infection, and there is also an air conditioner that emit fresh air and disinfectants, in addition to that, in addition to using negative air pressure to ensure prevention of infection [10]. (see Figure 2)
4.1.2. Professor Murat Dilmener Emergency Hospital in Turkey. Field hospital, it is one of two hospitals built in Istanbul’s Asian and European sides in less than two months in response to Corona epidemic, the hospital was quickly built because of its modular structure and prefabricated construction system, the hospital takes its name from Murat Dilmener, a health care doyen who died on 3rd of May 2020 at the age of 79, after losing his battle against the coronavirus. The hospital was established on an area of 125000m², the hospital which has a closed area of 75000 m², has a capacity of 1008 beds, and it has 16 operating rooms, 576 patient bedrooms, 432 intensive care beds, 36 emergency observation beds. The hospital was characterized by three main characteristics, namely: Classification, Adaptable and Variability. Finally, the multi-purpose emergency hospital is aimed to be used as an epidemic, earthquake and disaster hospital, and it will continue serving patients when the pandemic ends [11]. Some pictures of this hospital are shown in Figure 3.

4.2 Analyzing and discussing the results:
The paragraph clarifies the variance of the percentages of the achievement of the theoretical framework vocabulary in the selected samples, relying on code (1) to indicate verification and symbol (0) to indicate lack of verification as shown in Table 4 and Figure 4.

4.2.1 Results (Foundations of epidemic-resistant architecture _ X.1): their percentage (31%), this indicator (X.1.1.1-X.1.1.2-X.1.2.3-X.1.2.4-X1.2.5) achieved (100%) in the elected projects, while the percentage of the indicators (X.1.1.3-X.1.1.5-X.1.2.2) decreased to (50%) and the two indicators (X.1.1.4-X.1.2.1) did not exist (0%).

4.2.2 The results of (Characteristics of sustainable flexible architecture _ X.2): its percentage (53%), the indicators (X2.1.2-X.2.1.4-X.2.3.2-X.2.3.3-X.2.3.4-X.2.5.1-X.2.6.2) achieved a (100%) in the elected projects, and the percentage of achievement of the two indicators decreased (X.2.1.1-X.2.6.1) to (50%) in project (B) only, finally the existence of the indicators (X.2.1.3-X.2.3.1-X.2.2.3-X.2.2.2-X.2.2.1-X.2.4.2-X.2.4.1-X.2.5.2) was not achieved as it came (0%).

4.2.3 Results (Standard for social spacing architecture_ X.3): its percentage (16%), the indicators achieved (X3.2.1-X.3.2.2-X.3.2.3) (100%) in the elected projects, while only two indicators (X3.1.1-X.3.1.2) were not achieved, meaning that it is (0%).
Table 4: Project Analysis (A, B), (researchers).

