Functional flexibility as a criticism mechanism in contemporary architecture

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Abstract. With the beginning of the emergence of modernity, the concept of functional flexibility emerged from the perspective of the possibility of modification and fragmentation within the internal spaces exclusively by adopting the principle of the structural network in its projects. Adapting spaces to everything that is new today can match technological progress within the levels of form, mass and space, and thus architectural schools and government gave institutions the flexibility in the importance of evaluating and criticizing architectural designs in the stages of architecture and competitions. The mechanisms, objectives and results that have been implemented are still unclear, by adopting the goal of flexibility in architecture, as an organized characteristic that stems from the basis of thought that influences in one way or another the nature of the utilitarian relationship. To evaluate projects and find a better alternative, commensurate with time, to the space infrastructure capable of adapting to different conditions. Accordingly, a set of previous studies and examples were analyzed by adopting functional flexibility as a criticism mechanism, and a set of evaluation strategies and characteristics were identified, and the criteria used in such type of projects that need to be expanded in the future were determined. The tool has been tested in a range of projects. It is chosen for each level of flexibility (flexibility at the internal level without change or addition in the main building block, in addition to the building blocks with the intent of functional expansion and at the level of functional change used by the entire building). In addition to the influence of block shape (geometric, organic, crumbly blocks) with functional flexibility, to derive important recommendations for the designer and evaluator.

Keywords. Functional flexibility, adaptability, space structure, integrative thinking, evaluation and criticism.

1. Introduction
In this research, we will deal with the concept of flexibility and function as a concept that has received great attention in many fields, especially in the field of architecture, where studies have indicated its importance and its connection with its interaction with the individual and society. And architecture to achieve temporal and spatial affiliation. In order to enhance the knowledge presented about it in the field of architecture, and to adopt the concept of functional flexibility as a mechanism for evaluating
and criticizing architectural projects, and by adopting the goal of flexibility in architecture, as an organized characteristic that stems from the basis of thought that, in one way or another, affects the nature of the utilitarian relationship. To evaluate projects and find a better alternative, commensurate with the time, to the space infrastructure capable of adapting to different circumstances.) The research relied on studying these two terms throughout the history of architecture in general and in short in the era of modernity. To achieve the goal of the research (the most important basic criteria that can be employed in evaluating and criticizing architectural projects in the future were highlighted), by proposing the conceptual framework for each function and the flexibility and relationship between them, through which specialized studies are conducted. To reach the application and conclusions.

2. The theoretical framework

2.1 Functionalism: The importance of function has been devoted to architecture since ancient times. But what is the nature of that job? Function: defined broadly as that made things perform the purposes for which they are mad. And for it to have what comes according to these purposes or functions. Function as a general principle is almost self-evident.

The element of utility is a basic condition that must be fulfilled in all human crafts and in the appropriateness of the form for the job, which suggests confidence and confidence in the validity of the manufactured thing, the function in architecture is one of the main conditions that must be met in architectural work. Architecture is the scientific art of erecting buildings, in which the conditions for utility, durability, beauty, and economy are met. It fulfills the individual and collective needs of people, material, psychological, and spiritual, and utilization here is a job that, in turn, is classified into a material and social function [1,2].

In relation to the built environment, the term "function": refers to the purpose of the building or structure. It can also relate to the proper operation, processing, or performance of something and how it functions, Buildings can be evaluated in terms of their function, that is, the extent to which they are fit, and their ability to serve a specific purpose or process to which they were intended.

2.2 Modernity and functionality

In architecture: function (or "form follows function" is the slogan of modernity architecture), and it came in forms with a high level of reduction, and it has no historical precedent is the principle that instead of designing buildings according to previous styles or stylistic trends (aesthetics), the building's primary purpose must determine its shape. A function is the product of a structure that plays any specific role [3,4].

Modernity is a distinct style that stands against the traditional style, meaning that it opposes all ancient and traditional; Modernity is like a unit spread globally from the West, that is, it is ethics, values, and modern ideas, Modernism architecture gained its importance from being a new orientation in society, A new free society was created.

Ideas emerged that emphasize the role of architecture through its forms, configurations, and function to affect society, and it adopted a pragmatic approach that places the law of utility and interest at the top of the list of design priorities translated into the function of architecture and the efficiency of its performance, as for the form, it is a product after the function, i.e., in short, “form follows the function, and it came in forms with a high level of reduction. And it has no historical precedent, beauty, and convenience as an inevitable consequence.

Accordingly, modern architecture in its forms has become a functional function, and by virtue of the association of these forms with the functional program prepared for them. In the sense that the architectural form was achieved without the intentional intervention of the designer on the condition that his goal, or ultimate purpose is achieved, The architecture of modernity has been ignored, which is a practical result of design, and as forms have become, as Mies Van Druh says, (formation is innovation) Thus, the form is the product of submission to the authority of those determinants or the principles that modernity imposed on itself, It tried to make function the main meaning that dominates all other meanings of architecture[5].
2.3. Function and evaluation of the building

Function-based evaluation, as a usage, is made by judging the interior design by the extent to which it supports the human activities that take place in it, two levels of judgment were applied to interior architecture in the twentieth century: responsiveness and flexibility. Response refers to the precision with which space is made to meet its functional program.

Although this includes an assessment of how to support any area of activities that will take place in it, the level of response was in most cases indicative of the areas of distribution. Indeed, one of the most important reasons that led to the diversity of shapes in the twentieth century and the problems of distribution. The other level of job evaluation is flexibility. It can be interpreted as the reversal of the response if flexibility is intended to use a given space for a number of different functions, but it is also possible to consider flexibility as matching the response as a level at which space can continue to support activity under variable conditions in terms of utilization of daylight and capacity [6, 7].

