From efficient to smart: transitioning from certified high-performance commercial buildings

Do eficiente ao inteligente: transição de edifícios comerciais certificados de alto desempenho

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ABSTRACT
The technology, integrated security, and communication systems building-oriented had a great evolution in the last decades. Likewise, the energy efficiency concepts and the greater concern related to sustainability in the civil construction sector have both been enlarged. Although buildings certified as intelligent have gained more prominence in recent years, their highlight is still minor considering that they are one step ahead of those certified as sustainable due to improving technology and tools to achieve maximum energy efficiency. In this context, this work aims at providing a foundation for a better understanding of the various parameters required for the transition from a sustainable building certificated to an “smart building”, using the Smart Readiness Indicator (SRI) as a reference. To this end, a checklist was proposed to better guide the transition from sustainable to smart. Moreover, a Leadership in Energy and Environmental Design
A LEED certificated building located in Belo Horizonte, Brazil, was taken as the object of study to assess its potential to meet the requirements of building intelligence. The results revealed that the building sustainable certification of LEED does not ensure that it reaches a significant potential for intelligence, but it contributes to the fact that part of the criteria required for its transition is already being met. In general, it is understood that the proposed checklist may be also applied in other cases to assist in the purpose of analyzing the transition from efficient to smart buildings through the analyzed parameters, as well as contribute to a new generation of automated and ecologically sustainable buildings.

**Keywords:** smart buildings, building efficiency, smart readiness indicator, sustainable certification.

**1 INTRODUCTION**

Nowadays, there is a lot of discussion about smart buildings in the universe of civil construction. With the advent of technology, integrated security, and communication systems building-oriented, what once seemed unreal - such as a fire outbreak in a building automatically triggering the region's fire department - today seems fully plausible, and
even essential (SINOPOLI, 2010). Technological advances have made it possible that, for instance, the light in a room can be turned on or off via tablet, or the access to a residence can only be done through fingerprints, ensuring greater security for residents. All this has become possible by the arrival of innovative products to the construction market, ensuring the continuous advance of high-standard buildings (DEMÉTRIO et al., 2016).

Even before the emergence of smart buildings, the concept of "building efficiency" was proposed in civil construction. Based on a sustainable approach, building efficiency is not only related to its energy efficiency, but also includes its safety, cost optimization, and asset valuation (OTONI et al., 2018).

As a guarantee to the market, however, it is valuable for the so-called efficient buildings to be recognized as such, by employing certifications. Today there are several certifications in the market that ratify the efficiency of a building. Besides, many countries have their own building performance regulations and certifications in place. Among them, the LEED is one of the methods most used in the world, due to its easy applicability in different types of buildings. It is also possible to find new parameters for efficiency evaluation in the market, introduced to support trends and technological innovations that have emerged in recent years.

The Smart Readiness Indicator (SRI), for example, an European indicator created in 2018, aims to to raise awareness of the benefits of smarter building technologies and features and make their additional value more tangible to smart building users, owners, tenants, and service providers (VERBEKE et al., 2020). For this, a "smart readiness" rating linked to the building is estimated through the analysis of systems and services present in its development process. In addition, SRI is intended to raise awareness about the benefits of smart buildings - in particular from an energy perspective - by stimulating and supporting investments in technologies in the building sector.

In this context, the present work aims at providing a foundation for a better understanding of the various parameters required for the transition from a sustainable building certificated to a smart building, using as a reference the SRI, and taking as a study object a building with sustainable certification located in Belo Horizonte, Brazil. Specifically, the objectives are i) to identify the common and divergent parameters of a building with sustainable certification concerning smart buildings, according to SRI; ii) to establish a reference checklist, to guide the transition from sustainable to intelligent;
and iii) to evaluate the potential of a building located in Belo Horizonte, Brazil, that has a sustainable certification, to meet the SRI criteria applied to smart buildings.

2 LITERATURE REVIEW

2.1 SMART BUILDINGS

Civil construction, one of the most relevant sectors for the economy of developing countries, is experiencing a moment of vast economic, social, and technological growth. Given the process of constant development and increase in demand for construction activities, new challenges and demands never before imagined arise for this sector in developing countries. One of these demands is characterized by the insertion of a new type of consumer in the market, connected to technology and interested in innovations. Such innovations seek to make domestic life more agile and functional, facilitating even the performance of trivial activities in a residence (SILVA and GAMBARATO, 2016).

