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The impact of industry 4.0 technologies on the environmental sustainability of commercial property by reducing the energy consumption

D Hübner[1], A Moghayedi[1] and K Michell[1]

[1]S⊕CUBE, Department of Construction Economics and Management, University of Cape Town, South Africa

Alireza.Moghayedi@uct.ac.za

Abstract. This research examined the concept of industry 4.0 technologies (IT4) and identified the effects that they have on the environmental sustainability of commercial properties in South African. The extensive literature review revealed that IT4 used to reduce the energy consumption of commercial properties is not widely adopted in South Africa. This could be attributed to South Africa's energy building regulation, SANS 204, which provides the minimum energy saving specifications for local building requirements. It was discovered that only green buildings implemented industry 4.0 energy-saving technologies to reduce their energy consumption above the SANS 204 standards. Furthermore, it was found that buildings waste large amounts of energy which can be prevented through the use of industry 4.0 energy-saving technologies. The researchers attempted to evaluate the impact of IT4 on the energy consumption of South African commercial properties through an overarching constructivist paradigm. The research was conducted using a multi-case study approach, utilising qualitative and quantitative data on green buildings which have IT4 installed. Descriptive statistics was used to analyse the quantitative data (energy consumption), while qualitative data was collected through semi-structured interviews for an in-depth analysis. The research findings revealed that IT4 could reduce a commercial building's energy consumption by as much as 23%. The study also found that IT4 reduced a building's carbon footprint and improved employee productivity. This paper would provide value to developers and landlords who have limited information regarding the factors around the implementation of IT4.

1. Introduction

The drive towards sustainable development has accelerated, and the importance of being green has become an essential element within companies. This follows the trend that consumers, shareholders and employees are beginning to align their habits and goals with that of sustainability [1].

92% of South Africa's electricity is produced using fossil fuels of which the commercial property sector accounts for 18% of total electricity consumption [2]. Eskom's failing infrastructure, their inability to maintain a constant supply of power and its incapacity to meet the power demands of the country has resulted in rolling blackouts, commonly referred to as load-shedding, across the country [3]. In addition, commercial buildings waste large amounts of electricity as electrical appliances and fixtures are left on when they are not in use, and these everyday energy inefficiencies compound into significant energy wastages [4]. Shaikh, *et al.* [5] argued that innovative technologies, encompassed within the industry 4.0, such as intelligent control systems can be used to manage and optimize a commercial building's energy consumption in a manner that is more efficient than the human potential.

Against this backdrop, this paper aims to determine the impact of implementing IT4 on the energy consumption and environmental sustainability of commercial properties in South Africa. To do this, the study examines whether IT4 can reduce the energy consumption of commercial buildings. It seeks to identify the types of implemented IT4 and evaluates the impact that these technologies have on the sustainability of commercial buildings.

2. Literature review

South Africa's economy is classified as emerging with a growing middle class, which stimulated large investments in commercial buildings [6]. However, a slowing economy, over supply of commercial properties and an increase in 'work from home' policies, has caused a decrease in the demand for office space. This has increased the importance of managing a commercial property's operating expenses so that favorable profit margins can be maintained while remaining competitive. South African Property Owners Association [7] reported that electricity contributes to 30.5% of total operating costs within South African commercial properties, and air-conditioning and lighting where the main energy consumers, attributing to 40% and 28% of electricity consumption respectively.

95% of South Africa's electricity is generated by Eskom, with 92% of this energy being produced by fossil fuels [3, 8]. Moreover, Eskom's ailing infrastructure has begun to fail and the power utility has not been able to meet the increased demand for electricity [3]. This emphasizes the need to reduce a building's energy consumption to help negate some of these negative factors. Furthermore, the cost of electricity will increase by 22% over the next 3 years [8]. This will increase the importance of reducing a building's energy consumption and the costs benefits of implementing energy saving techniques will only improve. South Africa's building regulations and minimum energy efficiency standards are set out in SANS 204 [9]. These standards have only improved the energy efficiency standards marginally in relation to previous building regulations.

The inefficiencies of energy usage within a building have a significant impact on the energy consumption levels due to a building's long lifespan. The operational period of a building is considerably longer in relation to the building's other phases (design, construction or demolition), because occupant comfort and health has to be catered for [10]. Moreover, building occupants can be classified into 3 energy usage categories ranging from a high energy user to a low energy user [11]. High energy usage occupants are generally considered individuals who have total disregard for reducing their energy consumption, on the opposite side of the spectrum, low energy usage occupants are fully aware of their energy usage patterns and they make a concerted effort to save energy.

The implementation of IT4, energy management systems, new energy saving techniques in commercial buildings will be optimized and negative building occupant behaviors can be neutralized, which can result in achievable energy savings between 30% - 50% [12].