2.4. Fixed and Moving (shifting) in function

The constant in the function is represented by the function physical characteristics, and the physical function is concerned with the requirements of the building (dimensions and dimensions) and how to provide protection for it, as well as providing spaces suitable for human movement in it. If the functional consideration "deals with the shape, size, and composition of the human body and its relationship to the physical space required to accomplish the functions of certain tasks, then this indicates the necessity of the existence of the pure fixed physical function of architecture.

“The fixed properties of the physical functions in the architecture are divided into two parts: the first is the physical control of the environment and the second is the provision of the spatial space to perform activities physical control means controlling the climate, such as lighting, sound, and external factors. This control is done either by natural methods represented by construction methods and building materials, or industrially through devices designed to achieve appropriate functional performance levels [1], as for the functional shift, it is represented by form, formations, and forms, as form and function are among the main justifications for taking new transformed designs is the emergence of new functions and that some of the old functions have changed.

For nearly forty years, modern designs often interpreted as if their shapes were decided absolutely based on the jobs that it had to fulfill its requirements, and that the total form of its buildings depends on the total number of jobs, in his view, architecture is not a single-function but rather a multi-functional one that is variable with the change of time and the result of evolution, transformation, and change [5].

3. The concept of flexibility

In language: the ability or ease of changing something to suit new circumstances [8]. As for its definition idiomatically: it is the designer’s ability to give a variety of responses that do not belong to one appearance, that is, it is creativity in designing more than one form. Resilience in architecture: Resilience is seen as a proactive trait designed in a system, rather than an interactive behavior that may result in a waste of time, effort, cost, and performance [9].

Flexibility from the point of view of modernity: the ability to change through the transformation of the functional characteristics and features that were present in the original building and the ability to adapt to changing needs, which means the ability to change in light of the needs of the user, that is, the change in the physical, aesthetic or technical characteristics within a specific response period. (The most flexible space is the open floor plan because it allows the environment to be adapted and divided according to needs according to activity, function, etc.) [10, 11].

The concept of resilience is three-dimensional, meaning that resilience (spatial, functional, and aesthetic), refers to the ability to change (place, function, and identity) over time. This allows the flexibility to meet long-term sustainability requirements by extending construction life. They appear at different levels of manifestation and application, and within each level, the partial characteristics that are distinctive to them appear. It begins with guided thought, then crystallizes into an attribute in the output of the perceived processor in the method of its realization, so that the process becomes a creative act and flexibility represents an indicator of the characteristics of stability and change in
thought and order. In organic systems, we have a typical example of flexible systems, so by reference to nature, the idea of elasticity in the system can be drawn[12].

So, flexibility is the feature that provides the possibility of change in the building and modification in the functional spatial system and aims to enable the building to respond to temporal and spatial variables and meet the requirements of new jobs for the user within the life span of the building so as to ensure the continuity of the building’s work in the best possible way within the specified time period[13,14].

Levels of flexibility: Flexibility in architecture is an organized characteristic of the designer’s action that stems from an intellectual foundation that carries applications at different levels and is manifested in two main aspects. The first is that it is a quality perceived through the physicality of the architectural product. And the second: in that, it is a continuous act inherent in the formation, growth, and continuation of this product. Therefore, it was divided into three levels (the level of space formation, the level of the place, and the level of the pattern)[12].

With regard to the concept of flexibility of the architectural space structure, a division into two levels has been adopted: complex space flexibility and simple space flexibility. The first level is the level of spatial formation based on its formal organization, and through three main relationships represented by the center and boundary relationship, the exterior and interior relationship, and the relationship between the boundaries. The second level is the level of place in architecture based on its space organization and through two main relationships represented by the nature of the link between parts and the relationships between parts, as for the third level, which is the level of style, it is concerned with defining the style of architecture in relation to the nature of the style therein[12,15].

3.2. Concepts related to flexibility

3.2.1. Adaptation: It is described as the ability to adjust to suit new situations and needs, and this means that adaptation is the embodiment of flexibility. (The building is extendable, flexible, recyclable, movable, and reusable).

It includes adaptation[16]: Accessibility: To describe the availability of related spaces and various special physical conditions. Open plan: It refers to a land plan that allows the use of open spaces according to needs[17].

Response construction: to describe an interactive building that responds to changes with time through the use of kinetic systems in response to environmental changes [18].

Adaptability has two distinct approaches to resilience: the pre-configuration that accompanies the initial design phases and the reconfiguration approach [11].

If resilience is defined as the ability of space to adapt functionally or structurally to changes in time or with respect to building uses, including social, sustainability, and economic issues.

3.2.2. Sustainability: sustainable buildings support concepts related to resilience. There is a need for a conceptualization to integrate the key resilience aspects of buildings into the sustainability-oriented design. Flexible design helps ease change and adaptation in the key concept of sustainability by reducing material and energy consumption as well as environmental pollution[19,20].

The American Institute of Architects has described flexibility in the sustainability initiative. Adaptive: designed to accommodate the changing environmental and social conditions expected throughout the life expectancy of a building.

Avoids Maladaptation: Ensuring that the building and infrastructure designed to protect users from hazards does not reduce the quality of resilience and make them more vulnerable in the future. Disruptor preparer: integrate systems supporting the building and users, and the mission of the structure in the event of downtime or failure[21,23].

3.2.3. Change: Change is in different concepts of flexible designs, and there are two methods of categorizing change, according to the methods you advocate. First, in principle, the absorption of change without adaptation, as the resulting building remains suitable for the activities present before and during the change, as the building maintains its characteristics even with the change, and secondly,
when change is met with adaptation, the building will still be suitable for older events as it changes by changing its properties from those specified in the initial design[22].