Another consideration refers to the environmental issue, widely discussed in civil construction field, and its implications arising from the growing urban and industrial expansion. Thereby, sustainable buildings can bring several advantages to their users and entrepreneurs, providing a huge positive influence on the environment and society, such as reduced costs, greater comfort, and environmental preservation (RIBEIRO, 2008).

Buildings represent the largest energy consuming sector in the world. In 2018, the building and construction sector accounted for consuming 36% of final energy use and for emitting 11 gigatons of carbon into the atmosphere, which represents about 39% of the direct and indirect global energy-related emissions (GLOBALABC, 2019). In Brazil, the buildings of the industrial, commercial, residential, and public segments represent the main demand for electricity in the country, being responsible for the consumption of approximately 70% of the total amount (EPE, 2021). On the other hand, through the sustainable construction movement, in which energy efficiency stands out as one of the main approaches, buildings are no longer presented as major consumers of energy and have become the main solution to the global energy problem (GBCB, 2022).

It is in this scenario that the conceptions of smart buildings unfold. At first, automated buildings emerged, which were later called as smart due to new architectural design solutions, the use of modern materials and construction techniques, and especially the insertion of information technology (COELHO and CRUZ, 2017).
The concept of intelligent building originated in the 1980s when the automation of hydraulic, mechanical, and electrical systems became more accessible and economical. These aspects allowed control actions to depend as little as possible on human intervention, reducing energy costs and making security and firefighting processes much more efficient (SINOPOLI, 2010). More than that, smart buildings are capable of adapting to the needs of individuals and corporations - their users - increasing comfort, efficiency, durability, and safety (SIEMENS, 2022).

By exerting interaction between building automation, telecommunications, climate control, security, sound, and fire suppression systems, it is possible to save energy and water resources in a building. Programming the air conditioner to acclimate the internal environment based on the external temperature can reduce the unnecessary consumption of electricity in a home, for example. Thus, it promotes a better quality of life for its users and a significant reduction in future maintenance costs of the building (SINOPOLI, 2010).

Concerning this perspective, today there are several other parameters for evaluating the efficiency of buildings in the construction and energy efficiency market. In the European Union, for example, a directive introduced by the European Parliament in 2002 guides member countries on the energy performance of their buildings. One of the central points of the Energy Performance of Buildings Directive (EPBD) is to better exploit the potential of intelligent technologies in the building sector (PARLAMENTO EUROPEU E DO CONSELHO, 2010).

2.2 SMART READINESS INDICATOR

In the 2018 revision of the Energy Performance of Buildings Directive (EPBD), provisions were made to establish a "Smart Readiness Indicator" (SRI) as a tool for rating smart building systems. The revision strongly emphasized the potential of smart technologies in the building sector and their ability to improve both the energy efficiency of buildings and the well-being of society (PARLAMENTO EUROPEU E DO CONSELHO, 2010).

In addition, the European Green Pact, presented by the European Union (EU) Committee on Environment, Climate Change and Energy in December 2019, and the Renewal Wave, announced by the EU in September 2020, have contributed vigorously to
the SRI becoming more widespread and better applicable among countries on the European continent (VERBEKE and MA, 2022).

The European Ecological Pact aims to improve the health and well-being of citizens and their future generations by transforming the European Union into a modern, efficient and competitive economy. For such guarantees to be achieved, the European Commission aims to provide renovated and energy-sufficient buildings, less polluting energy systems and cutting-edge technological innovations, fresh air, clean water, healthy soil, and biodiversity, among other benefits, committing to combat climate change and environmental degradation (COMISSÃO EUROPEIA, 2022).

The Renewal Wave, in turn, encourages better buildings energy performance, proposing rehabilitation aimed at reducing and decarbonizing greenhouse gas emissions and lower energy use, stimulating the use of renewable solutions and innovative and sustainable construction practices. One of them is to reduce greenhouse gas emissions from heating and cooling systems in European buildings by 60% by 2030. Against this background, state members are invited to implement SRI in their territories still as a preliminary test phase (COMISSÃO EUROPEIA, 2022).

