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THE LINK BETWEEN INTELLIGENT AND SUSTAINABLE BUILDINGS
CONCEPTS AND PRACTICAL STUDIES

BY

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Abstract. The need to construct intelligent buildings is due to the inhabitants' need to live in a building that is capable of fulfilling their needs, a building that is confortable, convenient and offers the necessary elements for productiveness; all these are possible due to the unprecedented evolvement of technology. The need to construct sustainable buildings was motivated by the decrease of resources caused by the increase of the globe's population. Producing resources from alternative sources, reusing and recycling materials and overall protection of the environment is possible only by constructing these sustainable buildings. The current trend in succeeding all of the above is possible only by constructing sustainable intelligent buildings. Therefore, a state of the art of the link between the intelligent and sustainable buildings is presented in the following article, the way in which they aggregate, their commonalities and the way their relate and their intercooperation.

Keywords: sustainable building; intelligent building; innovation; management; smart cities.

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1. Introduction

The concept "hierarchy of needs" (Maslow, 1943) was introduced by Maslow in the 1950s and it states that an individual has certain needs that can be ranked into a hierarchy: at the basis of this hierarchy are the physiological needs (hunger, thirst), followed closely by safety needs. In the safety needs category one can find the need for shelter, the need to have a home.

The following article is comprised of 5 sections. The first section is the introduction part, followed by the chapter called "Intelligent buildings nowadays", where intelligent buildings are described and exemplifyed. The third chapter contains the definitions and the characteristics of sustainable buildings nowadays, along with existing examples of such buildings. Furthermore, in the next chapter is presented the intelligent and sustainable buildings' link, and lastly, the conclusion part.

2. Intelligent Buildings Nowadays

Technology evolved rapidly in the modern era as global communication networks are at the basis of our society (Kluver, 2000). Therefore, a tremendous progress took place in all fields. The construction industry was no stranger to this progress. Within this stepping stone progress, people started constructing everywhere, even in the steepest of places, places they have never dared to before.

In the US, Asia, Europe and basically all continents, the industry of constructing intelligent buildings is the newest and most wanted of trends. The wealthiest countries are investing heavily in integrated intelligent systems that are used to control and to monitorize the intelligent buildings.

2.1. The Concept of Intelligent Building

Intelligent Building Institute (Anon. 1988, Anon. 2001g, Brown 2001, Lehto *et al*. 1993, p.12.) gave one of the first definitions of intelligent buildings. In their opinion, an intelligent building is a building that it is optimized and it is capable of ensuring productivity. The most important specification requirements of these types of buildings are the safety, the comfort, the costs and the market value, but also in assisting the process of the inhabitants and/or owners in order to understand, acknowledge and embrace these goals.

Himanen, (2003), states that an intelligent building is one that incorporates the following:

a) fulfills all the necessities of the inhabitants;

b) is focused on the building's systems in order to support them in working efficiently;

c) is focused on progressive technologies and on economy;

d) the entire life cycle of a building is its concern;

e) ensures the proper functioning of modulated operational environments as systems, structure and architecture;

f) respects and ensures social and sustainable development.

Bennett *et al.*, (1987) (in Atkin, 1988), envisions the following attributes an intelligent building must comply with:

i) the building must know everything is happening inside and outside it;

ii) the building must find the optimal solution to offer inhabitants a confortable, convenient, productive and enjoyable ambiance;

iii) whatever the inhabitants' requests are, the intelligent buildings must answer them immediately

There are several characteristics that describe an intelligent building, amongst which the following must be mentioned: adaptability to the inhabitants' needs, adaptability to the inhabitants' desires, incorporated technology, sustainability and health conscious on the entire life span of the building, from design to construction to post construction evaluation (Gray, 2014). For all these to be obtained, people, processes and products must always be integrated. This integration will help in reducing the costs, enhancing the inhabitants' lives and reducing the use of resources. This integration of all the systems in a building is due to several crucial improvements in technology and communication protocols. In order to control the integrated systems and make sure they are interoperable, one has to have a management system and to provide the inhabitants with its control.