Either way, it can be said that the assimilation of change means that the building is constantly viewed as flexible and suitable for the uses that take place in it because it is subject to change with time, and according to the need for change in the future[24].

3.2.4. Transformation: The act of transformation is the most important starting point that would trigger a series of changes[25]. In order for architecture to be convertible, much more important changes are needed than modifications or interior design and furniture renovation.

A transformable is one that changes its make-up, composition, size, or appearance by changing the structure or physically altering the inner surface to allow for a major modification in the way it is used or perceived. It is a structure that opens, closes, expands, or contracts. The functions of the building can be changed through the parts that change the spatial configuration: walls, floors, movable ceilings, or through the parts used to restructure the spaces and develop new activities[15,18,22,26].

3.2.5. Interaction: At present, interactive engineering is the field that can be exploited to achieve interactive flexibility. Where there are automation elements responsible for inducing changes in spaces or a specific structure (mechanical or sensory). It consists of a sensor (receiver) and a trigger (responsible for effective change).

The system will then be able to detect the changes that have occurred in a specific environment and react according to the required need with variation in responses. With the need for building systems to connect to external systems: satellites, communications, the Internet. Intelligent automation systems are getting more advanced every day and can be integrated into various fields such as security, sanitation, telecommunications, electrical installations, and more.

These systems have become more commonly used thanks to the level of comfort they provide to the user. As well as the energy efficiency generated when the building is able to respond to changes in its environment, and change its reactions according to needs[26,27].

3.2.6. Rehabilitation: the flexibility of the built environment as a way to revive. Relationships between building resilience and heritage appear well, as the primary goals of flexible adaptation (flexible reuse) are sustainable development, to preserve heritage, Utilizing the old buildings in a way that serves the city economically, environmentally, and culturally[28], which is a strategy of double change and opening spaces to each other.

And the flexible addition to heritage buildings by taking into account two variables: the nature of the additives and the nature of the old combination of the heritage building materials and its parts of the link relationship, which of the two parts is dominant and the joints between the two structures? And the divisive nature, the new structure, and the old structure[28,29].

3.3. Types of flexibility
First: Evolutionary spatial flexibility: (functional and structural) Evolutionary spatial flexibility includes technological flexibility related to building techniques. Replacing static components to enable more effective modification and reuse of functional and psychological domains, design characteristics, and spatial features that meet the job[23,30]. Ability to change status based on add. This flexibility is related not only to structural changes to add blocks to the original building block but also to physical changes that occur in the interior space. The building can be changed according to the preferences of the beneficiary based on professional intervention[15,31].[32] Stated that the spatial flexibility related to the multiplicity of functions, that is, the designer must take into account the future changes of the buildings and the possibility of adding new parts to the structure of the building, so it is necessary to develop preconceived ideas for how to expand. Spatial flexibility also includes external flexibility: it has to do with adding a new mass to the building with the aim of expanding it, for example, or adding new activities that are not accommodated by the building spaces in the original design before modification. It also includes Transformability: changing the function of a building through a certain amount of construction work. By planning the conversion during the design stage, potential future
needs can be assessed and the required time and cost can be reduced. The resulting changes are often permanent[15]. Self-resilience, flexibility over time: refers to the role of the building and its relationship with the external context, whether urban or not, and how it leads to change and transformation during construction and reconstruction in addition to the original mass (the relationship of the building to the context)[13,18].

Second: - Functional flexibility: the ability to change the state of the building and depend on defining jobs, or changing the function of spaces or the relationship between spaces without the need to change or add to the structure[14,33] include: Internal flexibility: it has to do with changing the functions of spaces or merging functions with each other, or it has to do with changing the shape of the space. It also includes: Adaptability and Transferability. Flexibility of building personality: the ability to change only the facade or certain aspects of the building without the need to change the structure [33].

Mobile: Movable flexible buildings consist of movable or repositionable structures or buildings that can be demolished and reassembled at another location [15].

Responsive: responsive buildings can respond to a number of external stimuli, including but not limited to “energy, environment, interaction, use, or function” (e.g. the Arab World Institute)[34]. Interactivity: It means the building’ s interaction with users, furniture, technologies, and all building contents, the building contains sensors and kinematic systems that change space or services that change the environment or materials that change their condition. Buildings “interact” when they respond to user requirements automatically or intuitively, and when users become participants instead of users (from Yona Freeman)[15,18,35].

3.4. Flexibility strategies
First: A strategy that focuses on the internal system of the building whose changes are to be made and includes a set of strategies (not to define space and generalize it during design to deal with it, Independent structures and modular units, the hierarchy of spaces, the relationship between spaces, service and technical areas, ease of access to maintenance, separation into permanent and non-permanent areas, application of mobile partitions and furniture)[23,30,31].

Second: The strategy of sustainable flexibility is represented by (ensuring transparency and accessibility to the building, which is demountable, reusable with flexibility, developing tools that can evaluate the flexibility of new and exciting designs that are adaptable for future disassembly, and the possibility of estimating the expected life span of the building components)[19,21].

Third: The general and specific space plan strategy, the regularity of plans, use of mobile technologies and sections, iterative access (the possibility of connecting different spaces with each other, specifying specific service areas and technical areas, and the possibility of examining equipment, technologies, and services)[20,36].

Fourth: A strategy for interior spaces and moving parts (open plan, prefabricated parts, similar spaces, extendable parts, connecting and separating adjacent parts, common space between adjacent spaces, transformable walls, movable furniture in a multifunctional space)[35].

