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Perspectives of Built Environment under the Impact of Digital Technology

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ABSTRACT/RESUME

Abstract:*The purpose of this paper is to highlight the perspectives and conceptual scopes of built environmentas a result of digital technology. The design approach has been developed based on data analysis. This approach is conducted in three phases: It consists first of all of processing data from various uses and functions of the built environment in the digital age. However, the second step is used to fix concepts and indices revealing environment, while the third analytical step highlights the relationship between digital tools, concepts and indices arising from the use of intelligent built environment. These concepts will be optimal in a building that meets the revealing characteristics of intelligent architecture.The results reveal four groups of indices resulting from the particularities of each concept indicating built environment in the digital age those that affect and evolve the exterior appearance, those that transform, dissolve and reconfigure the initial function to another, those that modify the sensitive and lastly, those that improve and optimize the technical management of space.This study focuses on the perspectives of optimizing the quality, performance and intelligence of built environment; that designers can refer to when designing intelligent and appropriate spaces to users' needs.*

I. Introduction

The arrival and profusion of digital tools and devices in recent years has revolutionized the field of architecture and has influenced the materiality of buildings and their spaces. These technologies compel designers to reinterpret architectural spaces, influence their appropriations, exert spatial effects and tend to mobilize users, to make them act or react… Then, a new space is born; from a traditional architectural space with its physical limits to a hybrid space in its simplicity, complexity, flexibility, responsiveness and originality generating a sensitive experience for the human body that is involved and immersed in it.

At this level, we are faced with a new dimension which triggers a redefinition of the uses and practices of built environment and which supports new concepts that reveal it "fluidity, interactivity, transformation, automation, sustainability, openness...". These uses and concepts coexist and cooperate with new technologies and new digital means (Figure 1) so that the built environment is efficient, intelligent and of good quality.

Figure 1.*Impact of digital technology on the design, use and practice of space*

II. Impact of digital technology on the use and practice of built environment

Built environments receive our human bodies by offering them a space to inhabit, to meet, to cross, to rest, to maintain, to work, to observe, to visit and to participate in events... Today, these spaces widespread use of digital technologies and reveal a transition and transmutation of uses and practices found in different fields of activity, whether in the scientific, educational, commercial, administrative, medical, cultural, industrial sectors, etc....

The paradox underlines the constructive or disruptive aspect of the transformations in uses imposed by digital technologies (Figure 2). The latter, already exploited by many companies, offer possibilities for automation, optimization, flexibility, simplification and strengthening of performance, quality and intelligence by giving consistency to the entire building and any convenience required by users.

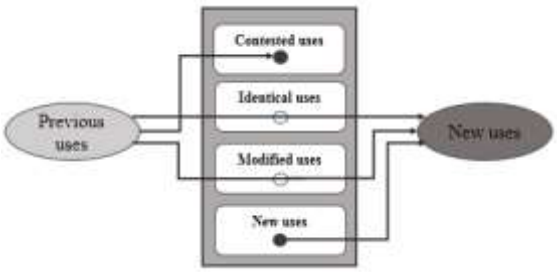

Figure 2.*Transformation of uses due to the integration of new technologies*

A brief overview of the changes that built environment has undergone in different uses is developed below.

Digital technologies are revolutionizing the organization of the structure, the mediation and the professions that take place in cultural buildings such as museums, exhibition halls and cinemas... They offer a new identity to expand cultural practices and a formidable opportunity to intensify the scope of the functions of exhibition, projection, communication and animation. These technologies erase the notions of boards, guides, panels, physical supports...by offering interactive, immersive, lively, attractive, modern, non-noisy, dynamic and adaptable spaces. Furthermore, the use of digital technologies and innovations in libraries that has increased dramatically in recent years. These technologies break all the stereotypes of space that we know, strengthen the exchange of ideas, promote collaborative work, allow access to information, use it in a revolutionary way and give more fluidity in the transmission and dissemination of knowledge…Consequently, the model of these buildings has become open-planed, adapted, personalized, connected, flexible and fun… Likewise, digital technologies are revolutionizing the design of hospital medical establishments and strongly contributing to the progress and changes in medicine, many of whose terms have appeared e-health, medical robotics, smart hospital, artificial intelligence, ultra-connected rooms, computerized files, home monitoring…'. These modify the doctor's way of practice, the doctor-patient relationship, the reactions of patients and those accompanying them, the quality of services, their organization and their mode of operation. The goal is to promote assistance, medical care, wellness, create a fresh contemporary interior space, pleasant, well-lit, ventilated, scalable, ergonomic and automated.

