THE MAIN INDICATORS FOR THE ASSESSMENT OF SMART BUILDINGS PERFORMANCE: CASE OF THE CYBER PARC OF ALGIERS

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Received October 2017 • Final Acceptance: April 2018

Abstract

The advent of digital technologies in architecture marked a turning point in the evolution of the needs of society and led to a radical change in the design, production and exploitation process of architectural projects; giving rise to new paradigm called smart building. This concept refers to all advanced technologies and integrated systems and responds to technological, environmental and economic challenges while offering a wide range of services to users by providing them comfort, safety and security. In developing countries, particularly in Algeria, many construction projects defined by high energy efficiency and fitted with automated systems have been planned in order to accelerate the transition of the country towards an economy of knowledge and technology. However, these projects remain confined to limited places and face obstacles which can be explained by the lack of national method approved by the state that supposed to provide information and recommendations to the architects and engineers during the design, production and operation of smart buildings. This research aims to interpret the current definitions of smart building and identify their requirements in order to develop new platforms that could be useful as a reference framework for the design, evaluation and development of future smart buildings. The study examines the nature and contribution of assessment tools of smart buildings performance and identifies and analyses key indicators to assess their degree of intelligence. An analysis of a representative sample for technological buildings in the cyber parc of Algiers was carried out to identify all the key elements covering environmental, socio-cultural, economic and technological indicators taking into account the user's well-being. The research's results show that the requirements of smart buildings are not only limited to the integration of technological systems of information and communication but include others such as environmental, socio-cultural and economic indicators. Finally, a conclusion summarizing the main results obtained is presented by developing a practical model for the assessment of the degree of intelligence of buildings, and prospects for future work are proposed.

Keywords: Indicator, assessment tool, performance, smart building, degree of intelligence, cyber parc.

Word Count: 4869

1. INTRODUCTION

In recent years, the contemporary world knew an unprecedented rise and awakening, induced by the continuous evolution and profusion of the New Technologies of Information and Communication (NTIC). These technologies open new horizons in several sectors of society, notably architecture. This by the development of a new dimension of imagination and mechanisms of design, simulation and modelling which enabled the creation of more complex, dynamic, flexible and fluid architectural forms which have never been reached before. The smart building is an answer to several problems which arise currently in the building sector. It made its first steps in the early 1980s in the United States [1] for initial aim to better reconcile the reduction in energy consumption and the improvement of comfort. Later, it evolved into a new model of a modular, flexible, interactive, mutant, adaptable, multifunctional platform...offering new services to users by providing them with all means of convenience and comfort, safety and security.

Algeria, contrary to what happens in its counterparts, the Mediterranean countries, is witnessing at the moment an imperceptible entry of the digital in the field of architecture and urbain design. this can be explained by the lack of a method that is supposed to provide all the information and recommendations to be considered by designers-architects or other stakeholders during all phases of the development of smart buildings from the beginning design process to the appropriation and exploitation of it.

The Cyber Parc of Algiers, one of the Pharaonic projects in Algeria, equipped with the most advanced technology, is an opportunity for the rapid take-off of the country in the field of digital technologies. It's about to develop strategic structures of national scope, a catalyst of the ICT sector and propellant of innovation that will have to flourish over the years to become the flagship of the Algerian technological landscape. The present research aims to interpret the current definitions of smart buildings, examines the nature and contribution of the evaluation tools of smart buildings such as: BREEAM, BiQ, IBI, TIBA ...and allows identifying and analysing their main indicators to measure their performance. Besides, the aim of this work is to develop a new platforms that could be useful as a reference framework for the design, evaluation and development of future smart buildings. An analysis of a representative sample for technological buildings 'cyber parc of Algiers' was carried out to identify all the key elements covering environmental, socio-cultural, economic and technological indicators taking into account the user's well being. The research's results show that the requirements of smart buildings are not only limited to the integration of technological and information and communication systems but include others as an environmental, socio-cultural and economic indicators. Finally, a conclusion summarizing the main results obtained is presented by developing a practical model for the assessment of the degree of intelligence of buildings, and prospects for future work are proposed.

2. INTERPRETATION OF SMART BUILDING BY COUNTRY

The concept of smart building represent today a reality and an object of technological innovation. it commonly concerns administrative centers and buildings, luxurious residences, museums and buildings of cultural mediation, medical centers, research centers and technological poles. Its definition, connotation and denotation have changed a lot with the time where we can distinguish three periods of its development [2]:

Since its appearance in the beginning of the 1980s to 1985 the Smart Building was simply qualified by the installation of automatic control systems, which would increase the flexibility of the building and improve the aspects of its usability and control in the environment. From 1986 up to 1991 the Smart Building has evolved toward a building that meets the changing needs of users on multiple levels as well as the external conditions. However, from 1992 up till the present day the Smart Building has become an effective building equipped with different features for the control and management of comfort, energy and security.