Fifth: (Building Information Modeling (BIM) strategies, including (BIM), determines the transition from unidirectional and asynchronous workflow to integrated and joint models, three-dimensional modeling allows the possibility of performing a specific analysis based on the engineering information of the model, it can give information about the building capabilities and the method of dealing With him and expand it, a number of analyzes are performed with the help of building performance simulation tools[36].

Sixth: Strategies that adopt indicators of flexibility measurement, which are (divisibility, add ability and removability, portability of functions, controllability, separability, adaptability, accessibility, extensibility, column locations, job integrity, universal components)[14,23].

3.5. Indicators and criteria for assessing flexibility in buildings:
3.5.1 Degree of flexibility: it is a criterion for the ability to measure modification to buildings. It facilitates the establishment of clear steps in the design process and testing of adaptability in the construction process. In the goal-setting stage, the designers analyze the declared needs of the
beneficiary and define the flexibility targets required in cooperation with the beneficiary. The concept of adaptability is developed, describing the steps of how to implement functional flexibility in different parts and systems of a building \[13,17,37\].

3.5.2. **Functional flexibility criteria are:** (function, capacity, and flow) Interactions between building systems provide information about the building’s ability to meet job performance requirements. A job is defined as a group of (events, activities) or components to achieve a specific goal. As for capacity, it is defined as the building's ability to meet the building's functional performance requirements. Whereas flows are defined as the movements in and around a building in relation to the surroundings and users. Different systems interact within the building through different mechanisms, and these interactions affect the building's flexibility in response to different types of changes. System interactions include three types: (functional, spatial, physical) \[20,37\].

3.5.3. **Interface flexibility index:** Flexible building façades refer to the degree of freedom between components and parts of the building and their ability to be modified and added \[19\].

3.5.4. **Indicators:** adaptive (disassemble, rebootable, adjustable, swappable, configurable), extendable (capacity, dimensions), multi-functional (intelligent, automated, universal, integrated) \[38\].

4. **Previous studies** as shown in Table 1.

| N  | Study Title                                                                 | Cognitive subtraction                                                                 | The most important cognitive aspects                                                                 |
|----|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| 1  | FLEXIBILITY IN THE DESIGN OF BUILDINGS \[24\]                               | The study talks about Function change depending on the degree of Function change (Functional flexibility). The study dealt with many reasons related to the degree of change in the activities' requirements, which are related to the characteristics of each activity, and that the change in activities takes place through successive stages. **First:** The change occurs in the environment of the event, which includes its economic, social and technical aspects. **Second:** The stage of taking a decision to respond to the change and depends largely on the type of activity and the nature of the building in terms of the degree of complexity of the job. **Third:** The process of making the change, which is of two types: - Change the overall effectiveness to include a change in the building’s function as a whole. The change is limited to one type of activity. **Fourth:** It includes the set of problems resulting from the change process, which includes the difficulty of replacing new requirements within the available capabilities. **Fifth:** the process of compatibility. This situation is attributed to the human ability to adapt to the changes that have occurred. (In addition to a number of changes at the level of the movement system and the functional relations of the building, as the movement inside the buildings is one of the most important problems facing the design process as it is a spatial component that affects the building’s functionally success, **which are different types:** 1. **(linear)** This type is the simplest type of movement because it represents a main axis and other axes branch from it. 2. **(toroidal)** This type depends on the continuous kinematic nodes, which are the starting point for another axis. 3. **(central)** This type depends on a central node from which... | -The reasons for change that benefit the use of flexibility for change. -The change in the economic and social aspects related to the function of the building. The change is the function of the building as a whole. -The vocabulary of flexibility is Compatibility and adaptability to changes. -Motion pattern effect and design, design... |
2- Design flexibility as one of the most important criteria for economic housing [39]

It addresses the concept of design flexibility as an important criterion, and addresses the participation of both the architect and the user in achieving this purpose. The study was able to reach the following results:

- Design flexibility is of great economic importance; With the aim of meeting its ever-changing needs, That is, extending the life of the building, and thus reducing the waste of environmental data. Design flexibility requires on the one hand to provide various options for building models to suit all users' styles during the design stage. On the other hand, it requires providing the possibility of making changes over time in the occupancy phase, and this is achieved on two levels:

  1) Structural is related to choosing the most appropriate, flexible, and functional structural system related to adopting the most efficient method for shaping the architectural space and furnishing it in a way that allows it to be modified in a flexible manner in the future, taking into account that this is done on the two scales of the building as a whole.

  2) Adopting a well-thought-out design module and surveying standards corresponding to the approved design codes for buildings is the most important basis for efficiency in making any change to the side of the building to the importance of flexible furnishing for use.

- The user is the best person familiar with his changing needs, and the architect has a role in achieving flexibility in the design stage, through the implementation and up to the occupancy stage.

3- FLEXIBLE ARCHITECTURE FOR THE DYNAMIC SOCIETIES

Reflection on a Journey from the 20 [15]

The paper deals with the development of critical controversies over "flexibility" in the 1960s into divisive debates over whether an architect should leave his work unfinished and thus provide an opportunity to develop a final design in the future, or whether the design of the building must be completed, but nevertheless it is flexible. John Wicks, an English architect, was one of the advocates of the "unfinished" solution on the ground, since all large institutions such as airports or hospitals are unable to foresee the changes that a building may require after its use. He mentioned in the research types of flexibility (mobility, which means moving the building completely from one place to another and it is called mobile buildings, and this requires structural and (functional flexibility) to deal with backward places, And the second type, which is the ability to transform in fixed and non-mobile buildings, is meant the ability of the building to change its external shape in addition to the exotic spaces The third type is flexibility in interacting buildings, and it refers to the interaction of the building with users, furniture, devices and all building contents, i.e. the building contains sensors and the operation of motors that can lead to a wide range of actions. Physically kinetic systems that change space or services that change the environment or materials that change their state "interact" when buildings respond to user requirements automatically or intuitively, and when people become participants instead of users).
5. **Criteria for selecting samples**: The theoretical framework for flexibility will be presented as a mechanism for criticism of architectural projects, and a group of projects will be selected for implementation on them within levels that will be mentioned in the table below. A set of indicators and criteria have been taken into consideration in order to select these samples, namely: The clarity of using flexibility in projects and employing or using at least one of its types or strategy in the selected sample. The difference in the selected samples in terms of functions and uses, in order to understand different types of flexibility applications in the samples.