By judiciously exploiting the innovative products and services of digital technologies, residential uses in connected residences and accommodation in luxury hotels, become more attractive and innovative. Through automatic systems, the user can control manage his home remotely, control all the installations and equipment (lighting, heating, ventilation, security, monitoring energy consumption...). All these improvements work together to ensure that the home and the accommodation are ecological, user-friendly and adaptable to the needs of a hyper-connected user. In the same manner, innovation and creativity in laboratories and research locals and the management of today's workspaces, have become fun, flexible, designed for everyone and appropriate to the needs of users. These spaces can be open for working together by sharing information and knowledge, closed for meetings, isolated for further reflection... In fact, they promote collaboration, co-working, desk sharing, flex office ..., improve the quality of service and increase the productivity and the pleasure of exploring and working by improving user and customer satisfaction . All mentioned improvements transform these buildings into a living space, respectful of the environment, open space, intelligent, modular and versatile, ultra-connected and flexible...

In the same manner, the industry has undergone a new evolution with the expansion of digital technologies. We are talking about industry 4.0, the industry of the future, cyber factory, the digital factory... Manufacturing and production have changed and become more targeted and personalized, agile and intelligent, connected, automated and robotic. These smart buildings aim to reshape new uses in a precise time and with greater assiduity (simplification of product manufacturing, flexibility of production circuits, management and maintenance of carried out operations…). All these consolidations improve costs, quality, performance

and delays. Apart from that, the digital transition offers new opportunities to relaxation and leisure buildings as well as to the various catering and sales service areas. This transition offers new possibilities for interaction and immersion: evolves practices, transforms the management of space and lived experiences, modernizes and expands interior design in different ways... In short, it promotes these spaces to socialize in a comfortable, safe, productive and functional environment while meeting the specific needs of these guests.

III. Architectural design, building and digital technology: The state of art

Several research works have tried to identify notions and concepts in architecture that could lead to the creation of a more efficient, intelligent, economical space and appropriate to the needs of the users. In order to identify notions and concepts revealing intelligent built environment, a selective research based on the analysis of the different uses and a literature review-addressing question of use, perception and practice of the intelligent built environment has been conducted.

In a study report, Titouan Chapouly examined ambiguous and interactive spaces as new practices of urban and residential spaces that arise from contemporary fluidity [1]. Likewise, Carlos Zerpa Guzman argues that the fusion of new technologies with architectural practice has led to a transformation of uses and lifestyles. He discussed perspectives that characterize architectural fluidity such as curvilinear, liquid and evanescent [2].

Cédric Radosavljevic, and Emélie Boron have been interested in their research on the reasons for the popularity of the intelligent open space and aim to know the perception of its users and their behaviors [3] [4].

Likewise, in his research on flexible, mobile, transformable and interactive architecture, Robert Kronenburg addresses the dynamic and vital scope of the architectural practice of intelligent space [5] [6]. While Maziar explores the potential of transformable and transportable architecture and identifies design management criteria that could lead to the creation of a space that is more efficient, intelligent, economical and appropriate to the needs of users [7]. However, Lee Joshua David provides an analysis of four terms belonging to intelligent spaces which are expressed as ‘adaptable, kinetic, responsive and transformable’ and justifies their necessity for contemporary architecture [8].

In order to give a broad overview of the motivations and goals of adaptive architecture, Holger Schnädelbacha has implemented a conceptual framework appropriate to this architecture [9]. He was able to develop with others the relationship between physiological monitoring, the behavior of the inhabitants and the dynamic adaptation of the building through a prototypical adaptive space [10]. He then explored with Jäger and others the role of immersion in the generation of specific interactive effects in the developed prototype [11] [12].