The scope of SRI is to strengthen synergies between energy, buildings, and other policy segments, in particular in IT areas, contributing to the cross-sectoral integration of buildings sector into future energy systems and markets. SRI evaluates buildings based on their ability to satisfy three key functionalities: optimize their energy efficiency and overall use performance; adapt their operations to the user’s needs; and adapt to grid signals, striving for better performance (VERBEKE et al., 2020).

The level approach of this indicator is proposed based on nine domains (i.e., energy services) and seven impact criteria, presented in Figure 1 and Figure 2, respectively. Different levels of functionality are assigned to the characteristics of the considered service. Each one of these has its degree of intelligence, on an increasing scale from 0 (i.e., "non-smart" service) to a maximum value, which can range from 2 to 5, depending on the service, for more advanced characteristics.
According to the SRI methodology, a building’s intelligent operational availability score is a percentage that expresses how close - or far - the building is from maximizing its intelligent systems. The higher the percentage, the smarter the building. This percentage can also be converted to another indicator, such as a star rating or an alphabetical score (A, B, C) (VERBEKE et al., 2020).

The SRI evaluation method provides detailed scores by domain and impact criteria, which reach up to 57 scores (Figure 3). The percentage obtained at the domain level aggregates a macro percentage to the criteria, which in turn aggregates a macro percentage to each one of the three key functionalities. At the end of this method, the key functionalities scores will result in an overall percentage for SRI, which will indicate how intelligent the evaluated enterprise is (CINTRA, 2020).

Through the SRI implementation, technological innovation in the construction sector receives support and stimulus for its development, contributing to a new generation
of more conservative and sustainable buildings. Thus, the integration of state-of-the-art intelligent technologies in buildings is encouraged, leading to a greater energy efficiency, reduction of carbon emissions, as well as a greater comfort and convenience for building occupants (FOKAIDES et al., 2020).

Figure 3 – SRI scores

| IMPACTS | Energy efficiency | Maintenance and fast protection | Comfort | Convenience | Health and well-being | Information to occupants | Energy Reliability | SRI |
|---------|-------------------|--------------------------------|---------|-------------|-----------------------|--------------------------|-------------------|-----|
| Total   | 39%               | 18%                           | 60%     | 71%         | 48%                   | 59%                      | 0%                | 42%|
| Heating | 32%               | 18%                           | 62%     | 55%         | 24%                   | 74%                      | 0%                |     |
| Sanitary Hot water | 17%               | 0%                            | 45%     | 70%         | 67%                   | 83%                      | 0%                |     |
| Cooling | 65%               | 51%                           | 78%     | 72%         | 61%                   | 55%                      | 0%                |     |
| Ventilation system | 41%               | 0%                            | 55%     | 60%         | 34%                   | 44%                      | 0%                |     |
| Lighting | 85%               | 14%                           | 90%     | 100%        | 83%                   | 15%                      | 0%                |     |
| Dynamic building envelope | 10%               | 0%                            | 31%     | 56%         | 22%                   | 46%                      | 0%                |     |
| Electricity | 10%               | 0%                            | -       | -           | -                     | 68%                      | 0%                |     |
| Electric vehicle charging | -                 | 38%                           | -       | 82%         | -                     | 84%                      | 0%                |     |
| Monitoring and control | 52%               | 43%                           | 62%     | 72%         | 45%                   | 64%                      | 0%                |     |

Source: Cintra (2020)

2.3 LEED CERTIFICATION

Some certifications are required to recognize high-performance of commercial and residential buildings. The Leadership in Energy and Environmental Design (LEED) certification, created in 1999 by the United States Green Building Council (USGBC), is one of the reference certifications in the world market and is globally recognized in the sustainable construction sphere. Moreover, it can be applied to any construction type (COSTA et al., 2021).