2.2. The Greatest Intelligent Buildings Worldwide

The development of technology exponentially intensified the designers', the engineers' and the owners' desire to construct buildings that incorporate a series of systems, networks and automation in order to sustain an easy and inexpensive way of life. The following buildings are some of the greatest intelligent buildings constructed thus far.

Makkah Royal Clock Tower Hotel, also known as Abraj Al-Bait Tower, is a complex of buildings in Mecca. This complex is comprised of several buildings, one of which is the third tallest in the word. This complex hosts a shopping mall, a prayer room with a capacity of 10,000 persons, a hotel, a garage, two heliports and a fully equiped conference center (http://en.wikipedia. org/ wiki/Abraj_Al_Bait). Makkah Royal Clock Tower Hotel has over 10,000 km of optic fiber and 76 elevators (Greenbang, 2011).

GreenSpaces, situated outside Delhi, India, is a gigantic intelligent building of 533,400 square feet. This building takes sustainability to an upper level as is rated Super Platinum LEED. This building demonstrated that a building can reduce energy costs from 40% to 10% with the help of technology (http://www.greenspaces.in/).

Venetian Resort Hotel Casino from Las Vegas is one of the most intelligent constructions in the world. Builders have incorporated into it: sensors that detect the absence of employees in the service areas and that automatically turn off the lights, a general switch in every apartment that permits maneuvering all the lights at once, a solar thermal system on the roof that heats the pool's and the spa's water, a management system that operates lighting, heating, cooling and ventilation of the entire building in order to optimize consumption (Greenbang, 2011).

Burj Kalifa or Burj Dubai is one of the safest and most intelligent buildings in the world (Greenbang, 2011) and it incorporates: automatized biometric control systems, systems acting on touch, intelligent parking, voice and data networks for guests, audio-visual commands etc. (Architizer Editors, 2014).

30 The Bond is the first documented intelligent building in Australia that succeeded to incorporate sustainable technologies, amongst which: automated inclining systems in facades, natural ventilation systems and systems that detect water leakages in the building (Greenbang, 2011).

Bahrain World Trade Center, besides being one of the most sustainable buildings in the world, is considered to be one of the most intelligent. The intelligent features are: extremely advanced security systems, high speed internet through IP telephony, unified wireless messaging through a singular voice-data-video network (Architizer Editors, 2014).

The Environmental Systems Inc. (ESI) Headquarters from Brookfield, Wisconsin, is also situated in world's top ten intelligent buildings. In the building's lobby there are monitors that show a real time feed on the performance of the building with regards to the consumption of energy from the HVAC system, lighting and plugs. Another interesting feature are the fire extinguishers that are operated through internet. The alarm system is also connected to these extinguishers, the system verifies whether they are in place and adequate to operate (Architizer Editors, 2014; http://www.realcomm...).

Beijing Airport, terminal T3, is one of the safest and most energy efficient terminals in the world. Its safety and energy efficiency is closely monitored by 25.000 sensors and monitors and 10 stations that control water consumption and the HVAC system in the building (Joao Lima, 2015).

Afi Park 2, situated in Bucharest, is the first building in Romania lighted entirely with a LEED intelligent system that controls the intensity of the light at every moment and therefore reduced human interaction and operation on the entire 12.000 square feet of the building (http://www.csrmedia.ro/...). This system reduces energy costs by 85% a year or, translated into money value, it saves somewhere around 100.000 euros per year http://www.wall-street.ro/articol/Real-Estate/...).

3. Sustainable Buildings Nowadays

100 years ago resources were more than plenty for the world's population. The explosion of population in the last century, however, led to a perilous decrease in resources. Taking this into consideration, people all over the world started being interested in protecting the few resources left. In this respect, all industries, including construction, commenced developing products friendlier to the environment and able to recycle resources and produce them from alternative never-ending resources. This is how sustainable buildings appeared.