The official definition of this concept has not yet been standardized throughout the world, it can be interpreted differently according to the culture of each country, the field of activity and the interest of the constructor or the user.

-Definition in the United States: According to the Smart Building Institute (previously named Intelligent Building Institute IBI in the USA); the smart building is defined according to four basic elements: structure, systems, services and management, and the interrelationships between them in order to better reply the needs of users [1] [3].

-Definition in the United Kingdom: The European Intelligent Building Group (EIBG), based in the United Kingdom, considers the intelligent building as an environment having maximum efficiency of the occupants and effective management of building resources with minimum cost [1].

-Definition in France and Switzerland: According to the French Institute for the Performance of Buildings (IFPEB), the concept of smart building is seen as a means of energy performance management and focuses mainly on the needs of users [1].

-Definition in Singapore: According to the Public Works service of the Government of Singapore, the smart building is the one that disposes [1] [3] :

-Advanced automatic control systems to control various technical installations: air conditioning, lighting, security, fire protection ... In order to ensure a comfortable working environment for occupants.

-Network infrastructure and the appropriate communication equipments for data exchange.

-Definition in China: In Shanghai, the concept of smart building refers to automatic functions dominated by high technology and described by "3A" or "5A" which means: communication automation (CA), office automation (OA), Building Management Automation (BA), Fire Protection Automation (FA) and Building Maintenance Automation (MA) [1] [3].

-Definition in Japan: The smart building in Japan was inspired and developed from the American model, but with a climatic adaptation, it dispose four main aspects [1] [3]:

-Reception and transmission of the information and effective management.

-Satisfaction guarantee, the convenience and comfort for the occupants.

-Rationalization of management and administrative services with less cost.

-Rapid, flexible and economicresponses to changing sociological environments, work complexity and business strategies.

3. METHODS FOR THE EVALUATION OF SMART BUILDINGS

The realization of smart buildings goes through a chronological chain and fits in a perfect continuum. This chain is not anymore linear with the traditional methods that we have learned to work with; but becomes a series of simultaneous evolutions that require innovations and intelligent solutions in the field of engineering, energy management, computing, telecommunication...

In fact, the genesis of these buildings is carried out in many phases; from the phase of reflection on innovative intelligent solutions to their design phase then the installation of the equipment until reception of the project. Then, a phase of user awareness to the working of the technological facilities is essential to help users to well exploit and learn about the evolution of their operating process in terms of comfort management and security.

So,These buildings should be sustainable, automated and interactive, and should achieve objectives related to environmental, energy (performance), economic, sanitary, social and technological aspects while offering comfort and cost-effectiveness to users. In this regard, several methods for assessing the performance of smart buildings have been generated such as :

-**BREEAM** (Building Research Establishment Environmental Assessment Method) which evaluates the environmental behavior of new and existing buildings [4] [5], using the factors indicated in the figure below:

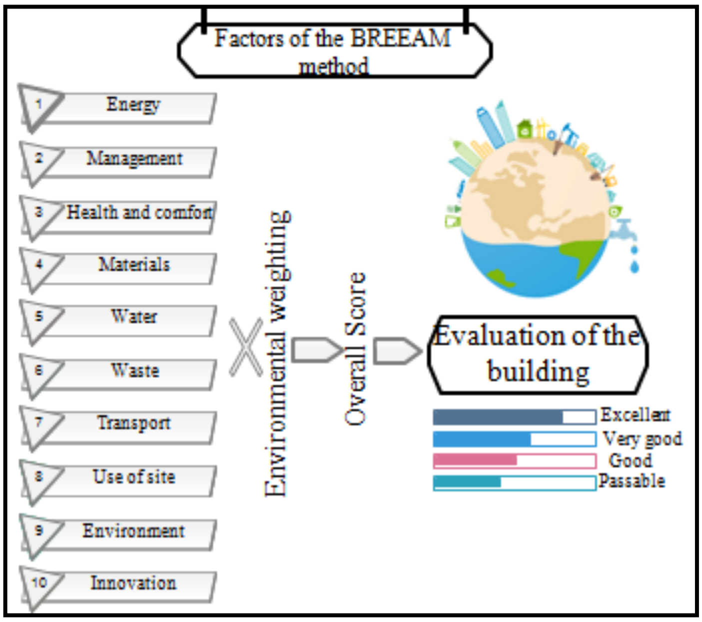


Figure 1: Factors of the BREEAM Evaluation Method

Source: Authors, 2017

-**IBI** (Intelligent Building Index): developed by the Asian Institute of Intelligent Buildings (AIIB) in Hong Kong, China [6], The IBI model aims to ensure the quality of the environment, meet the needs of users and achieve the principles of sustainable building. It consists of 10 modules (Quality Environment Modules), whose each contains a group of elements used for the evaluation of intelligent buildings [7] [8].