According to the Green Building Council Brazil (GBC Brazil), by the year of 2022, 767 projects have already been certified by LEED, in its various levels and versions. On a global scale, the number exceeds 95,000 (USGBC, n.d.). Still in Brazil, 975 enterprises are registered to seek certification, to go through the GBC Brazil's evaluation.
According to USGBC data provided in 2020, Brazil occupied the 5th position, among 180 countries, in the world ranking of sustainable buildings certified by the LEED tool.

The existing buildings or building design in the operation phase can be ranked in one of the four possible qualifications, according to the points obtained in its evaluations (Table 1). The maximum score to be acquired by the building is 110 points, being certified as LEED Platinum level (USGBC, n.d.).

| Certification | Number of points |
|---------------|------------------|
| Certified     | 40 up to 49      |
| Silver        | 50 up to 59      |
| Gold          | 60 up to 79      |
| Platinum      | More than 80     |

Source: USGBC (n.d.)

LEED has four typologies, which consider the different needs for each type of development. The Building Design + Construction (BD+C) typology applies to new construction and major renovations; the Interior Design + Construction (ID+C) category evaluates commercial offices and retail stores; Operation & Maintainance (O+M) qualifies existing developments; and Neighborhood recognizes neighborhoods. Specifically, the LEED BD+C v.4.1 typology looks at nine areas: integrative process, location and transportation, sustainable land, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and processes, and regional priority credits (EPE, 2021).

2.4 INTERNATIONAL CERTIFICATIONS IN THE BRAZILIAN CONTEXT: THE STATE-OF-THE-ART

The sustainable construction industry was studied from the perspective of LEED certification and its performance in the Brazilian market (OLIVEIRA et al., 2020). The study discusses the certification system implemented by the Green Building Council and the relationship of its aspects with the Brazilian construction industry. The authors found that LEED is currently the most widely used sustainable certification in the country and that the requirements of the system are directly related to increasing the performance of the building, reducing operating costs, efficient use of natural resources, and the mitigation of environmental impacts caused by the construction of buildings and their surroundings.
The contribution of environmental certifications to the challenges of Agenda 2030 established by the United Nations (UN) was also studied (Nunes, 2018), comparing the strategies proposed by the best-known certifications in the Brazilian market. The LEED certification, the AQUA certification (from Portuguese, High Environmental Quality), and the Caixa’s Casa Azul seal (from Portuguese, Blue House Labeling) were addressed by the author. Specifically, Agenda 2030 presents 17 sustainable development goals and details them in tasks to be fulfilled by the government, society, and the private sector by the referenced year. In the study, the author shows how good practices in civil construction activities, promoted by reference environmental certifications in the market, can contribute to fulfill the goals set by the UN (Nunes, 2018).

In addition, a preliminary comparative study was conducted between the requirements of ISO 21931:2010, the AQUA and LEED certifications, and the Brazilian building Performance Standard NBR 15575:2013 (not yet updated at the time of the study), aiming to identify the common requirements to all of them (Costa et al., 2021). They observe, in this scenario, that the Performance Standard, the AQUA seal, and the LEED certification have their systems aligned with the criteria of sustainability, comfort, and user health, while ISO 21931:2010 has them as optional (Costa et al., 2021).

Finally, a comparison between the LEED and Brazilian certification programs were performed, such as AQUA, PBQP-H (from Portuguese, Brazilian Habitat Quality and Productivity Program), and Caixa’s Casa Azul seal, classifying them according to their compliance with the following parameters: concern with energy management and the internal environment; waste and resources; innovation; integration in the environment; health and well-being; and transportation (Moreira et al., 2020).

Regarding the SRI, the public release of the proposed methodology is evaluated (Vigna et al., 2020), discussing the feasibility of its implementation and the results obtained through a practical application. The SRI was applied to a certified commercial building located in Italy and presented, as a result, a set of recommendations for a broad and effective implementation of the SRI, capable of increasing the relevance of its assessment and effectiveness, as well as improving the comparability of smart readiness of buildings.

The applicability of the SRI in cold climate countries located in the far north of Europe is also investigated (Janhunen et al., 2019), where there are advanced information and communication technology and high building energy consumption.
profiles. It was concluded that the SRI was not able to recognize the specific characteristics of cold climate buildings, specifically those employing district heating systems, which use water for heat transport (JANHUNEN et al., 2019).

