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TECHNOLOGICAL AND SPATIAL FLEXIBILITY FOR NEW HOME DESIGNING

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One of the main problems of home design is that, of all technological systems, it is the most at risk of becoming technically or functionally obsolete. This is partly due to the fact that interventions on housing construction have oriented themselves toward the Optimal Point logic Design (OPD), which has the single goal of living in the more traditional sense of the term, therefore eliminating all possibilities that do not comply with those specific features. Once removed, the results become rigid towards new tasks. It is obvious that in the building sector, the inability to handle the uncertainty of social and economic contexts, the changing needs of users, and the environment, makes the system obsolete and reduces its useful life. If flexibility is the ability of a system to be easily modified and to respond to changes in the environment in a timely and convenient manner, then flexibility can be considered an antidote to obsolescence. This paper provides a critical assessment of the implementation of flexibility starting on four lines of action for design flexibility in homes: Spatial flexibility with constant surface, spatial evolutionary flexibility, technological flexibility relating to construction techniques, and technological flexibility concerning the plant maintainability. This research therefore proposes that project strategies incorporate these factors aimed at ensuring the survival over time of the building, implementing its cycles of use, and reconfiguring the internal structure to intervene in a simplified way regarding the technological system that governs the space.

Keywords: Uncertainty, Obsolescence, Housing construction, Maintainability.

1 FUNCTIONAL AND TECHNOLOGICAL OBSOLESCENCE OF LIVING SPACE

In general, one of the main problems of housing construction, if not of all engineering systems with long lifespans, is the risk of becoming technically or functionally outdated. Obsolescence refers to all the factors of aging, degradation, and deterioration that occur when performance levels fall below acceptable set values, i.e., because their services are no longer competitive, or because they are no longer useful or necessary. Obsolescence can be attributed to the inability of a system to meet changing needs contextual or the users. It is obvious that in the building sector, new lifestyles and the growing interest in environmental issues have resulted in a residential hardship for users that has changed the way people live, and in the inconvenience of unsustainable and disposable systems unable to evolve with market changes. Housing construction has been designed according to the logic of Optimal Point Design (OPD) with the optimization of a specific task: to produce housing that ensures the simple function of living in a traditional vision. This single-mindedness of purpose has eliminated capabilities that are superfluous to complying with those specific features, and made the system inflexible towards new tasks. This rigidity prevents the system from bringing together skills again for tasks that occur over time, rendering it obsolete (Mark 2005).

In other words, the space of the house project, structured according to the concept of optimization, operates today in an extremely uncertain context dominated by rapid processes of functional and technological obsolescence, defined as follows:

- **Functional Obsolescence**, affecting the degree of satisfaction of users, is due to the inconvenience of users in terms of expectations and needs. It occurs when the system does not guarantee the optimum performance of the functions for which it was designed, or else guarantees it with a lower level of satisfaction. This "Opacity" of competitive advantage makes the system obsolete.
- **Technological Obsolescence**, affecting the system performance, is due to the obsolescence of one of the components of the system. A mechanism for component obsolescence is attributed to technological advancement and/or marketing of new components. As replacement parts for obsolete components become scarce, expensive, and unavailable, it costs more to replace a part in the component than to replace the entire component (Di Sivo & Cellucci 2013).

2 FLEXIBILITY AS A STRATEGY FOR THE PROJECT

In this scenario, a project aimed at extending the lifespan of the building or its parts must be designed to promote interventions that can overcome market uncertainties and functional obsolescence. This would occur through flexibility allowing possible reuses of product over time, a quick and easy maintainability and replacement of plant components, as well as possible adjustments from the onset of technological obsolescence.

One may identify two strategies to extend of the lifespan of the house, meaning that the same level of performance is guaranteed over time:

- **Spatial flexibility** that typologically guarantees the modifiability of the house and goal changes reflecting specific requirements of users. This should be linked to "the possibility of preparing functional variables models, spatial configurations and technical alternatives and constructive intended to be implemented by users within different temporal thresholds." (Nardi 2011)
- **Technological flexibility** that technologically ensures easiness of modifiability, allow all operations that do not alter the original objective, and aims to improve the technological apparatus. This should be linked to the relationship between maintainability and reversibility, easiness of repair of any breakdowns, the installation of new components, the upgrading of existing ones, and the recycling of disused ones.

In this way housing can maintain its competitive advantage despite changing conditions (e.g., change of function or users). The resulting system is flexible enough to rearrange its basic components for satisfying new needs and future possible developments. This flexible management of space also allows the user to customize it for more personalized use. But, flexibility is tied to the ability to reconfigure the structure and to intervene in a simplified way to change the technological system that governs space (Campioli 2009). The easiness of adaptability of space is inversely proportional to the presence of structural constraints or plant. Then flexibility involves both the technological and typological context.