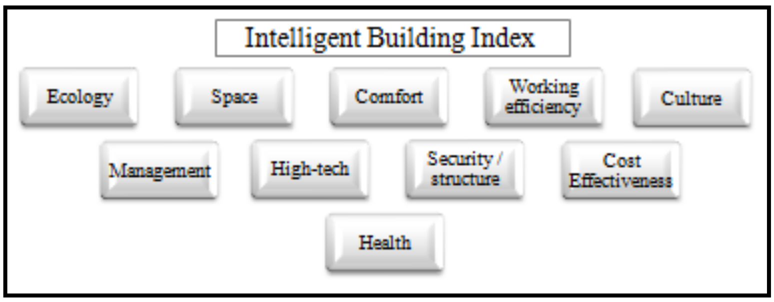


Figure 2: Modules of the IBI Evaluation Method

Source: Authors, 2017

-**MATOOL:** developed by BRE (Building Research Establishment) in UK, it is a matrix tool used by designers and engineers involved in the smart building sector to evaluate their performance in a fast and easy way. Five performance indicators are specified and used in this tool, taking into account five factors that influence them: people, building systems, critical, processes, design [9] [10].

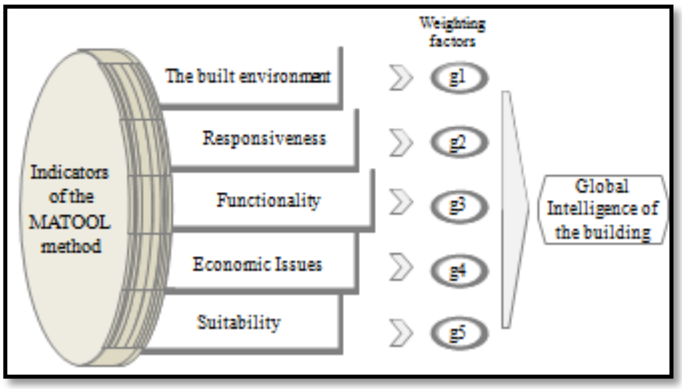


Figure 3: Indicators of the MATOOL Evaluation Method

Source: Authors, 2017

-BIQ (Building Intelligence Quotient): developed by the Continental Automated Buildings Association (CABA) in North America. The BIQ tool has three functions: a means for the assessement of intelligent buildings performance, a design guide for new construction projects and an action plan tool for the modernization of building automation. This tool provides a basic online assessment of an existing building by answering a set of questions (315 questions) covering 8 domains [11]. The BIQ system then generates a report with the total percentage of building intelligence and also recommendations for further improvements in future constructions.