Bullivant in 4d space: Interactive Architecture studies the reality that perceptual boundaries between virtual and physical worlds have been broken and wonders how architecture and its tasks can creatively adopt a fourth dimension [13]. However, Alma-Dia Hapenciuc and others have analyzed the principles that give birth to contemporary architecture, based on ideas of change, flexibility, responsiveness and interaction with the user [14].

In short, intelligent architecture is not limited to these peculiarities only, but includes others, related to sustainable and automated architecture. Bragança, Markeljet and others, have focused on new solutions in the building in favor of the environment: reduction of gas emissions, recovery of clean materials, energy management, water and waste management... [15] [16]. As for Derderian, he presents in his study the design, construction and installation of a building automation system in a villa in order to supervise and control all the electromechanical equipment installed there [17]. In the same area of interest, Pat So and Chan presented a variety of current technologies applied to HVAC systems, security and surveillance services, fire departments... [18]. Likewise, Beddiar and Lemale discussed in a chapter of their book, active building management, connected objects, ambient intelligence...and their role in sustainability and energy optimization [19].

IV. Notions and concepts revealing intelligent built environment

The summary analysis of the various works allows us to fill research gaps and identify several architectural specificities as digital technology has integrated into built environment. These specificities of a spatial and functional nature (continuity, dynamic, complexity, evolution, change, indeterminacy, versatility, mixed use, reconfiguration, deformation, displacement, transparency, freedom, decompartmentalization, reactivity, immersion, virtuality, hybridization, computerization, communication, respect for the

environment, ergonomic, etc.) helped us to determine the most relevant concepts to the intelligent built environment, which can be synthesized in Figure 3.

