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FLEXIBLE SYSTEMS DESIGN

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The research explores the relationship between uncertainty, flexibility and Life Cycle Design in the design of complex systems, in general, and in the particular case of the design of building systems. In the architectural-engineering works, conceived as activities aimed at generating new systems, the comparison with the uncertainty is inevitable. There is a wide range of types of uncertainty; a possible simplification is to consider two types of causes of uncertainty, the presence of the internal or external uncertainties to the system. That is the variability of demand (unknowns about the social and economic context) or the variability of technological market (unknowns about the performance of the system), in other words the functional obsolescence and the technological obsolescence. 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, then the flexibility can be considered the antidote to obsolescence, or the characteristic of the system that guarantees slippage over time. It's that property that makes the system resilient able to absorb the shock and/or disturbance without undergoing major alterations in its functional organization, in its structure and in its identity characteristics. In the paper, the flexibility is therefore seen as a fundamental property for designing a generally complex system, and particularly in architectural design, through the identification of design criteria for the implementation of this requirement, that influence on architecture (form more technology) of the system.

Keywords: Uncertainty, Flexibility, Technological flexibility, Spatial flexibility, Life cycle design.

1 INTRODUCTION

One of the main problems affecting the architectural design in the last decades has been the disposal and renovation of these inherited buildings, as well as the risk of becoming technically or functionally obsolete in the short term, because the performance of the buildings no longer has a competitive edge in the housing market nor do they satisfy the needs of the user. This inability to manage the uncertainties of the socio-economic context and the various needs that arise from different types of housing usage tends to render the housing system inadequate and reduce its shelf life. This suggests the need to rethink the concepts of obsolescence, life span and flexibility during the design phase. If flexibility is defined as the ability of a system to be easily modified and to respond to user needs in a timely and effective manner, then it can be considered an antidote to obsolescence and a characteristic of the system that ensures the extension of its life cycle over time. In the paper, the flexibility is therefore seen as a fundamental property for designing a generally complex system, and particularly in architectural design, through the identification of design criteria for the implementation of this requirement, that influence on architecture (form more technology) of the system (Cellucci 2014).

2 UNCERTAINTY: CONTEXT VARIABLES AND SYSTEM VARIABLES

Uncertainty, as "unpredictability" is a fundamental condition in which natural and man-made systems are compared and generally all complex systems. One way to deal with uncertainty is to incorporate flexibility in the initial design, so as to ensure the possibility of choice in the future and be able to tackle successfully the changes that may occur during the life of these systems. Flexibility reduces the exposure of a project uncertainty, provides useful solutions to mitigate risks related to changes and market constraints, and the risks associated with technological obsolescence; is so, that property that makes the system resilient, that is, able to "absorb the shock and/or disturbance without undergoing major alterations in its functional organization, in its structure and in its identity features" (UNEP 2005). A system, in this sense is resilient if retains the idea of its shape, which is maintained despite the subsequent metamorphosis, but it is not permanent for eternity, caged in an unchanging order. There is a wide range of types of uncertainty; a possible simplification is to consider two types of causes of uncertainty, the presence of the internal or external uncertainties to the system. That is the variability of demand or the variability of technological market, in other words the functional obsolescence and the obsolete technological (Sethi and Sethi 1990; Shi and Daniels 2003).

The presence of the internal or external uncertainties to the system (context variables and system variables) involves the application of different theoretical approaches to mitigate the uncertainty of the context and of the system (Fig. 1).

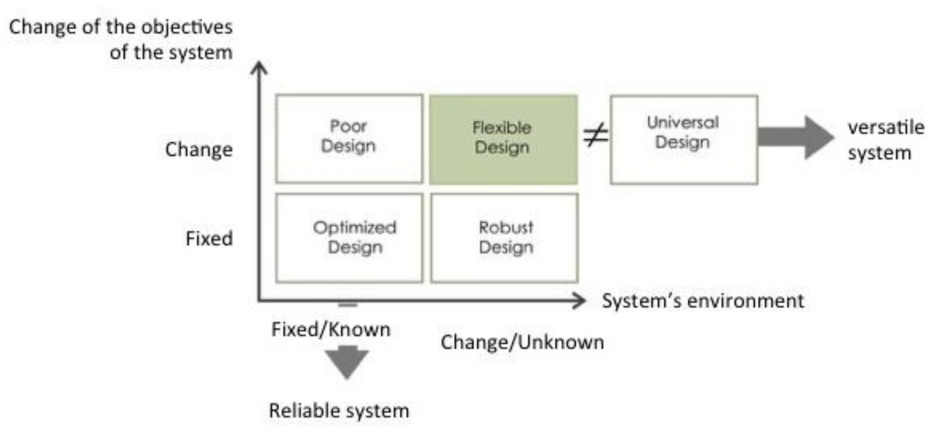

Figure 1. Different theoretical approaches to mitigate the uncertainty of the environment and the system.