3.1. The Concept of Sustainable Building

As prior mentioned, a sustainable building is a building that is capable to produce water and energy and use them at maximum of potential. It is also capable to ensure its inhabitants' health and safety and make sure they achieve their best productivity capabilities. Furthermore, this building is protective of animals, plants, the environment, while being cheap to live in and cheap to maintain. Other concerns stated in the existing specialized literature are the efficience of wood use and low carbon emissions (Lopez Barnett & Browning, 2007).

As stated in a theory by John Elkington, the principal of sustainability has three important elements that interact, creating a unified perspective, as shown in Fig. 1 (Elkington *et al*., 2004): society, environment, economy.

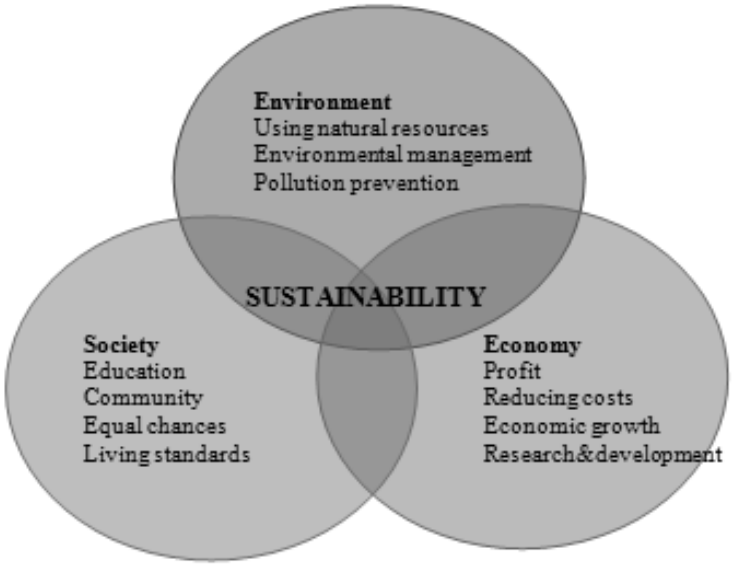

Fig. 1 – The three elements of sustainability.

3.2. The Greatest Sustainable Buildings Worldwide

The perspective of sustainability is intensely sought for by more and more designers and constructors worldwide. Taking into consideration the international trend, everywhere on the globe there are buildings that want to be the most sustainable ones ever built. Taking into account the numerous sources and rankings existing on the globe, below are presented some of the most remarkable sustainable buildings ever constructed.

The Tower at PNC Plaza (The Guardian, 2015) is considered to be the greenest skyscraper in the world and is located in Pittsburg. The building has 33 floors and 74,000 square feet. The sustainability factor can be seen in: a double-layered operational façade, a system that reuses oceanic water, the building's coat and furniture are made of recycled materials and 33% of the heating and cooling systems in the building are carbon free.

The Change Initiative, located in Dubai, is considered the most sustainable commercial building in the world, hosting companies that promote and sell sustainable solutions. 40% of the building's energy needs is produced by solar panels and paints that reflect heat. In the construction process were used preponderantly recycled materials, including recycled water, and the building's insulation is 3 times stronger than a common one (http://www.your amazingplaces.com/).

One Angel Square, Manchester, UK, was ranked by BREEAM as Outstanding. This building is a cooperative that hosts over 3000 employees. The building draws its energy from a CHP system (Combined Heat and Power) that is fuelled with rapeseed oil grown on their own land (Anmar Frangoul, 2015). Besides this, the building has LED lighting and recycles pluvial water and wastes.

The Crystal, London, is ranked by LEED with Platinum and by BREEAM also as Outstanding. This building is operated entirely by self produced electricity through photovoltaic solar panels and geothermal heat pumps. Furthermore, this building collects pluvial water and recycles residual water (Anmar Frangoul, 2015; http://www.thecrystal.org/).

Shanghai Tower from Shanghai, China is the second tallest building in the world after Burj Kalifa. The interior and exterior lighting of the building is supported by wind turbines located on the superior part of the building. Ventilation, heating and lighting are monitored by intelligent systems that are in charge with reducing consumption. The energy consumption is also reduced by interior and exterior transparent layers of the windows that favor natural lighting and permits it to be used at maximum of potential. Every year Shanghai Tower saves 550,000 dollars in energy and emits 34,000 cubic meters less carbon dioxide (Anmar Frangoul, 2015).