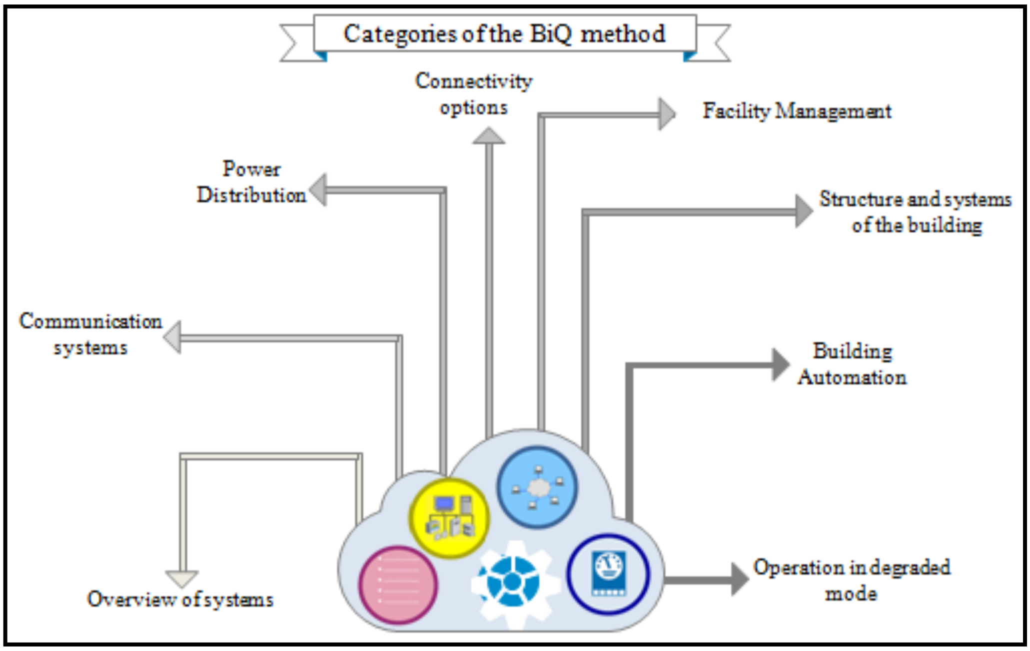


Figure 4: The categories of the BiQ evaluation method

Source: Authors, 2017

-TIBA (Taiwan Intelligent Building Association): developed by ABRI (the Architecture and Building Research Institute) in Taiwan, China. TIBA uses 8 indicators to assess the intelligence level of buildings [12].

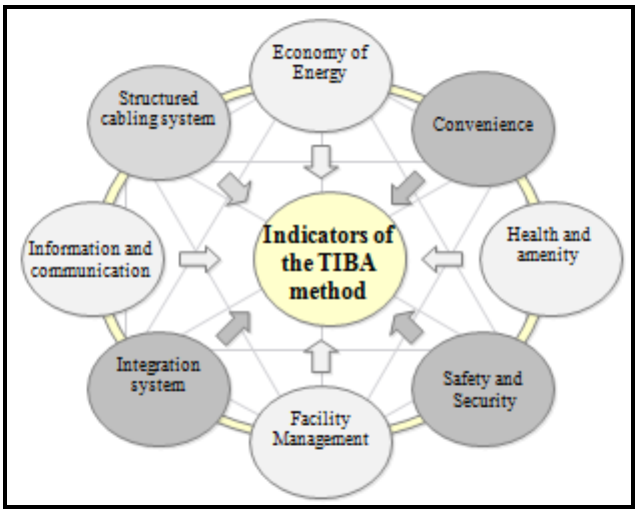


Figure 5: Indicators of the TIBA Evaluation Method

Source: Authors, 2017

4. WORKING METHODOLOGY

In order to identify the main indicators for the assessment of smart buildings performance, a methodology has been established, whose steps are presented below:

- The first step consists to choose the most appropriate criteria for the evaluation of a smart building from the definitions discussed at the beginning of the work. In fact, a smart building relies on three main dimensions: environmental (energy, materials used...), economic (life-cycle cost, operation and maintenance costs...) and technological dimension (communication system, automation of technical infrastructure, control system...) while taking care of the needs and requirements of the users.

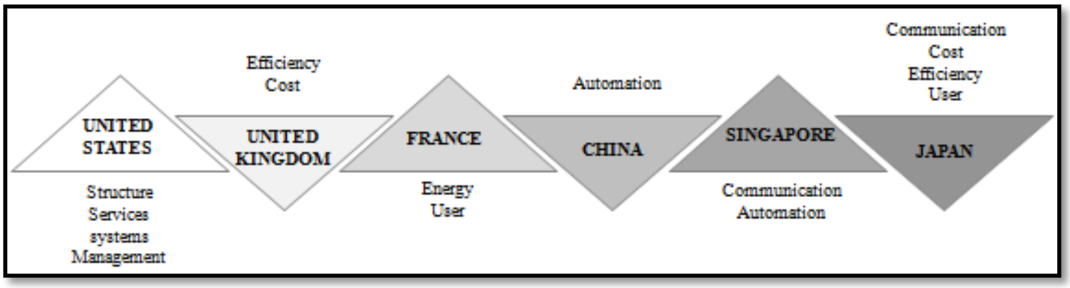


Figure 6: Synthesis of Smart Building Definitions

Source: Authors, 2017

-The second step consists to select the most appropriate criteria from the BREEAM method which relies on the sustainability assessment, one of the key parameters of the ıntellıgent archıtecture, added to additional criteria derived from assessing tools of building intelligence such as (TIBA, BIQ, MATOOL, IBI, etc.). At this effect, four dimensions have been considered and are presented in the folowing figure:

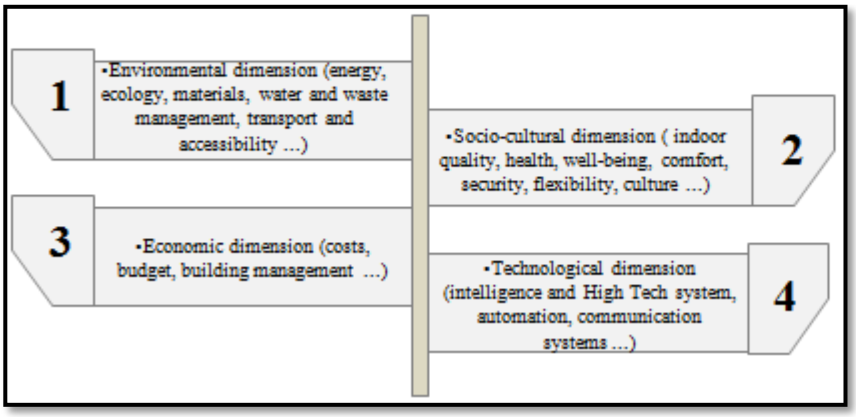


Figure 7: Emerged dimensions from the methods for the evaluation of smart buildings.