5.1. **Method of Measurement**: The descriptive and analytical method will be adopted to analyze the selected projects, by analyzing different functional projects and depending on the external and internal design and the types of flexibility strategies used.

5.1.1. **The first level**: flexibility at the horizontal level (the plans) from the inside without change or addition in the main building Mass: (the concept of functional flexibility that focused on modern architecture). Through samples A, B, C

A. **Crown Hall, the architecture building at Illinois Institute of Technology in Chicago** [40].

Types of strategies:
1. Evolutionary spatial flexibility (the ability to change the state of the building without adding to the structure) (open plan): And because the building is characterized by an open plan, it can accommodate different types of uses, because the internal space of the open plan is less defined by the types of functions that can be accommodated, which allows increasing or decreasing the internal space of the building, and the ease of forming separate or connected internal units according to the type of use.
2. Internal functional flexibility: The possibility of predicting future changes and the multiplicity of options (different types of uses).
3. Flexibility of the external appearance: Since the building considered a qualitative transfer in the world of architecture and construction, and it affects the styles of buildings that spread in a certain period, it is difficult to change its external shape. The building accommodates internal changes and accepts functional change, as well as accepts the technological change to continue its performance to save energy, for its continued use in various activities and functions [38].
4. Technological flexibility related to construction techniques: The possibility of modifying the building envelope by investing in shading devices is more cost-effective than wind turbines and photovoltaics. In addition, its adaptability to the external and internal environment [23,40], as shown in Figure 1.

![Figure 1](image1)

**Figure 1**: (A) 3D Drawing. (B) Ground floor plan. (C) Outside perspective. [52]

B. **The Synaptic Building** [41].

Types of strategies:
1. Strategic flexibility or (spatial flexibility in interior space) (open plan): space flexibility as space is remodeled based on users' behavior and needs, and the ability to quickly respond to external and internal changes at different times of the day.
2. Technological flexibility related to predictive construction and modeling techniques: modification of the building envelope or the possibility of changing the facade, its environmental adaptability, multiple-use, and various functions.
3. Technological flexibility related to easy maintenance of the building and subsystems: automated building systems integration, redundancy and equipment testing, equipment, this example follows the
idea of modernity architecture about flexibility within the building structure, but using contemporary technology, the building becomes interactive and sensory with different times of the day[23,42].

4. Services and Planning: the structure allows easy access for adjustment and maintenance. With the possibility of adding to the floors in the future, allowing the vertical growth of the building, made with large steel cellars, site layout for future changes to structure layers, services, and interior partitions. The cells (units) are placed in a grid-like structure, to facilitate cell movement, and improve space utilization. On the upper floors, individual workspaces are located at the ends, and the common work areas are pushed toward the building center. While the kitchen and recreational spaces are isolated in the center of the scheme [42].

5. Responsive design: the building consists of “units” or “cells.” These cells can move “semi-automatically” thanks to the motors in the bottom panel. During the day, the units can be moved easily and folded for storage, while the automatic trolleys assist furniture. The building goes through a set of stages, each of which corresponds to a specific layout in the area of each of the cells (units) and furniture, with suitable lighting conditions. This “choreography,” or metabolism, is the daily activity of a building.

6. The flexibility of the external shape: preserving the shape of the blocks, with the possibility of changing the facade through the movement of cells at different times of the day, for example at noon, the cells of the floor can extend to the street, and I invite the audience to the interior, by expanding the internal space[23], as shown in Figure 2.

![Figure 2.](image1)

(A) Interior Design. (B) Ground floor. (C) Vertical section plan. (E) External view of the building. [53]

C. Rolex Learning Center LausanneSwitzerland [43,44].

Types of strategies
1. (Strategic flexibility) or (spatial flexibility in interior space) (open plan): The ability to quickly respond to external and internal changes, as the spatial system connects the interior landscape with the surroundings, expanding the illumination of seemingly endless space. Use of: mobile equipment (equipping walls, ceilings, or interior partitions with moveable parts).

2. Ensuring transparency and accessibility to the building.

3. (Scalability): the designs simulate organic growth, lack of interest in hierarchies of functional distribution, with the possibility of expansion and adding new blocks with a horizontal extension that connects to the main mass of the building.

4. (Flexibility of the external shape): the building is rectangular but appears to be more organic, due to the way its roof and floor gently flaunt it represents the use of iconic and mythical images of nature, which allow for change and adaptation to changes over time.

5. Services and Planning: site planning for future changes and services. Glazed units positioned as individual zones that allow communication with the outside surroundings; the building lends itself to create quiet, acoustically separate areas created by changes in height. Slopes, valleys, and plateaus within the building, as well as the shapes made by the courtyards, contribute to defining the insulating space. In addition, these enclosed glass 'bubble' sets make small containers for small groups to talk or work together. The terrain lends an extraordinary fluidity to the open-plan, thus providing flexible features for the building, as shown in Figure 3.
5.1.2. The second level: flexibility on the vertical level by adding floors or Masses on the main building towards the top. In the sample (D, E)

D. Massachusetts General Hospital [45].

Types of strategies:

1. (Building Information Modelling) (BIM) (possibility of estimating the expected life span of building components): this information allowed to manage the complexities of installing a 14-story building in a compact site; Due to multiple connections to existing buildings; All while increasing the chances for future flexibility[36].