Amera Tower in Cluj-Napoca is one of the greenest buildings in Romania. This is an office building that hosts numerous companies. The sustainability of the building is given by a system that recycles thermal energy and by heat pumps (http://www.rogbc.org/ro/proiecte/...).

The title of the greenest building ever constructed was given to *NuOffice* in Munich, Germany. This building has a luxurious green roof covered with plants and large photovoltaic panels that insulate the building and produce energy. Heating and cooling in the building is partially executed with the help of fountain water. 3 layered windows and the great insulation of the building help maintain the ambient temperature. While an usual office building uses about 100-150 kilowatts/m/year, NuOffice uses only 30 kilowatts/m/year (The Guardian, 2015; Lori Zimmer, 2016).

4. The Link Between Sustainable and Intelligent Buildings

In debating the link between sustainable and intelligent buildings, whether they should merge or not, two schools of thought have formed. The smallest of these schools of thought considers that energy can be reduced, and therefore less money spent, using natural solutions (Clarke, 2008; Moore, 2009). They affirm that intelligence in buildings is synonym to opulence and extravagance, and therefore opposite to sustainability (Frost & Sullivan, 2009). The other group, the largest of them, considers intelligence to be at the basis of sustainability, taking into consideration the fact that intelligence supports several technologies that help reduce the use of resources as water, energy, wood etc. (Mitchell, 2009; Gray, 2006; Ehrlich, 2007; Rios-Moreno *et al*., 2007).

Without any doubt, the authors of this paper agree with the ones that support the merge between intelligence and sustainability. Technology has changed the way people work and live through: internet, mobile phones, micro-chips, control systems and further on. This advance in technology made us aware of the potential to growth, generally speaking. Foremost, technology improves the lives of the persons living in a building, it reduces operational and maintenance costs, it increases productivity, it creates comfort, it reduces CO_2 emissions, it controls the energy consumption through intelligent systems that detect whether at any point of the day there are inhabitants inside and whether lighting and heating is necessary or not etc.

Having in mind technological, societal and environmental changes, the program called SMART2020 was created. The goal of this program is to transform us and to enable us to thinking smart. Its focuses are to promote smart grid technologies, intelligent management systems and smart communication technologies in order to reduce CO_2 emissions by 15%. The consumption of energy in a building is reduced by 25% if the building has a building

management system incorporated, according to Johnson Controls (Mazza, 2008). Furthermore, IBM states that water consumption will be reduced by up to 50% and energy consumption by up to 70% in intelligent buildings (Moore, 2009).

Clarke conducted a study (Newsham *et al.*, 2009) in which he demonstrated that by reducing temperature in a building by 1ºC, one could save up to 70% of the energy consumption. In order for this to be possible, the building must have an integrated heating and cooling management system to control the temperature. Mathew *et al*. also conducted a study in 2009, on 3 buildings that had different degrees of intelligence incorporated, in which he demonstrated that the degree of intelligence incorporated in a building is directly proportional to the reduction of energy consumption.

Clements-Crome also agrees that the two have common elements that are interconnected (Alwaer & Clements-Croome, 2010):

a) the people that live in the building;

b) all the materials and equipment existing in the building;

c) all the processes that led to the design of the building, management facilities and the budget.

According to Frost and Hartman, there is common ground between intelligent and sustainable buildings. The commonalities can be seen in Fig. 2 below.