Source: Authors, 2017

-The third step deals with the quantification of the smart buildings performance by formulating a set of indicators, classified into four groups of socio-cultural, economic, environmental and technological factors.

A value ranging from 0 to 100% is attributed to each group, indicating the rate of taking indicators in the evaluation of smart buildings. The following table shows the smart building classes according to the inclusion rate of indicators.

Rate	0-25 %	25-50 %	50-75 %	75-100 %
Classes	Bad	Good	Very good	Excellent

Table 1: Different classes of smart buildings

Source: Authors, 2017

5. THE FOUR GROUPS OF INDICATORS DEFINED FOR THE ASSESSMENT OF SMART BUILDING PERFORMANCE

In the course of these last years, it was important to understand the performance of smart buildings in a wide range of considerations. This has stimulated the development of a number of evaluation tools intended to measure the degree of project performance in terms of sustainability, automation and interactivity, quality of life and the economy of cost and time. In fact, the assessment of the degree of smart building performance depends on the complex interaction of four groups of indicators in response to users' needs by providing a healthy and comfortable space. These are:

-Group of Environmental Indicators: In a perspective of viable and sustainable development, the smart building must achieve the objectives relating to the environmental and energy aspects [13]. It aims to preserve, improve and enhance the environment and natural resources over the long term. In addition, it is important to take into account a series of requirements related to the location, orientation and shape of the building, the vertical circulation, parking spaces, choice of economical building materials, energy management (reducing energy requirements, managing the building according to the seasons, using renewable energies, using low-energy lamps, etc.), water and waste management, the vegetation...[14] [15].

-Group of Socio-cultural Indicators: The smart building aims to satisfy human needs based on issues of health, consumption, culture ... [13]. Therefore, users should be the centre of interest in any design because the smart building ultimately serves the well-being and satisfaction of those. Their behaviour will be affected on one side by the comfort, ambiance and, on the other side, by: influential aspects of their psychology such as: the quality of space (transformable, adaptable, polyvalent, flexible, fluid, dynamic, interconnected, sensual and reactive...), the competence and effectiveness of the services insured, the ease and flexibility of the use of digital technologies, reception, respect and security and the possibility of access to information without obstacles. These factors will contribute to the productivity of the users, and therefore to the smart building performance.

-Group of Economic Indicators: The smart building aims to find the best technique for the management of resources and control of budgets and expenditures and also to find cost and time-saving strategies of the life cycle of the building [13].

-Group of Technological Indicators: The smart building takes into consideration all forms of technological innovations [16]. It has more and more the sophisticated and automated systems; able to monitor, evaluate and respond to certain types of conditions (heating, air conditioning, ventilation, lighting, access, alarms, fire, counters, etc.) [17]. It also has communication systems and uses advanced solutions in building components (intelligent and reactive materials) [18], to ensure safety of the building and its occupants, to respond intelligently to the demands of their users, to adapt and dialogue with its environment, to promote and produce the comfort and ambiances (luminous, visual, sound, etc.) and also to improve quality of life [19].

6. EVALUATION OF THE DEGREE OF PERFORMANCE OF TWO BUILDINGS REPRESENTATIVE OF THE CYBER PARC OF ALGIERS

The Cyber parc of Algiers is a place of research, training, business and exchanges. It has all the convenienceswith advanced technology that will make of Algiers the city of the future. The cyber parc is based on a rich infrastructure and gathers buildings of modern architecture. The buildings selected as part of this work were chosen because they share a set of features of smart buildings. They are characterized by an architectural modern style, rich to ensure a comfortable environment and useful for a progressive development of the Cyberparc. The main objective of the evaluation method applied on the two buildings of the Cyberparc of Algiers; is to check the indicators determined in the present work to assess smart buildings performance based on the definitions and some methods of evaluation of smart buildings [20] [21] [22]. Using some search tools that have a reasonable degree of reliability and appropriate to assess the intelligence of buildings such as: observation, interviews as well as the consultation of graphic documents .The assessment of the degree of performance of smart buildings representative of the cyber parc was developed.