| Symbol | 1.1.1 | 1.1.2 | 1.1.3 | 1.1.4 | 1.1.5 | 1.2.1 | 1.2.2 | 1.2.3 | 1.2.4 | 1.2.5 | 1.2.6 | 2.1.1 | 2.1.2 | 2.1.3 | 2.1.4 | 2.2.1 | 2.2.2 | 2.2.3 | 2.2.4 | 2.3.1 | 2.3.2 | 2.3.3 | 2.3.4 | 2.3.5 | 2.3.6 | 2.4.1 | 2.4.2 | 2.4.3 | 2.4.4 | 2.4.5 | 2.4.6 | 2.5.1 | 2.5.2 | 2.5.3 | 2.5.4 | 2.5.5 | 2.5.6 | 2.6.1 | 2.6.2 | 2.6.3 | 2.6.4 | 2.6.5 | 2.6.6 | 2.7.1 | 2.7.2 | 2.7.3 | 2.7.4 | 2.7.5 | 2.7.6 | 2.8.1 | 2.8.2 | 2.8.3 | 2.8.4 | 2.8.5 | 2.8.6 | 2.9.1 | 2.9.2 | 2.9.3 | 2.9.4 | 2.9.5 | 2.9.6 | 2.10.1 | 2.10.2 | 2.10.3 | 2.10.4 | 2.10.5 | 2.10.6 | 2.11.1 | 2.11.2 | 2.11.3 | 2.11.4 | 2.11.5 | 2.11.6 | 2.12.1 | 2.12.2 | 2.12.3 | 2.12.4 | 2.12.5 | 2.12.6 | 2.13.1 | 2.13.2 | 2.13.3 | 2.13.4 | 2.13.5 | 2.13.6 | 2.14.1 | 2.14.2 | 2.14.3 | 2.14.4 | 2.14.5 | 2.14.6 | 2.15.1 | 2.15.2 | 2.15.3 | 2.15.4 | 2.15.5 | 2.15.6 | 2.16.1 | 2.16.2 | 2.16.3 | 2.16.4 | 2.16.5 | 2.16.6 | 2.17.1 | 2.17.2 | 2.17.3 | 2.17.4 | 2.17.5 | 2.17.6 | 2.18.1 | 2.18.2 | 2.18.3 | 2.18.4 | 2.18.5 | 2.18.6 | 2.19.1 | 2.19.2 | 2.19.3 | 2.19.4 | 2.19.5 | 2.19.6 | 2.20.1 | 2.20.2 | 2.20.3 | 2.20.4 | 2.20.5 | 2.20.6 | 2.21.1 | 2.21.2 | 2.21.3 | 2.21.4 | 2.21.5 | 2.21.6 | 2.22.1 | 2.22.2 | 2.22.3 | 2.22.4 | 2.22.5 | 2.22.6 | 2.23.1 | 2.23.2 | 2.23.3 | 2.23.4 | 2.23.5 | 2.23.6 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| A     | 1     | 1     | 1     | 0     | 0     | 1     | 1     | 1     | 0     | 1     | 0     | 0     | 0     | 0     | 1     | 1     | 1     | 0     | 0     | 1     | 1     | 0     | 0     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| B     | 1     | 1     | 0     | 0     | 1     | 0     | 0     | 1     | 1     | 1     | 1     | 0     | 1     | 0     | 0     | 0     | 0     | 1     | 1     | 1     | 0     | 0     | 1     | 1     | 1     | 0     | 0     | 1     | 1     | 1     | 1     |

| Percentage | 100% | 100% | 0%   | 0%   | 0%   | 100% | 0%   | 0%   | 0%   | 100% | 0%   | 0%   | 0%   | 0%   | 100% | 50%  | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 100% | 100% | 100% | 50%  | 0%   | 50%  | 0%   | 0%   | 50%  | 0%   | 50%  |

Figure 4: the ratios of verifying the vocabulary of the conceptual framework in projects, (researchers).

5. Conclusions.

- The research frames the flexibility of the sustainable architectural product resisting to epidemics within three areas, the first of which is foundations of epidemic-resistant architecture, the second area is characteristics of sustainable flexible architecture, and the third one is standard for social spacing architecture.
- The classification of spaces according to their functions was studied, as well as the use of flexible partitions movement to adapt to the requirements of quarantine, taking into account measures of social spacing, natural ventilation and solarization.
- The modular system was considered in designing quarantine spaces, as well as the use of sustainable smart building systems to reduce the spread of viruses.
- The Foundations of epidemic-resistant flexible architecture are based on low-rise buildings, self-sufficient strategies and green spaces design. Urban approaches were discussed based on expanding horizontally and less dense cities to reduce the spread of epidemics.
• The application results showed the architects' tendency to characteristics "variability & adaptable" more than "mobility & Interaction", while other characteristics such as "changeable & transformation" recede.

6. Recommendations.
• Using flexible architecture as a strategy to resist epidemics; due to the diversity of its foundations, characteristics and standards, as well as its direct impact on the space organizing process, the focal length of an architectural composition is determined in terms of degree of Communication or isolation to reduce the spread of infection.
• The research recommends the necessity to expand the criteria for social distancing architecture, especially (classification), as it allows the modeling of sustainable architectural space according to the epidemiological situation.

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