3 CLASSIFICATION OF APPROACHES TO FLEXIBILITY IN THE DESIGN OF THE HOUSE

In the course of the history of architecture, the implementation of flexibility was a central theme in housing design. Sometimes flexibility has been implemented within a typological context, as a possibility of versatility and internal convertibility of the housing through the variability of internal distribution. Other times flexibility was implemented from a technological point of view, through flexible networks and terminals (making them physically moveable, and designed according to the requirement of maintainability); or through morphological/structural choices and construction technologies that allow a reversibility and interchangeability of building components. There are four major trends, created in response to specific needs that evolved over time:

(1) **Constant surface spatial flexibility**. The first trend applying flexibility to space in a home consists in the study of possible design strategies conferring high internal adaptability without changing the total volume of the building. This consists of the design of impersonal spaces which can be assigned to different functions over time, and then in the provision of equipment and technical systems compatible with possible distribution structures (Turchini and Grecchi, 2006). This kind of flexibility is obtainable through technically-equipped bands within minimum spaces or multipurpose technical centers (fixed or mobile) within a single flexible space (see Figure 1).

Figure 1. *Nendo* architecture, Drawer House, Tokyo.

(2) **Evolutionary space flexibility**. This kind of flexibility, which anticipates a lifecycle programming of the house, alternates between phases of expansion and contraction, according to the variability of the requirements of users. It also requires spatial strategies and complex technological systems. This idea of transformation involves surface boundary surfaces and structural logic through an increase in the total volume of the building. These techniques give the building flexibility for radical redesign of spaces and surfaces within a relatively short time and with lower costs.

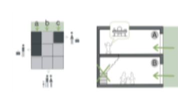
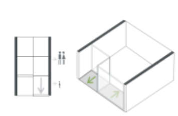
(3) **Technological flexibility relating to construction techniques**. Technological flexibility concerns the simplification of construction. In practice, the flexibility of housing is the capability for the user to take over space through easy intervention in traditionally fixed parts of the housing, e.g., floors, partition walls and seals, in order to shape them to suit your specific needs. This is achieved through technologies such as organized kit of prefabricated components to be assembled on site (see Figure 2).

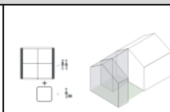
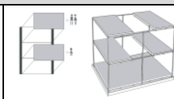
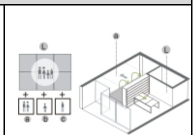
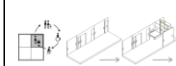
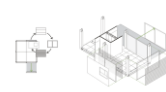
Figure 2. Loblolly House (courtesy Kieran Timberlake 2006).

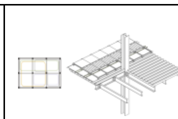
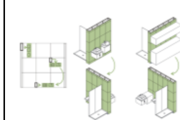
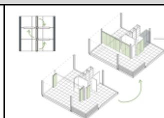
(4) **Technological flexibility concerning the maintainability of plant and construction subsystems**. This strategy aims to improve the flexibility of the housing by ensuring easy maintainability, so that the user can change the old components with new, low-cost ones in a timely manner.

4 CRITERIA AND STRATEGIES FOR IMPLEMENTATION OF FLEXIBILITY

In the four analyzed approaches above, flexibility is applied to mitigate specific forms of uncertainty (*viz.* variability of the intended use, the variability of users, etc.). Sometimes this is more related to the spatial typological aspect, and other times more to the technological theme. But as mentioned above, flexibility involves both typological and technological scope, so its implementation requires a reflection on the building system upon which the technological apparatus is organized. Let us consider the relationship between spatial and technological flexibility through the implementation of the following strategies within three important areas: spatial morphology, structural morphology and equipment:

Area: Spatial morphology. **Strategy:** Redundancy access.	
This strategy ensures the possibility of a decrease in the size of the house over a period of time, in which the user does not need more of the entire surface of the house and can divide it into two or more units, or may assign part of the surface to another home or to a task (studio). To schedule a minimum of two accesses can significantly affect costs (technical and constructive) related to the eventual realization of the same division into two units.	
Area: Spatial morphology, structural morphology. **Strategy:** Increased surface on existing support.	
This strategy allows the increase of the surface of the house through the closure of spaces that are already built and of relevance to the house (support existent) but that are not considered habitable, because they are open, for which there is no need to extend or modify the structure. The new space can be a balcony or a terrace, where small architectural interventions may be closed to form part of the interior of the house.	