The Indicators \ Evaluated buildings		Building 1 	Building 2 
Group of Environmental Indicators (En.I)			
Use and selection of site (En_1.I)	Situation	●	●
	Orientation	○	●
	Form	●	●
	Easy access	●	●

Transport and accessibility (En_2.I)	Lifts and stairs	●	●
	Access for people with reduced mobility	●	●
	Emergency exits	●	●
	Mobility	●	●
	Car park	●	●
Energy and natural resource (En_3.I)	Use of renewable energy sources	○	○
	Eco-energy strategies and conservation techniques	○	○
	Counting system and measure of consumption	●	●
	Energy management	⊙	⊙
	Management of Wastewater and Rainwater	○	○
	The Waste management	○	○
	Carbon footprint tracking	○	○
Application of ecologically sustainable design (En_4.I)	Respect of the environment	⊙	⊙
	Vegetation	⊙	○
	Plan of water	●	○
	Atrium/ patio	●	●
	Local materials	⊙	⊙
	Solar protection	○	●
Group of Socio-cultural Indicators (Sc.I)			
Health and well-being (Sc_1.I)		●	●
Comfort and ambience (Sc_2.I)		●	●
Indoor environmental quality (Sc_3.I)		⊙	⊙
Safety and security (Sc_4.I)		●	●
Quality of space, functionality and aesthetic aspects (Sc_5.I)	Versatility	●	●
	Flexibility and suppleness	●	●
	Transparency	⊙	⊙
	Interactivity / reactivity	○	○
	Dynamic	○	⊙
	Fluidity	○	○
	Mutation / transformation	○	○
	Adaptation	○	○
	Reconfiguration et evolution	○	○

	Harmony and color purifications, Lines, forms and volumes	●	●
	The void and the full	●	●
	Simple design, Interactive and refined	○	○
Quality of services (Sc_6.I)	Reception/ kindness/ respect	●	●
	Listening and understanding	●	●
	Accessibility to information/ Speed, reactivity	●	●
	Facility and flexibility of use of digital technologies	●	●
Group of Economic Indicators (Ec.I)			
Taking into account ~~of~~ cost and time saving strategies (Ec_1.I)		⊙	⊙
Cost of the life cycle of the building (Ec_2.I)		⊙	⊙
Affordability (Ec_3.I)		⊙	⊙
Mastery of budgets and expenditures (Ec_4.I)		●	●
Effective management of resources (Ec_5.I)		⊙	⊙
Integrated management of installations (Ec_6.I)		⊙	⊙
Group of Technological Indicators (Tech.I)			
Control Access and security system ($Tech_1$.I)		●	●
Video Surveillance System ($Tech_2$.I)		●	●
Automatic control and management system ($Tech_3$.I)	Heating, Ventilating and Air Conditioning	●	●
	Lighting and Electrical	●	●
	Hot water and plumbing	○	○
	Fire detection	●	●
	Pollutant detection	○	○
Telecommunications and data system ($Tech_4$.I)	Digital signalling system	○	○
	Easy access to Internet networks	●	●
	Interior location of the building	○	●
	Fax and telecommunications	●	●
	Cable management	⊙	⊙
Use of advanced solutions for construction ($Tech_5$.I)	Smart envelope	○	○
	Intelligent materials	○	⊙
	Interactive elements of construction (walls, floors, ceilings ...)	○	⊙
Advanced Artificial Intelligence ($Tech_6$.I)		○	⊙

Availability of digital tools (computers, 3D glasses, helmets, tablets, iPads ...) ($Tech_7$.I)	⊙	⊙
Management by digital mock-up ($Tech_8$.I)	○	○

Inclusion rate of indicators		
● : highly	⊙ : medium	○ : weakly

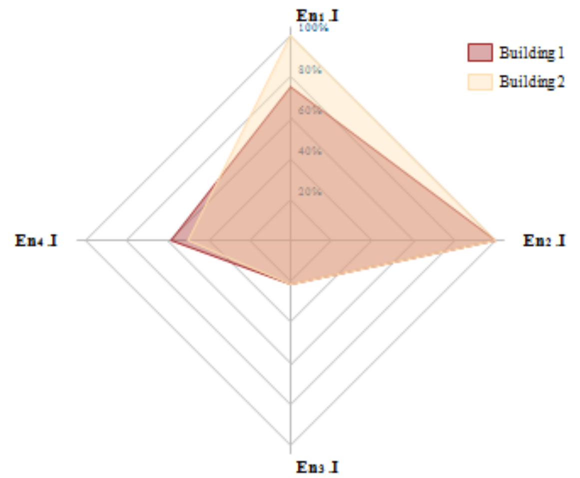
Table 2: Verification of the recommended indicators in two buildings of the Cyber parc of Algiers