2. Evolutionary spatial flexibility: increasing the interior space of the main building mass, by adding a serious Mass and merging it horizontally with five floors of the main building.

3. (Technological flexibility) related to building techniques: modification of the building envelope or the possibility of changing the facade, its environmental adaptability, multiple use and various functions[23].

4. (Technological flexibility) related to easy maintenance of the building and its subsystems: integration of automated building systems and the ability to check and maintain equipment, the flexibility of interactive floors by measuring the average noise levels in them.

5. Service and planning: the structure is separate for the newly added mass and linked with the main building on five floors, allowing easy access for adjustment and maintenance. Site planning for the possibility of future modification and change, structure, services, and internal intersections.

6. Design for adaptation: due to the dense nature of the site, the future adaptation is at the level of the interior and the horizontal change only.

7. Flexibility of the external form: the new mass is, geometric in shape, with the ability to change and modify the facades[23]. The new block façades have the ability to interact with light and introduce appropriate amounts to patients and are award with LEED NC Gold Certification. as shown in Figure4.

E. Antwerp port building [46].

Types of strategies:

1. Reusable with flexibility: by converting the old building (fire station) into a port.

2. (Evolutionary spatial flexibility) (the ability to change the state of the building in addition) (open plan): increasing the area of functions to accommodate the changing of functional use of the building, by building vertically, in addition to the open plan for both the old building and the new mass, where a large circular tower rises in the middle of the building Old and binds it to the added upper mass. It connects it with the old building.

3. (Technological flexibility) related to building techniques: a massive multi-faceted glass structure that sits on the roof of the old building, allowing easy access for adjustment and maintenance.
Modification of the building envelope or the possibility of changing façade of the added part and preserving the old façade of the fire station, and its adaptability to the environment, multiple-use, and various functions.

4. Adaptability design: The ability to respond to the surrounding environment, due to the nature of the open site it allows the possibility of addition and modification at the level of the interior or the outside, so the future adaptation is at the level of the interior and the horizontal change only.

5. Flexibility of the external shape: the new block is closer to the shape of an almost geometric diamond, with the ability to change and modify the facades. The facades of the new block have the ability to interact with light and introduce the right amounts of light that interact with daylight, as shown in Figure 5.

![Figure 5](image)

5.1.3. The third level: flexibility at the level of the façades through adding clumps on the façade. In sample (F).

F. judicial centre annex presented to Berkeley County Council [47, 48].

Types of strategies:
1. Reusable with flexibility: by converting the building from a woollen mill to a local community market, and then finally as a judicial centre.
2. Evolutionary spatial flexibility (the ability to change the state of the building in addition): increasing the area of functions to accommodate changing of functional use of the building, the flexibility of the common space between adjacent spaces, and adding a vertical mass that protrudes in the front facade of the building and connects to all floors of the old building.
3. Strategic flexibility at the block level: through the addition of a new mass to the building, and the ability to respond quickly to external and internal changes, with the intention of the City Council in 2016 to add a new expansion to the building by adding new masses that connect with the main building mass.
4. (Technological flexibility) related to building techniques: the general local character was preserving through the materials used, and the building was penetrated with three floors with a U-shaped glass structure that allowed the passage of lighting inside. The possibility of modifying the building envelope or the possibility of changing the facade of the added part and preserving the old façade.
5. Design for adaptation: the possibility of change and the addition of blocks in the future, enhanced by the functional flexibility of the building, its stature, and identity as a judicial facility, using appropriate materials that are in line with the character of the city, by emphasizing the shape of the building and materials in a new contrasting glass entrance.
6. Flexibility of the exterior shape: the added glass block is geometric in shape, with the ability to change and modify the facades, as shown in Figure 6.

![Figure 6](image)
5.1.4. Fourth level: at the mass level. In the sample: in samples (G, H).

**G. LIVESTRONG Headquarters** [49,50].

Types of strategies:
1. Reusable with flexibility: by converting a paper warehouse into a local cancer headquarters.
2. Evolutionary spatial flexibility (the ability to change the state of the building in addition): increasing the area of functions to accommodate the change in the functional use of the building and adding a vertical mass that appears in the front end of the building and is connected to all floors of the old building.
3. Strategic flexibility at the level of the masses: adding glass and metal structures at the front façade, achieving communication between the inside and the outside, and changing the external body, with the ability to respond quickly to external and internal changes.
4. (Technological flexibility) related to building techniques: modification of the building envelope, the possibility of changing the facade of the added part, and its environmental adaptability.
5. Services and planning: Re-planning the building site, as the designer added a number of spaces to the building for the new function, which is the renovation of offices, meeting rooms, dining spaces, gymnasium, outdoor patio, and parking for staff.
6. Adaptive design: possibility of future change and addition of blocks
7. Flexibility of the exterior shape: completely changing and modifying the facade, adding a new geometric glass block, with the ability to change and modify the facades, as the project won the LEED Gold Award, as shown in Figure 7.