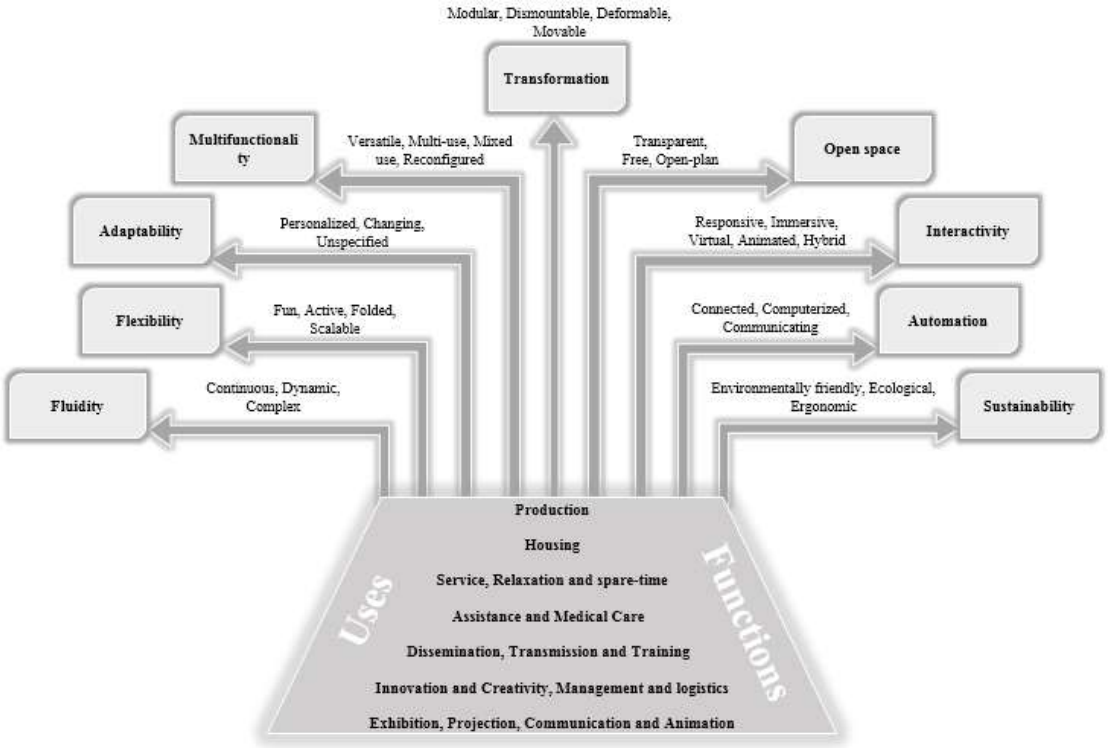

Figure 3. *Relevant concepts in architecture in the digital age*

Digital technology is deeply involved in creating a new fluid, cognitive environment, adapted to the environment and to space's use through the logic of the non-standard [20]. The concept of fluidity represents an accumulation of characteristics that associated to the form compared to the movement, the complexity and the dynamics of the volume. In addition, fluidity is associated to the interior space in relation to the continuity, homogeneity, transitive interweaving of spaces and uses and the dissolution of their limits. It is also associated to different materials constituting the construction elements and to harmony, elegance and architectural aesthetics...

Passing to the flexibility that is a concept linked to architecture that adapts, transforms, bends, evolves and interacts with a predefined use. Therefore, it suggests a mechanism for movement, change and displacement through elements constituting the architectural space such as the envelope, the circuit, the spatial arrangement and the furniture... [5].

Among the most relevant concepts to the intelligent built environment, the concept of adaptability that envisions changes requested by users faster and more easily unlike flexibility that responds to long-term needs and demands [9]. For example, we can make decorative changes to affect the atmosphere of the space or even offer sliding and folding partitions to allow users to adapt the space to their needs...

On the one side, we find the concept of multifunctional space that has been used in connection with mixed-use buildings or what is called multi-use and multi-purpose [21]. It must meet multiple conditions such as the reduction of built surfaces, the change of users, the reconfiguration of functions and activities and also the use of technology in an optimal way. On the other side, there is the open space that is now a more cost-effective, user-friendly, efficient and collaborative option. Its main quality is: to abolish limits by providing more flexibility and transparency, to bring places closer together by producing a collaborative, communicative, interactive, amorphous and neutral space, to lower some tensions by creating a feeling of freedom and immensity [3] [4].

Also addressing to the transformable space that undergoes under the effect of digital devices, changes at several levels: shape, surfaces, color, interior design, envelope, structural elements…[5]. For example, you can change the appearance of the envelope, modify the shape by opening and closing its constituent elements, repainting a wall or even changing the furniture in its place... Likewise, we have the active and reactive space that is the one that interacts with their users through electronic sensors

and smart devices. This space has the capacity to respond intelligently to the demands of their users, to adapt and dialogue with its environment, to interact according to the changing needs of society and also to promote and produce comfort and atmospheres [22] [23] [24].

Today, digital technologies are established in the name of sustainability. They are supposed to improve the objectives relating to environmental, energy and health aspects, in particular: the considerable quantities of energy (smart meters, intelligent management of consumption...) and new services (reflections on keeping the elderly at home for better quality of life…)[25]. In the same order of ideas, we come up with the automated space that has more and more sophisticated and automated systems; installed in the technical management of the building as well as in the communication systems. ; These systems are able to increase energy efficiency, monitor and ensure the safety of the building and its occupants, assess and respond to certain types of conditions [26] [27].

V. Perspectives for optimizing the use and practice of built environment under the impact of digital technology

The integration of digital tools and technologies into built environment has given rise to new uses that are manifested in different sectors of activity and life. These uses are expressed by concepts and indices justifying the flexible, adaptive, sustainable, transformable, interactive... that space has undergone in the digital age. In order to deepen the body of knowledge and based on a thoroughly analysis of the specifics of each concept, we sorted them into four groups of indices. The indices that affect and evolve the external aspect are classified in the first group, while the indices that transform and dissolve the interior space and over, reconfigure its function to another are classified in the second group. However, those that modify the sensitive are in the third group and finally, the indices that improve and optimize the technical management of space are classified in the fourth group. Through transformation processes: evolution, dissolution, fluctuation and optimization; perspectives of optimization in intelligent and innovative space are to be understood. These perspectives are revealed by the morphological complexity which appears on the building, in addition to the spatial-functional continuity that tends towards a dynamic and fluid visualization of the interior space. Added to that, the sensitive architectural expression discerned by the ambience and aesthetic appearance caused by the environment and lastly the efficient management of services which aims to manage and monitor the operation of all the building's technical equipment and infrastructure (Figure 5).