Source: Authors, 2017

7. RESULTS AND DISCUSSION

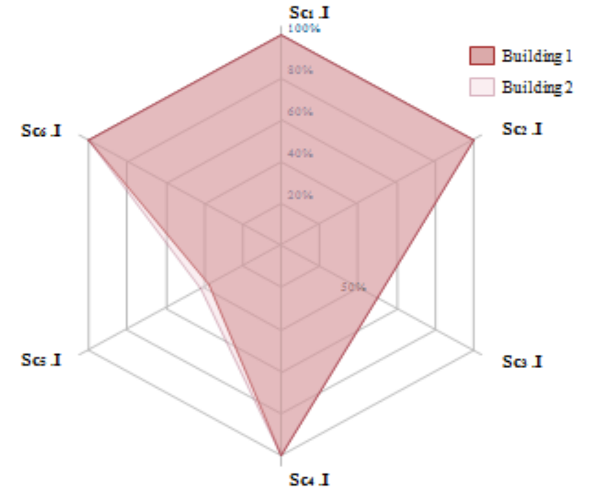
The study has highlighted two buildings representative of the technological environment of the Cyber parc of Algiers, The two buildings respond intelligently to relevant concerns of modernity, integration of new digital technologies and the needs of users.

According to the graphic representations of the results, it is apparent that the digital devices have not been integrated in the architectural spaces in particular in the construction elements such as the integration of tactile walls, interactive soils, interactive system, dome light... or in the development of spaces. In addition, it has been found that the provisions and measures concerning the setting of sustainability, such as water management, the use of renewable energies…have not been taken into consideration.



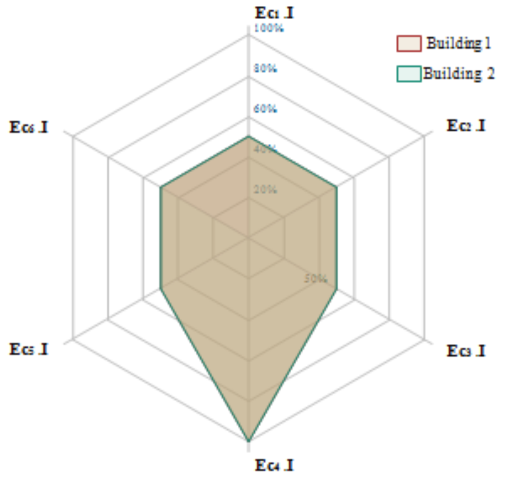
Graph 1: Representation of the inclusion rate of environmental indicators in two buildings of the Cyber parc of Algiers

Source: Authors, 2017



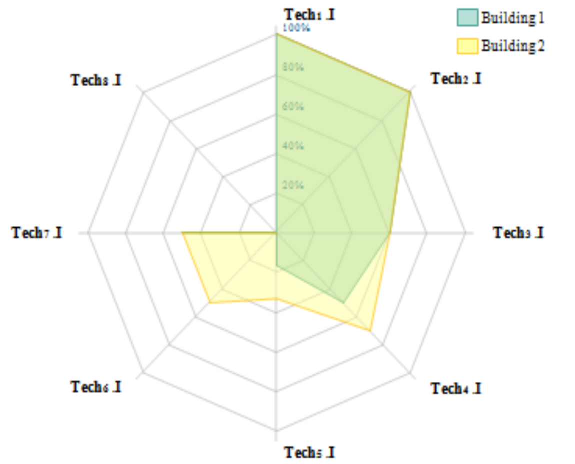
Graph 2: Representation of the inclusion rate of socio-cultural indicators in two buildings of the Cyber Parc of Algiers,

Source: Authors, 2017



Graph 3: Representation of the inclusion rate of economic indicators in two buildings of the Cyber parc of Algiers

Source: Authors, 2017



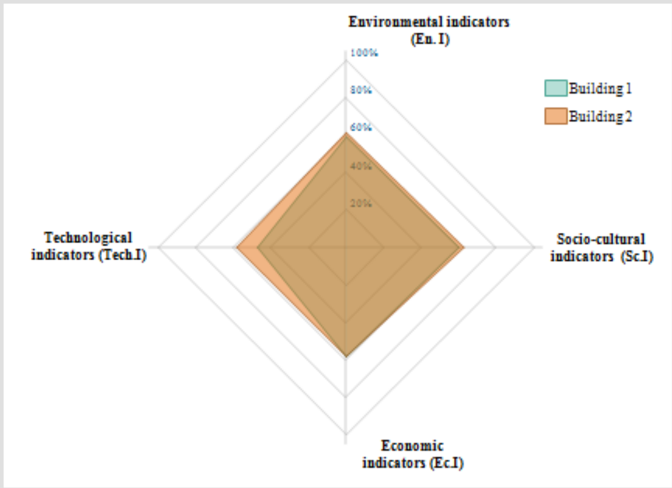
Graph 4: Representation of the inclusion rate of technological indicators in two buildings of the Cyber parc of Algiers

Source: Authors, 2017

On the whole, the models evaluated reached an inclusion rate of smart buildings indicators of 55 out of 100 for the building1 and 60 out of 100 for the building2; this reveals a good behaviour but also far from perfection. In fact, it shows many points on which designers should work.