Thus, from the foregoing considerations, it is clear that flexibility is required if:

- The uncertainty in the system's environment is such that there is a need to mitigate risks arising from exposure of the system to such uncertainty;

- The system is subject to one or more lens exchange during its life cycle, following the mutability of the user's needs, thus requiring a solution of mitigating risks associated with functional obsolescence;
- The system's technology base evolves on a time scale considerably shorter than system's design lifetime, thus requiring a solution of mitigating risks associated with technological obsolescence (Saleh *et al.* 2003).

3 DEVELOPMENT OF A METHOD FOR IMPLEMENTING FLEXIBILITY IN DESIGNING A SYSTEM

In summary, the flexibility is required if there are internal or external uncertainties to the system, that is if the system is subject to functional and technological obsolescence. In conclusion, we can point two strategies should ensure that extension of the life of the building as well as the same level of performance during the life cycle design (Cellucci and Di Sivo 2016).

UNCERTAINTY	VULNERABILITY	PROPERTIES
Variability of the environment (the uncertainties concerning the social and economic context)	Functional obsolescence of the system	**Spatial flexibility**: The ability of a system to adapt to different uses and functions to respond to the variability of users needs. Spatial flexibility is obtained from the relationship between the requirements that affect the form of the system, the versatility, the convertibility and the modularity of the system.
Variability of the system (the uncertainties regarding the system performance)	Technological obsolescence of the system	**Technological Flexibility**: The ability to work easily on the technological apparatus that governs space. The spatial flexibility is obtained from the relationship between the requirements that act on the structure of the system, which is the maintainability and reversibility.

The requirements of spatial flexibility are:

- *Versatility*. The multiple use of a system within an area with shapes and sizes that is altogether unchanged over time. We say that a versatile system is Universal. This requirement affects a system's internal configuration.
- *Convertibility*. The system's ability to adapt to different physical configurations through a transformation that alters its internal and external configuration, in order to meet the different needs and requirements that arise after the system has been made operational. This requirement affects the system dimension.
- *Modularity*. The Organization of the system into parts which can be subtracted or added to the system according to your needs.
- *Open System.* This requirement affects the system's dimension, its ability to expand over time.

The requirements of Technological flexibility are:

- *Maintainability*. The probability to repair a system at a given time when maintenance operations are implemented in accordance with the prescribed procedures and resources. The implementation of the requirement of maintainability can promote any redevelopment work which is necessary when there is an imbalance between the performance of the technical element and changing levels of need in the users, allowing you to quickly make those adjustment operations to new levels of quality (Di Sivo 2004).
- *Reversibility*. The Organization of the system in sub-systems and separable components, with particular reference to the "features and the" status "of connections. The reversibility of the system makes it possible to decrease the impacts resulting from the disposal of the system, such as for large systems such as buildings; the implementation of this requirement provides the demolition through the disassembly and consequently the separation of constituent parts and materials in order of their possible reuse or recycling.

The spatial flexibility implies a high degree of organizational complexity, which is indeed a fundamental attribute of resilient systems. It is evident that the multiplicity of solutions increases the resilience of the system, the possibility of evolution, of change and adaptation. The concept of technological flexibility implies the concept of simplicity of implementation, intended as quickness and easiness with which they can complete the maintenance operations and reversibility, undertaken in order to correct the gap between requirements and performance in order that the system won't cease its usefulness. The concept of flexibility implies that maintainability and reversibility operations can be performed without the need to undertake other unforeseen or unpredictable collateral activities. Wanting to try a list of the main moments of construction and control of the flexibility of the systems we have reached by developing a list of general criteria of flexibility to be used in reference to the design features of the system (Cellucci and Di Sivo 2016):

LIST OF GENERAL CRITERIA OF FLEXIBILITY	
Programmatic Complexity	Space solutions able to ensure easiness of modifiability over time relative to the variability of users needs and the satisfaction of psychological and functional needs.
Simplicity in the interface:	Choice of technical solutions capable of guaranteeing the possibility of intervening with easiness on system components, that is ensuring the dismantling, substitutability, reparability of system components.
Structural simplicity	Choice of reversible construction techniques, with a particular reference to the characteristics and status of the connections.
Optimization of components	Possibility of substitutability of components, through a modular organization and their optimization towards specific objectives in order to hinder the technological obsolescence.
Optimizing plant integration	Verification of coherence between technical-building solutions and inspection of plant equipment, ensuring the maintainability of the networks without affecting the functionality of other components or subsystems.

4 CONCLUSION

In the paper, the flexibility is therefore concerned as a basis for designing a complex system, through the identification of design criteria for its implementation, that influence on architecture (form more technology) of the system, through the relationship between mitigated requirements of specific sources of uncertainty. This approach can be useful: the uncertainty of the context is such that there is a need to reduce the risks arising from exposure of the system in this uncertainty; the system is subject to one or more target changes, due to variability of requirements of users, requiring a solution to mitigate the risks associated with functional obsolescence, the basic technology of the system evolves in a time shorter than the lifecycle of the system, requesting a solution to mitigate the risks associated with technological obsolescence.

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