These perspectives optimize the quality, performance and intelligence of the built environment. Quality is intended to be an effective and lasting success to the satisfaction of users through the strength of the building, livability and beauty. The performance designated by technologies and practices allow the reduction of energy consumption and greenhouse gas emissions. As for intelligence, this notion requires effective cooperation of intelligent design coupled with human intelligence, intelligent designer and user, in order to produce a comfortable and user-friendly living space.

In order to test the spatiality that allows the evolution of uses and functions within the building as well as the main scopes and perspectives that optimize the quality, performance and intelligence of built environments, a methodology has been established whose steps are the following:

-The first is synthetic. It consists of processing the data collected about the impact of digital technology on the different uses and functions of built environment to derive useful information for the next step.

-The second aims to prepare this information for further analysis. This step is used to fix the key concepts expressing the built environment that can adapt to the context, develop and transform, interact with its environment, like a living organism [28].

-The third step is analytical, it is used to show the relationship between the three parameters: digital tools, use of the building and concepts expressing built environment.

-The fourth step, through the transformation processes four main perspectives were distinguished, aiming both at the optimization of the built environment and the opening of the conceptual, imaginary and creative scope.

It should be noted that the aim of this research is not to create new architectural styles and currents, nor to demonstrate the external formal relevance induced by the various concepts defined previously. The study aims to define the important role of the triad cited above 'digital technology, uses and concepts' for the creation of a pleasant and stimulating living environment, the creation of an economical, efficient and intelligent environment and finally the

construction of efficient and secure communication and management.

VI. Results and discussion

The main aim of the research is to reveal the architectural scopes and perspectives of the relationship between technological tools, uses, and concepts expressing intelligent built environment. Passing through a chain of indices and processes classified into four groups, the perspectives and conceptual scopes, under the effect of digital technology, can be defined. The optimization of the built environment and the opening of a conceptual scope are distinguished by morphological complexity, spatial-functional continuity, sensitive architecture and service management. Indeed, the perspectives related to the qualitative aspects of the architectural space are to be defined by numerous improvements, which influence the visual and make the architectural space more productive, attractive and captivating, namely: comfort and ambience, safety and security, energy management, communication, maintenance…

-Architectural concepts generate a process of evolution and growth, which can be defined as the art of designing a structure or a building capable of withstanding subsequent modifications. It is associated with other precepts such as flexibility, adaptability, flexibility, convertibility, versatility ... [29]. This process manifests itself at the level of: volume, shape, envelope, structure and materials ... In this case, the expected perspective embodies emergence and development and is expressed through morphological complexity. Among the most recurring names of this aspect, the architect Kas Oosterhuis, Frank Gehry, Zaha Hadid, Jean Nouvel... They emphasize in their creations on dynamic volumes and free and wavy forms... For example, the Zaha Hadid'scultural center in Baku, capital of Azerbaijan, which is characterized by its shell shape and geometric dynamism of the envelope [20].

-Spatio-functional continuity is the result of a regenerated architecture, subjected to a process of dissolving limits in which the spaces are articulated and interlocked continuously to obtain a relaxed and free space. This process manifests itself in the group of indices reconfiguring the space, the surface, the circuit, the furniture and the design… This new architecture has opened up the walls and there by removes the separation of the interior and the exterior [30]. Zaha Hadid's Galaxy SOHO project in Beijing sets an example with a very clean, fluid and innovative interior design [20].