Evaluated buildings / The Indicators	Building 1	Building 2
Environmental indicators (En.I)	59.10%	61.30%
Socio-cultural indicators (Sc.I)	60%	62.50%
Economic indicators (Ec.I)	58.30%	58.30%
Technological indicators (Tech.I)	44.40%	58.30%
Final evaluation	55.45%	60.10%

Table 3: The inclusion rate of the evaluation indicators in two buildings of the Cyber parc of Algiers Source: Authors, 2017



Graph 5: Representation of the inclusion rate of the evaluation indicators in two buildings of the Cyber parc of Algiers. Source: Authors, 2017

The results of evaluation of the case study, lead us to remember the following points:

Sustainability plays an important role in the elevation of the degree of intelligence of the building.

Assessment of smart building performance is based on four intelligent features: compatibility with the environment and sustainability, cost and time savings, quality of life and the integration of digital technologies. With these characteristics, buildings will be described as smart. Moreover, it is essential to:

-Take into account the orientation of the building the fact that it participates in a design more thermally efficient and more economic in energy.

-Reinvent or well change the way of producing the architecture by the use of local materials and intelligent good thermal insulation and thrifty (the brick, wood, glass auto cleaners, the concrete bright or transparent, the photovoltaic glass…) in order to reduce the energy consumption and to increase the comfort.

-Intelligent use of energy by the exploitation of natural resources, integrate systems of recycling of wastewater and storm water and treatment of waste and also opt for the lighting and natural ventilation.

-Facilitate access; ensure the means of mobility, safety and security.

-Use of technical systems Automated: The automatic control of the temperature and the humidity according to the needs, the regulation of the intensity of the lighting in function of the natural light, automatic lighting via present detectors, System of fire detection and pollutants, energy storage system…

-Opt for information systems and telecommunications (digital signage, a qualitative connection to the Internet, positioning inside the building…) in order to inform, entertain and communicate in real time.

-Build adequate architectural spaces that respond to the different forms of adaptability, flexibility, fluidity ... and the needs of users over time.

-Assure a good quality of life (comfort, ambiance, health, security ...) which contributes to the satisfaction of the users, and therefore to the performance of the smart building.

-Thinking about economic solutions using effective strategies for managing cost, time and resources...

8. CONCLUSION

Smart buildings have a leading place in our everyday lives thanks to the everlasting evolution of technological, energy and environmental requirements. They are synonymous with quality of use, safety and security, flexibility and adaptability, interactivity and communication, performance and energy efficiency. All these solutions consider the building as a living object, interconnected, sensitive to its own environment and modular and serve to increase more the comfort and the quality for the wellbeing of the users.

The study began with a theoretical framework on smart buildings. It was followed by an analysis of five assessment methods to select the key indicators for these buildings. From these indicators, a method of assessing the performance of smart buildings is presented. It depends on the complex interaction of various indicators that can be classified into four groups (Environmental, socio-cultural, economic and technological indicators). They meet the requirements of sustainability, economic strategies, automation and interactivity and also the needs of the users.

The Cyber Parc of Algiers, one of the headlined projects in Algeria, is part of the national strategy to create an ICT industry with all the conditions for the valorisation of scientific and technical skills in the production of software, service and equipment. Its infrastructure provided with the most sophisticated technology is defined as smart viewing the dominance of the inclusion rate of the criteria resulting from the indicators defined previously. It also seems that the satisfaction of the users within these buildings has been strongly affected by the group of socio-cultural indicators.This confirmed that these criteria are important and should be taken into consideration in all contemporary infrastructures, especially in technological parcs.

The architect designer of smart buildings must rely on a set of criteria and recommendations from the beginning of the architectural design: carefully prepare the project's mission taking into account the change of the users' needs and the integration of technological systems which are necessary for the use and practice of the conceived space. From a practical point of view, the approach developed is a useful model for architects and engineers. It can help to configure the standards for the design and construction of future smart buildings, to which users and occupants can refer and opt for a smart design adapted to their needs.

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