**Figure 7.** (A) Outside perspective (OLD). (B) Outside perspective (NEW). (C) Ground floor. (D) Interior Design. [58]

**H. Toronto Museum of Natural History and Fine Arts (Royal Ontario Museum)** [51].

Types of strategies:
1. Evolutionary spatial flexibility (the ability to change the state of the building in addition): increasing the interior space, to accommodate the increase in the functional activities of the building and adding a deconstructive vertical mass that stands out at the front end of the building and is connected to all floors of the old building.
2. Strategic flexibility at the level of the masses: by adding a new mass to the building, changing the external body, with the ability to quickly respond to external, internal, and environmental changes.
3. (Technological flexibility) related to building techniques: the added structure of steel and glass in the style of deconstructive architecture, consideration was given to the seismic design, the shape of the new building, and the wind and snow tunnel tests that represent overloads on the added structure, and a programmatic model was used for the tests of the structure and its endurance. The possibility of modifying and changing the newly added part, while preserving the old part of the building, and its ability to adapt to the environment.
4. Services and planning: re-planning the building site as the designer added a new mass to the building, adding modifications to the façade and the eastern wing, including a round hall inspired by Byzantine art and a new main entrance.
5. Adaptive design: the possibility of change and modification of the shape of masses or materials used in the future.
6. The flexibility of the exterior shape: completely changing and modifying the facade, adding a disassemble block with different angles that give a kind of aesthetic and tries to integrate the old with the modern, but it throws some kind of challenges on the structure of the building in terms of environmental changes (snow and wind currents), as shown in Figure 8.
6. The abstracted theoretical framework, analysis and discussion of samples
Through a final dealt with in the theoretical framework, of strategies and types of flexibility, you will be adopted in the research to extract the main and minor vocabulary and possible values for the practical application, as shown in table 2.

### Table 2. Measurement table prepared by researchers.

| N | rating        | SU | H | G | F | E | D | C | B | A | symbol          | Possible values                                                                 |
|---|---------------|----|---|---|---|---|---|---|---|---|-----------------|--------------------------------------------------------------------------------|
|   | Analysis of selected samples | From theoretical framework | Evolutionary spatial flexibility | Types of flexibility |
| 1 | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.1         | Structural and functional flexibility related to construction techniques         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.2         | The ability to change the state of the building in addition                     |
|   | strong        | 6  | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | X.1.1.3         | External resilience includes:                                                  |
|   | strong        | 6  | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | X.1.1.4         | The possibility of changing the facade and aspects of the building without      |
|   | strong        | 6  | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | X.1.1.5         | The ability to change the state of the building without adding to the structure|
|   | strong        | 6  | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | X.1.1.6         | The ability to change the state of the building without adding to the structure|
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.7         | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.8         | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.9         | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.10        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.11        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.12        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.13        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.14        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.15        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.16        | Flexibility over time                                                         |
|   | Very strong   | 8  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | X.1.1.17        | Flexibility over time                                                         |
|   | Average       | 5  | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | X.1.2.5         | The possibility of changing the facade and aspects of the building without     |
|   | strong        | 6  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | X.1.2.6         | The possibility of changing the facade and aspects of the building without     |

**Figure 8.** (A) Outside perspective. (B) Ground floor. (C) Vertical section plan. [59]
| Structure          | Mobile Flexibility, including: | The ability to respond to external stimuli | Portability |
|--------------------|---------------------------------|--------------------------------------------|-------------|
| weak               | 2 0 0 0 0 0 1 1 0              | X.1.2.7                                    |             |
| Very strong        | 7 1 1 0 1 1 1 1 1             | X.1.2.8                                    | X.1.2.7     |
| Very weak          | 1 0 0 0 0 0 0 1 0              | X.1.2.9                                    |             |
| weak               | 2 0 0 0 0 0 1 1 0              | X.1.2.1                                    |             |
| Very strong        | 7 1 1 0 1 1 1 1 1             | X.1.2.11                                   | X.1.2.11    |
| Very strong        | 7 1 1 0 1 1 1 1 1             | X.1.2.12                                   | X.1.2.12    |
| Average            | 5 1 0 0 1 1 1 1 0              | X.1.2.13                                   | X.1.2.13    |
| Very strong        | 8 1 1 1 1 1 1 1 1             | X.1.2.14                                   | X.1.2.14    |
| weak               | 3 0 0 0 0 1 1 1 0              | X.1.2.15                                   | X.1.2.15    |
|                    |                                |                                            |             |
| Very strong        | 8 1 1 1 1 1 1 1 1             | X.1.3.1                                    | X.1.3.1     |
| strong             | 6 1 0 0 1 1 1 1 1             | X.1.3.2                                    | X.1.3.2     |
| Very strong        | 7 1 1 1 1 1 1 1 1             | X.1.3.3                                    | X.1.3.3     |
|                    |                                |                                            |             |
| Strong             | 8 1 1 1 1 1 1 1 1             | X.2.1.1                                    | X.2.1.1     |
| Very strong        | 6 1 1 1 1 1 1 0 0             | X.2.1.2                                    | X.2.1.2     |
| Very strong        | 8 1 1 1 1 1 1 1 1             | X.2.1.3                                    | X.2.1.3     |
| Average            | 4 0 0 1 1 0 1 1 0             | X.2.1.4                                    | X.2.1.4     |
| Very strong        | 8 1 1 1 1 1 1 1 1             | X.2.1.5                                    | X.2.1.5     |
| Very strong        | 8 1 1 1 1 1 1 1 1             | X.2.1.6                                    | X.2.1.6     |
| weak               | 2 0 1 0 0 0 1 0 0              | X.2.2.1                                    | X.2.2.1     |
generalizing it in order to deal with it better when the building needs to be changed

| weak | Average | Very strong | Very strong | Average | Very strong | Very weak | Average | Very strong | Average | Very strong | Very strong |
|------|---------|-------------|-------------|---------|-------------|----------|---------|-------------|---------|-------------|-------------|
| 2    | 4       | 8           | 8           | 4       | 7           | 1        | 4       | 8           | 4       | 7           | 8           |
| 0    | 1       | 1            | 1           | 0       | 1           | 0        | 0       | 0           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 0       | 1           | 1        | 0       | 0           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 0       | 1           | 1        | 0       | 0           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 1    | 0       | 1            | 1           | 0       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 0    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |
| 1    | 0       | 1            | 1           | 1       | 1           | 1        | 1       | 1           | 1       | 1           | 1           |