Other approaches on this topic, directed towards BIM, have also been made by other authors, such as the evaluation process for BIM concerning the CUB-e Certification (GOSLING et al., 2020), a checklist proposal to assess the implementation of BIM technology applied to reinforced concrete structures (BOTELHO et al., 2021), and the development of BIM certification process for application in tailings dams raised downstream, regarding the CUB-e GEO Certification (GOMES et al., 2021).

3 METHODOLOGY

After performing the theoretical foundation on the proposed subject and the literature review to understand the state-of-the-art on sustainable certification and smart buildings, the steps presented in the flowchart (Figure 4) were adopted.

![Flowchart of the methodological steps](https://via.placeholder.com/150)

**Figure 4 – Flowchart of the methodological steps**

The first step consisted in searching for a building that has sustainable certification and is amenable to the application of the proposed study, regarding its possible transition...
to an intelligent building, meeting the requirements evaluated and considered in the present work.

Subsequently, the second and third steps consisted, respectively, of verifying the environmental certification by the enterprise, ensuring about its version and year of recognition, as well as the availability of the building documentation in open access. If access to the necessary information was not provided or found in the free domain, a new building would be searched in which it was possible to obtain such conditions.

As a fourth step, a checklist was developed to certify that a building meets the smart criteria. This checklist can be replicated for other buildings or in future research related to the transition from LEED-certified buildings to smart buildings, as long as the limitation of the version obtained is considered.

After that, the fifth step consisted of characterizing the building for the case study, concerning its architectural and construction characteristics, location, use and occupation, recognition level (local, national or global), type of sustainable certification, and other design considerations. Through the building design documentation, its main information was compiled and a summary spreadsheet was prepared, which served as the basis for its comparison with smart buildings.

For the comparison stage, the Smart Readiness Indicator (SRI) was used as a reference for the qualifying application on these buildings. This comparison was important to highlight the key-criteria for characterizing sustainable buildings, observing which of them were also integrated to smart buildings, and for identifying which complementary parameters would be necessary to characterize smart buildings in their standards.

4 RESULTS AND DISCUSSIONS

4.1 CHECKLIST

Due to the lack of a reference indicator globally accepted for evaluating the building intelligence potential, as well as in Brazil, the present work aimed to develop a checklist, taking as a reference the domains and impacts analyzed by SRI, for guidance and application in Brazilian buildings that have sustainable certification.

Through this checklist, the object was to guide the transition between the sustainable and the intelligent, selecting the most important and applicable services, among the 54 examined by the SRI, to compose its evaluation criteria. At the end of the
evaluation, the number of criteria met by the building was added up and, like the SRI, a classification of the intelligence potential of the analyzed building was returned.

For a better understanding of the reader, the checklist will be presented in the next item, whose use was given by the application in a case study. The checklist contemplates nine domains and their respective criteria evaluated in each of them, adding up to a total of 39 possible points to be reached. The criteria have equal analysis weight and were classified as met (Y), not identified (?), and not met (N).

4.2 CASE STUDY

The Aureliano Chaves Building, commonly known as Forluz Building (Fig. 5), was chosen for the case study. It is located in the south-central region of Belo Horizonte, Minas Gerais in Brazil. The building is 121 meters high and has a total constructed area of 58,995 m². It has 30 floors and 12 elevators, of which 25 are for offices and 5 are underground floors. Its construction was completed in 2014 and its inauguration took place on November 20th of the same year.

The entire building design was conceived following the principles of innovation and sustainability. Technologies were used that allow for the use of solar energy, natural light, water reuse, and rational use of energy, among others. In its conception, it was estimated that drinking water consumption could be reduced by up to 40% and electricity by 20%.
The building received the LEED Gold seal, an international reference in sustainability, and was the first building in Minas Gerais state to obtain a LEED certification. Besides, it also received the Procel energy efficiency seal, a Brazilian building certification for those most efficient (Class A).

4.3 DATA SUMMARY

The Forluz building obtained its certification about a year after the end of its construction, on October 21st, 2015. In that year, the LEED BD+C New Construction version 2.2 certification was in effect at the USGBC, which had eight dimensions to be analyzed and 69 possible points to be achieved, which were 41 points less than the current version 4.1 (2022).