-The sensitive architecture, deliberate of feeling, immersion, reactivity and interactivity, is in a permanent fluctuation with a changing and variable character [20]. It is the result of the ambience caused by the indices associated with aesthetics, design, quality, harmony and architectural elegance… The project of NOX, Fresh H2O, Freshwater Pavilion in Netherlands, is a dynamic system within which interactions between users, environment and building constantly take place via IT. Visitors are immersed in an integral aquatic experience and must adapt to a constantly changing environment [31]

-The concepts expressing space also generate a process of optimization of intelligent systems, devices and sensors, serving more efficient maintenance and communication and better monitoring in order to improve the living conditions of users. The expected perspective is expressed through the management of services. The following example helps to better understand the digital devices that are used to automatically optimize control systems without human intervention (Figure 4).

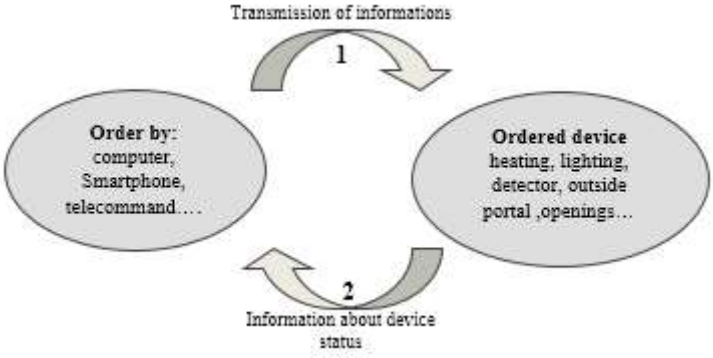

Figure 4. *Service management in an innovative building*

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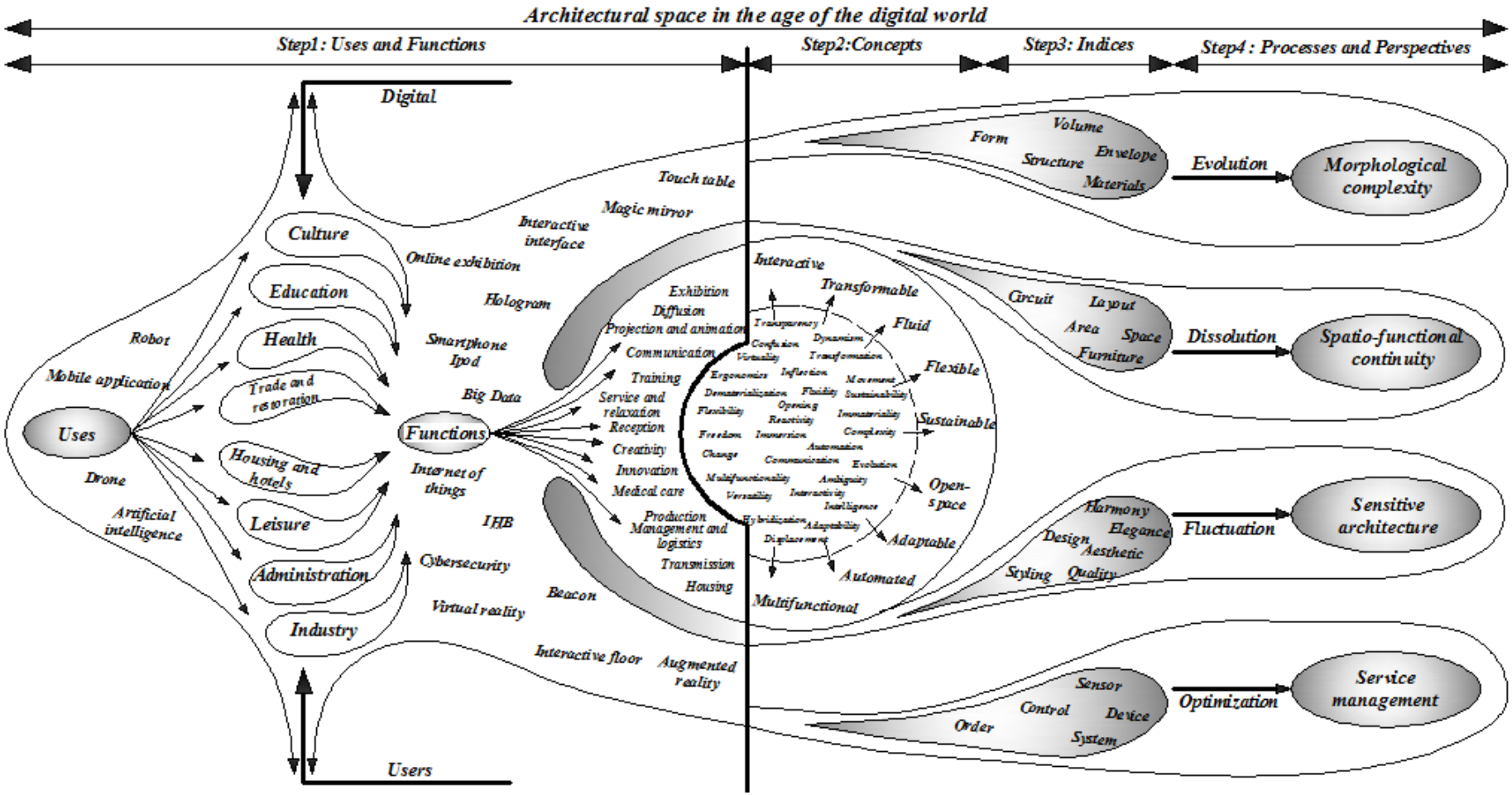