2.1. Sustainability in commercial property

According to the Brundtland and Khalid [13], sustainable developments must meet the needs of today without jeopardizing the needs of future generations. Sustainability is often viewed using a three-pillar sustainability model. The pillars being economic, social, and environmental sustainability. Högberg [14] describes the economic pillar of sustainability as organizing one's finance in such a way as to provide a continuous flow of income in the future. Pieterse [15] states that social sustainability is the action and policy that aims to provide fair access and distribution of rights to improve society's quality of life. The environmental pillar of sustainability is defined as sustaining global life-support systems by continuously protecting natural resources to ensure that their limits are not exceeded [16].

To apply the three pillars of sustainability to commercial property, Elkington [17] coined the term 'Triple bottom line', describing people, planet, and profit. This terminology allowed Elkington to tailor the traditional sustainability 'model' more towards companies and organizations. This enabled them to measure their success not just by their financial indicators, but also by their social and environmental performance and impact, thus allowing companies to communicate their ethical practices more transparently to key stakeholders [1]. Arowoshegbe*, et al.* [18] stressed that the underlying principle between sustainability and the triple bottom line was the drive towards a sustainable environment. Within the triple bottom line framework, people equate to social sustainability, planet corresponds to environmental sustainability and profit amounts to economic sustainability [19].

In 2011 the SANS 10400-XA: Energy usage in buildings and SANS 204: Energy efficiency in buildings was introduced. This standard only marginally improved the energy efficiency of the previous rendition. These standards are elementary in reducing building energy consumption and this did not develop a suitable sustainable baseline which developers could follow [20]. This has led developers to seek more sustainable rating tools such as the GBCSA's Green Star certifications which lays out more stringent sustainable requirements, and rewards companies who achieve significant sustainable gains, these developments are often referred to as green buildings.

The Green Building Council of South Africa (GBCSA) plays an important role in promoting sustainability in South Africa. They offer the tools and guidelines to educate and encourage property professionals to pursue sustainable developments in South Africa [21]. Subsequently, the GBCSA achieves these goals through a green star rating system that provides developers with a formal rating framework. This allows a building's 'greenness' to be measured and compared to other developments. Hoffman *et al.* [22] noted that the reduction in utilities and resources resulted in reduced operating costs, increased property values, improved marketability and helped companies reach their sustainability objectives. There are multiple factors that drive the demand for green buildings ranging from tenant desires, a company's corporate image, the financial benefits associated with green buildings and a reduction in a building's carbon footprint [23]. Despite these advantages, the uptake of green buildings in South Africa has been slow, which can be attributed to conflicting building codes, lack of knowledge, and the industry's reluctancy to adopt new practices and techniques [24].

2.2. Adoption of industry 4.0 technologies in the commercial property sector

The 21st century has created an environment where technology will grant an organization a competitive advantage as it has become a fundamental tool to reduce cost structures. Industry 4.0 is a drive towards an automated, real-time monitoring and measuring system which promotes high efficiency operations while reducing waste [25]. Technologies such as automation, artificial intelligence and real time data collection will increase the energy efficiency of a building beyond the human potential [5]. Furthermore, these technologies will enable large amounts of energy usage data to be collected, resulting in more accurate energy models [26]. Zeinab and Elmustafa [27] stipulated that these types of technologies will be interconnected through the internet of things, creating an integrated network system. However, the high capital costs to install these systems is one of the main deterring factors, but these costs are often offset by the energy savings achieved over a building's lifetime [28]. Furthermore, economies of scale will help to reduce installation costs as these types of technologies are improved because the cost to manufacture and install them will decrease over time [12, 29].

The adoption of IT4 within South Africa has been limited due to the government reducing their drive and investment [30]. Despite this criticism, some municipalities are promoting the use of IT4 indirectly through the installation of fiber infrastructure to propel the concept of smart cities [31]. This has resulted in the partial adoption of IT4 within South African premium grade commercial buildings [32]. Commercial buildings that have adopted IT4 to reduce their energy consumption focused on occupancy light sensors, smart meters and demand-controlled ventilation systems which have been integrated into buildings using building management systems [33].

3. Research methodology

To examine the impact of implementing IT4 on the energy consumption of commercial buildings a multiple case study methodology was adopted. In this regard, a mixed-methods approach was employed which utilized quantitative and qualitative data. Due to the limited adoption of IT4 in South Africa, three GBCSA green star rated commercial buildings were examined based on the following methodology.

The following criteria was used to determine if a green building was suitable for this research. Only 5 or 6 green star rated buildings were selected, because lower green star rated buildings were deemed to be entry level in terms of energy efficiency. Furthermore, only buildings that achieved a green star rating using the 'As Built' and 'Existing Building Performance' tools were evaluate because these tools reported on efficiency of the building in its post construction phase. Thirdly, the GBCSA evaluates the greenness of buildings based on 9 different categories and only the energy category was taken into consideration to ascertain the energy performance of the building. This energy score was analyzed against the employed energy saving techniques. To ensure buildings whose energy efficiency standards were attributed to innovative technologies were selected. Lastly, the company who owned the development was evaluated to ensure that the cases where diverse in terms of the corporate image, sustainable strategies and greening initiatives. Based on these 5 criteria points, 3 case studies were selected, and interviews were conducted with their facility managers.