The enterprise scored 42 points out of 69 and was certified as Gold level by the organization, second only to Platinum level. Detailed descriptions for meeting each prerequisite or credit can be found in the LEED® for New Construction & Major Renovations Version 2.2 Manual, published by USGBC in October 2005 and available on the organization's website for public inspection.

4.4 APPLICATION OF THE PROPOSED CHECKLIST

In the last stage of the study, the checklist was applied to the Forluz Building, after its characterization, compilation, and analysis, returning it to the summarized data presented in the previous item. Table 2 presents the results of the checklist application, broken down by the fulfillment and non-fulfillment of the listed criteria by the enterprise.

| Domain        | Criterion                                                                 | Y | ? | N |
|---------------|---------------------------------------------------------------------------|---|---|---|
| Heating       | Heat emission control.                                                   |   |   | X |
| Heating       | Temperature control of the water circulating in the distribution network. |   |   | X |
| Heating       | Control of the pumps that make the distribution network.                 |   |   | X |
| Heating       | Storage of thermal energy.                                               |   |   | X |
| Heating       | Operation control of heat generators.                                    |   |   | X |
| Heating       | Communication of information regarding heating performance.              |   |   | X |
| Heating       | Flexibility and interaction with the network.                            |   |   | X |
| Domestic hot water | Control of stored water heating.                                        |   |   | X |
| Domestic hot water | Control of operation of hot water generators.                           |   |   | X |
| Domestic hot water | Communication of information concerning the performance of sanitary water heating. |   |   | X |
| Cooling       | Cold emission control.                                                   |   |   | X |
| Cooling       | Temperature control of the water circulating in the cooling network.     |   |   | X |
The building achieved 17 of the 39 criteria listed in the checklist, returning an intelligence percentage of approximately 44%. Among the main bottlenecks is the failure to communicate information about the building's water and energy consumption and
energy performance to its users, an indispensable factor for a building to be recognized as intelligent.

Another element considered essential is the presence of natural ventilation, which reduces the burden of use and maintenance of HVAC systems, which the building does not meet since it has no windows that can be opened on its facade.

As the last point, there is also the need to perform Indoor Air Quality (IAQ) measurements with constant frequency because, since the building does not have natural ventilation, the circulation of indoor air is predominantly done by the air conditioning system in use in the building.

The criteria related to energy exchange and communication of information from electric vehicles were qualified as non-conclusive since the necessary information to evaluate them was not obtained. The criteria related to heat control and generation were qualified as not met since the building does not have a heating system.

By obtaining the Procel energy efficiency seal, in addition to LEED certification, most of the criteria related to hot water, cooling, lighting, and electricity controls were met by the building, signaling an assertive point for its transition to a smart building.

5 CONCLUSIONS

This investigation studied the parameters necessary for the transition from a building with sustainable certification to an intelligent building, using as reference the Smart Readiness Indicator (SRI) and a commercial building with sustainable certification located in Belo Horizonte, Minas Gerais (Brazil).

It was expected as a general result that, concerning the criteria for meeting sustainable certifications, LEED-certified buildings would be closer to what is assumed by smart buildings, even with different approaches. However, the case study of the Forluz building revealed that the version of the LEED certification considered in this work does not guarantee that the building reaches a high intelligence potential when evaluated by the reference checklist developed by this study.

On the other hand, the achievement of LEED certification by the building design contributes to the fact that part of the criteria necessary for its smart transition are already being met since they are also prerequisites determined by the USGBC and GBC Brazil, LEED certification bodies.
In this scenario, the proposed checklist can, besides acting as an evaluation method, guide buildings in the transition from their efficient models to their intelligent models, and contribute to a new generation of automated and ecologically sustainable buildings.

Finally, the results of this work allow us to suggest for future research: i) to promote a survey of buildings with sustainable certification and the application of the checklist proposed in this study, aiming to verify if there is a tendency regarding the percentage of intelligence among them; ii) to refine the checklist in its weighting, establishing weights for criteria of greater complexity and importance; and iii) to elaborate a manual with detailed descriptions of these criteria, aiming to enable better orientation for buildings analysis.
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