Figure 5. *Synoptic diagram summarizing the process of change of the use and practice of built environment in the digital age*

The results lead us to retain the following points:

• The introduction of new technologies in the building sector generates concepts revealing built environment, resulting from various uses and functions analyzed. The particularities of each concept make it possible to sort four groups of indices and transformation processes (Evolution, Dissolution, Fluctuation and Optimization) and lead to highlighting four perspectives (Morphological complexity, Spatio-functional continuity, Sensitive architecture and Service management) which are relative; to the optimization of the quality, the performance and the intelligence of the built environment and to the opening of the conceptual, imaginary and innovative scope (Figure 5).

• Built environments in the digital age meet the demands of occupants. In addition, it is essential to:

-Construct adequate built environments that respond to both the different forms of adaptability, flexibility, fluidity and suppleness ... and to the needs of users over time.

-Create a sensational, innovative and ambient environment, of good light, visual and sound qualities ...and productive at an optimal level.

-Promote sustainability and improve energy efficiency and moderation of the use of smart materials.

-Enrich the possibilities of communication and access to information; ensure the security, surveillance and control of the entire building.

-Think of economic strategies for the management of cost, time and resources.

VII. Conclusion

The contemporary world is now experiencing a radical change in the use and initial practice of space. It has multiplied according to technological devices, giving users more freedom to experience new spatial dimensions with more comfort and ambience, safety and security, management and communication... The acceptance of this new space by users is not predictable unless they live in it and interact with it because the human body modifies the atmosphere of the lived environment and in return provokes sensations and impressions in it. Indeed, these spaces fulfill different uses and practices and provide new possibilities of interactivity, immersion, fluidity, sustainability, transformation.

The study aims to highlight the perspectives and conceptual scopes of built environment as a result of digital technology. It consists first of all of processing data from various uses and functions of the built environment in the digital age. However, the second step is used to fix concepts and indices revealing environment, while the third analytical step highlights the relationship between digital tools, concepts and indices arising from the use of intelligent built environment. These concepts will be optimal in a building that meets the revealing characteristics of intelligent architecture.

The results reveal four groups of indices resulting from the particularities of each concept indicating built environment in the digital age those that affect and evolve the exterior appearance, those that transform, dissolve and reconfigure the initial function to another, those that modify the sensitive and lastly, those that improve and optimize the technical management of space.

The results also discern the significant effect of the transformation processes as well as the defined perspectives on the optimization and strengthening of the quality, performance and intelligence of the built environment; which designers can refer for intelligent design tailored to user needs.

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