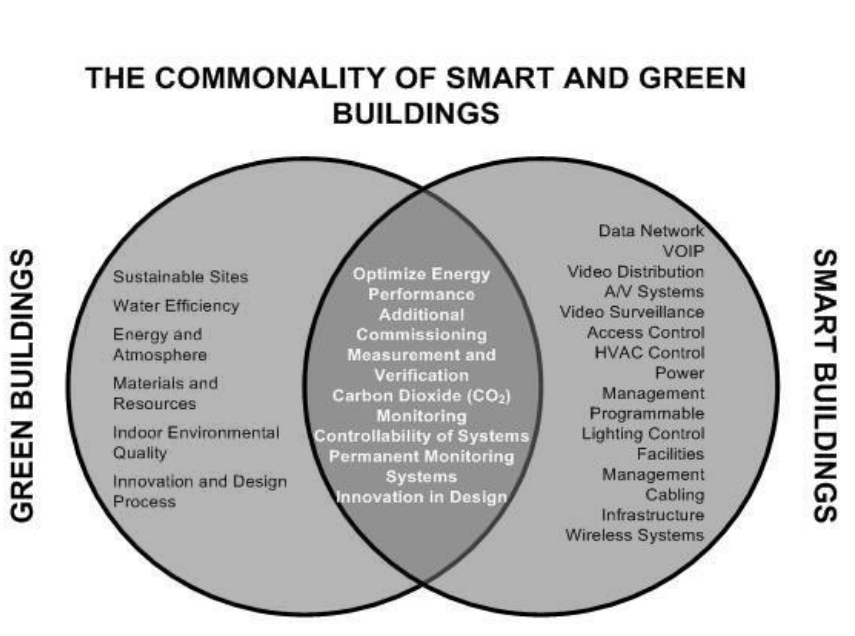

Fig. 2 – Common ground for sustainability and intelligence
(source Frost & Hartman, 2009)

4. Conclusions

Taking into consideration the world population has increased tremendously and considering the number and quantity of resources has decreased in the last 100 years, all domains, and especially the construction industry started being invested in developing products that are caring of the globe's resources and its future. These sustainable buildings are protective of the environment as they are able to produce resources from alternative sources and reduce the quantity of resources that must be used. Some of these buildings are able to sustain themselves entirely, while other only partly.

Over the years studies show that a person spends most of their life in buildings, whether it's the home they live in, the office they work in or just a passing through building. Considering this fact, the building industry commenced in developing structures that best fulfill their inhabitants' desires and needs. In enabling these needs, the industry created the intelligent buildings.

Constructing intelligent sustainable buildings is now a growing concern for the developers in the construction industry. These building are able to take care of the inhabitants, their needs and desires, and furthermore, make sure the environment is protected. Building these kinds of buildings has numerous perks:

1) the number of resources used will decrease;
2) the environment will be protected;
3) inhabitants will have safer and more secure homes;
4) the interior ambient will be healthier;
5) the exterior ambient will be safer and healthier;
6) the level of comfort will increase dramatically.

Concluding, the buildings in which we live must be our sanctuaries, they must provide us with the best of care, they must grant us our wishes, they must protect us – intelligent buildings, while making sure the health of everything surrounding us is being protected and safeguarded for all the generations that are about to come – sustainable building.

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LEGĂTURA ÎNTRE CLĂDIRILE INTELIGENTE ŞI CLĂDIRILE SUSTENABILE
Concepte şi studii practice

(Rezumat)

Nevoia de a construi clădiri inteligente se datorează nevoii inhabitanților de a trăi într-o clădire care este capabilă să le îndeplinească nevoile, o clădire care este confortabilă, convenabilă şi care le oferă elementele necesare pentru productivitate; toate acestea sunt posibile datorită evoluției fără precedent a tehnologiei. Nevoia de a construi clădiri sustenabile a fost motivată de scăderea resurselor, scădere datorată creşterii populației globului. Producerea de resurse din surse alternative, reutilizarea şi reciclarea materialelor şi, in general, protecția mediului este posibilă numai prin construirea acestor clădiri sustenabile. Tendința actuală în a reuşi toate cele menționate mai sus este posibilă doar prin construirea clădirilor inteligente şi sustenabile. Prin urmare, un stadiu actual al legăturii dintre clădirile inteligente şi sustenabile este prezentat în următorul articol, modul în care acestea agregă, asemanarile lor şi modul în care relaționează şi intercooperează.