Independent structures and modules

For a hierarchy of spaces

The relationship between spaces, service areas and technology

Easy access to maintenance

Separation into permanent and non-permanent regions

Application of mobile partitions and furniture

Ensure transparency and accessibility to the building

Dismountable, reusable with flexibility

Develop tools that can assess design flexibility

The ability to estimate the expected life span of the building components

General and specific space plans

Regularity of plans, use of mobile technologies and sections

Redundant access (the ability to connect different spaces together)

Defining specific service areas and technical areas, and the ability to examine

Sustainable Resilience Strategies

X.2.3
7. Conclusions

7.1. Conclusions of the theoretical side:

- Studies on functional flexibility have shown that many of the known building principles are already in use. It will be possible to reconsider its evaluation at the long level as a result of not taking into account the potential of flexibility, which requires integrative thinking with all disciplines in addition to the absence of collective awareness of the importance of functional flexibility, especially in service buildings, taking into account good design thinking that is adaptable to future social challenges.

- Flexibility is Three-dimensional (spatial, functional, aesthetic) that is able to meet the requirements of sustainability over time within creative activities aimed at not wasting time, cost, and performance.

- The addition and the ability of the building to expand horizontally and vertically without damaging the building mass, horizontally and vertically, is the most important key indicators in evaluating the building.

- The ability of the building to accept the addition and omission at the functional and mass level without damaging the general formation and what is reflected in the building block is the most important criteria in evaluating the building.

- To assess the importance of the flexibility of building components, this is done through a set of measures to determine the building’s ability to accommodate functions or functional change by testing the spatial configuration of the building or the building system, the ability of functional distribution, the possibility of integrating jobs in one space, the ability to transform space, the ability to change and take formation New space.

- Functional flexibility works at different physical levels, and it is necessary to refer to the long period of time that architecture needs to continuously adapt to the changing contexts of fields (technological, technical, economic, organizational, and social).

- Architecture that does not respond well to change runs the risk of stagnation, which means its death. Therefore, buildings must be adaptable and developed in line with the temporal and intellectual changes to meet human needs. The challenge begins with creating a flexible and responsive architecture by studying and observing prime examples of historically successful buildings, where the use of buildings has changed. In addition, the flexible design opens the door to encourage creativity and innovation.

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- The bearing structure is distinguished by its ability (reserve or additional) to add floors; The load-bearing structure is far enough from adjacent buildings to make horizontal extensions possible. While the steel structure has the potential to give a greater space height due to the relatively light and compact structural elements (columns and beams), the designer should pay special attention to potential changes in the variable loads on the structure. The success of architecture must be related to the degree of flexibility it offers in its use.
- “Form and space” were among the most important architectural forms used in the square, circle, and triangle. Patterns obtained from overlapping, superposing, or repeating these shapes are often used. Therefore, basic geometric shapes are preferred in antiquity. While at the present time many designers naturally tend towards buildings (curved or organic, superposed, disassembled, moving), but this does not mean stopping the use of basic shapes, we focus here on which shapes are more flexible in relation to the function, through the samples that were dealt with and testing them, we found that the basic or geometric shapes are the most flexible to add, especially at the level of the interior, if they provide clear and wide spaces.

- As for the external shape of the mass, the basic masses are easy to add to it any types of blocks even if they are combined with masses (curved, folded, disassembled, moving). The process of adding and merging the surfaces after studying the original shape is much easier than adding to a deconstructed or organic building. To complex measurements and studies to complete the process of addition or deletion, and play (strategies, flexible building characteristics, types of flexibility) the appropriate role and stimulate thinking in the forms that qualify for achieving the flexibility to fit the building.

It is necessary to abandon the stereotypical blind following of the representation of a function in space directly, as this pattern leads to the division of space rather than its integration, especially with the changes taking place in the world.

7.2. Conclusions of the practical side:

- Through the application, it became clear that the most common types of flexibility strategies used in the samples are (divisibility, ability to add and delete and integrate functions) because they achieve flexibility and functionality by adding new parts of the building or changing the interior more than others at the remote level.

- The tendency of all designers to use strategies (the relationship between spaces and service and technical areas, ease of access to maintenance, separation into permanent and non-permanent areas, and the possibility of changing the life span of building components) achieves great flexibility regarding the addition process at the interior level and how to deal with events and jobs New, whether at the level of expansion or changing the use of the building.

8. Recommendations

The necessity to oblige architectural schools to expand the knowledge base of students regarding functional flexibility issues due to its immediate importance, through the subject of architectural design and a future beyond implementation and work.

The fact that the building was not affected (symbolically, functionally, formally, and aesthetically) through subsequent functional additions is evidence of the creative designer's ability to create flexible designs that are adaptable to change over time.

As designers, the future requires some kind of use of the architectural imagination to anticipate what will happen in the future and how the building can cope and adapt to the temporal, technological, environmental, and economic changes of future decades uncertain by developing several scenarios relying on the design and functional flexibility as a factor to critique the expectations set for projects or scenarios. Imagining and applying resilience strategies or their properties to these expectations. Hence, architects can use those creative skills to envision a changing context when designing for flexibility.

The architect must conceive of an architecture worthy of eternity outside its immediate time, not with the intention of seeking permanence or imposing fixed standards, there is no eternal architecture, but it is possible for a flexible architecture for a long time, here again, we see the importance of flexible architecture open to functional change and social, cultural and technological adaptation in the future.

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