Area: Spatial morphology, Structural morphology. **Strategy:** Increase in house size on new media and increasing the initial volume.	
This strategy allows the growth of useful surface of the house by creating new spaces, compared to the initial volume, over a new support, then through the addition of structural elements. The implements of the house can be annexed to the initial space, through the utilization of a patio or an external garden. In this case, the house must be designed for modular elements that can be expanded in the three spatial directions, according to needs planned for in the design stage, through the use of prefabricated modular elements.	
Area: Spatial morphology, structural morphology. **Strategy:** Increased of the inner surface by adding environmental units.	
This strategy allows an increase in the useful surface of the housing, without affecting the initial volume because the increase takes place within it. This increase is possible inside a house on two levels, such as through the closure of horizontal full-height spaces in favor of environmental new units, or by adding an extra bedroom for the birth of a child.	
Area: Spatial morphology, equipment. **Strategy:** Customization of privacy/sociality.	
This strategy aims to create an appropriate balance between privacy and socializing within the household, through an organization of space that guarantees privacy for the room-bathroom while sharing environmental units intended for sociality of cohabitation. This affects both the arrangements of environmental units and systems that guarantee environmental well-being: e.g., illuminants for modulation of light and heat, movable walls, and equipment that guarantees the size of the space as a function of use, etc.	
Area: Spatial morphology, equipment. **Strategy:** Indeterminacy of environmental units.	
This strategy is based on providing the house with indeterminate spaces. Users can change the use of space without physical changes. This is possible either through a neutral downsizing of the environmental units to accommodate any function and a hierarchization of the same (for example, a room can be transformed into a studio, etc.), or through the conception of space as a universal container in which the organization of environmental units and their transformability is given by moving walls and furniture containers.	
Area: Structural morphology. **Strategy:** Adequacy and modifiability of the housing casing.	
This strategy allows an upgradable facade of the housing, which usually needs to be rehabilitated every twenty years for technical or esthetic considerations. The adequacy of the casing can be related with the possibility of an extension of the interior space on a new or existing support. Among the possible solutions is the use of movable facades that slide on preexistent lodges to ensure the expansion of the internal space; non-bearing curtain walls that allow users to dismantle some closure elements and replace them with others, or to reassemble them later with a new configuration. All of these options have shorter timelines and lower costs than those required for modifying traditional perimeter walls.	
Area: Structural morphology. **Strategy:** Using closures that are dried and stratified.	
This strategy allows for housing reversibility with fast deadlines that reuse part or all of the components. This strategy allows, therefore, a total housing reversibility, the replacement of some components with others that provide higher performance, and the change of position of the same (e.g., seals or partition walls). The vertical closures that are opaque or transparent can be thought of as stratified dry packages united with mechanical junctions without the use of adhesives or sealants, meaning they are easily removable and replaceable.	
Area: Structural morphology. **Strategy:** Structural regularity and adaptable floors.	
This strategy consists in organizing the structural system on a regular grid, essential	

to ensure the easy convertibility of the building. It also involves the use of materials that ensure maximum reversibility of the system and the flexibility of interior spaces through the installation and reinstallation of metal components. Hollow beams or trusses are also used that are capable of integrating the plant system in a structural morphology, making the interior space completely free from constraints that might hinder the convertibility of the space. It will also be important oversize properly (taking into account the increase in costs) the bearing structure in anticipation of possible extensions.	
Area: Equipment, Structural morphology. **Strategy:** Introduction of home automation systems.	
This strategy allows for the easy transformability of internal space through the use of home automation systems. Such systems can be linked to specific vertical lockings, programmed to move on lodges and terraces to increase internal space, or to a mobile container system able to transform the space based on its use. This strategy provides a programming of spatial solutions and is particularly useful for certain categories of users, such as disabled or elderly.	
Area: Structural morphology. **Strategy:** Redundancy and inspection of the equipment.	
This strategy consists in downsizing technological systems to allow changes or additions of technical nuclei (e.g., kitchen or bathroom). In the case of refunctionalization, enlargement, or reduction, users must be able to reprogram the plant system possibly implementing it, reduce it or replace parts without having to change the system. A significant strategy is the planning and scheduling of points of adduction (e.g., water and gas) at design time, and of access function or possible divisions that require adding additional technical areas, etc.	
Area: Equipment. **Strategy:** Use of mobile equipment.	
This strategy allows the spatial and functional reorganization of the entire housing unit with quick turnaround, thanks to the displacement of equipped walls, furniture cabinets or prefabricated modular interior partitions mounted with dry joints. This solution is effective especially in small spaces, without partitions, where the partitioning is done through the use of mobile equipment enabling the user to use the same surface differently.	

5 CONCLUSIONS

The relationship between relevant strategies for morphological space, morphological structure, and equipment involves living models, whose level of flexibility depends on the strategies used and the level of interaction among the areas identified. These strategies can be used as a checklist to evaluate projects from the point of view of flexibility or as a guide to the design of flexible housing.

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