Qualitative data was collected through semi-structed interviews of facility managers from these three case studies, and supplementary quantitative data of building performance and energy consumption of case studies were collected at the end of each interview. The qualitative data was analyzed through thematic analysis, where it was encoded using NVivo to identify key emerging themes. Statistical analysis was used to describe the relationship between the energy consumption of the case studies and electrical consumption of a conventional building as described in SANS 204. This allowed the researchers to identify trends and relationships between IT4 and the effects they have on sustainability.

4. Findings and discussion

After performing a thematic analysis using NVivo, the following themes emerged from the interviews with the FMs from the three case studies: The impact of IT4 on sustainability, the application of IT4, and the impact of implementing IT4.

4.1. The impact of industry 4.0 technologies on sustainability

The first emergent theme identified from the three case studies is that of sustainability.

Firstly, the economic element of sustainability revealed that the installation of IT4 has the potential to increase a property's value, lower operating costs, and reduce the number of maintenance staff.

"The moment I put up a PV plant, I have the green credentials, I have the energy efficiency drive and all of that, and I have the direct financial returns"

Secondly, the results revealed that there is an indirect social benefit to IT4. IT4 improved the building's working environment, which in turn, positively impacted employee productivity. Moreover, these energy saving technologies also created awareness amongst employees, who began practicing energy saving techniques at the office and at home.

" And a lot of staff went home and tried to see how they could do things differently in their own homes. I still get a lot of calls today, from people asking me how they should wire their home or what can they do to be more environmentally friendly."

Thirdly, the environmental element of sustainability was the secondary focus of the technologies after finance. In addition to IT4 reducing a building's carbon footprint, the commitment to environmental sustainability did not end with the completion of a single project, but rather investors and developers kept seeking to improve building operations across their portfolio, improving their environmental footprint and company image.

"I think in my opinion and obviously with my company, you know, was leading the way in terms of energy management… And I think one of the things was that they looked at as and obviously wanted to start with something similar".

4.2. The application of industry 4.0 technology

All the interviewees reported that the installed IT4 reduced their energy consumption. On the other hand, participants did note that occupants desire a comfortable working environment which can lead to occupants overriding a building's management system. This will prevent a building from running optimally and cause a reduction in energy savings. Despite this criticism, the operating costs of a building were reduced, and it was reported that IT4 integrations has helped dampen the effects of a slowing rental market. This allowed landlords to charge lower rentals, maintaining their building's marketability and tenant base while maintaining a profitable return.

The main driving factor behind the installation of IT4 is the financial costs to install them. In some exceptions, the core values of the shareholder and employees to reduce their environment footprint was the main driving factor. The main method used to determine the feasibility of an installation adopted by the participants, was to determine the payback period. In the case of light and sensor fittings, a payback period of 5 years is deemed optimal, while a photovoltaic plants optimal payback period is between 20 – 25 years. These payback periods are based on the average life expectancy or time period before the technology becomes obsolete. However, in certain cases the payback period can be shorter than the life expectancy or time period before the technology becomes obsolete, in the case of a photovoltaic plant the monetary payback period ranges between 5 – 7 years.

"So solar PV. We're looking at, say… the general payback for that installation was around seven to eight years."

The attractiveness of IT4 originates from the desire to be environmentally friendly and the certification attributed to a GBCSA green star rating. The GBCSA rating associated with a development automatically increases the perceived value of the subject building, illustrating that IT4 themselves do not increase the value of a building, but rather the GBCSA green star rating. It was further observed that the improved marketability of the GBCSA green star rating resulted in tenants wanting to be associated with an environmentally friendly building. By the same token, green star buildings have more comfortable working environments, and they are perceived to be more luxurious compounding their improved marketability over conventional developments.

"it's not necessarily linked to the actual implementation date of the technology, but rather when we got the certification."

All three FMs in charge of the case studies were very familiar with the concept of sustainability. The sustainability and efficiency of the IT4 installed in the case studies were carefully evaluated by a group of experts to select the most suitable and optimum technologies for each case study.

4.3. The impact of implementing industry 4.0 technologies

The statistical analysis revealed that case 1 achieved the highest energy savings of 23.59%, case 2 achieved an energy saving 19,34%, and case 3 achieved the lowest savings of 16,81% in relation to SANS 204. An increase in energy savings was positively linked to the number of installed IT4 and the age of each case. Where cases had the same number of installed IT4, the more modern building achieved a higher energy saving. This resulted from the modern building containing more advanced and efficient IT4 which reduced the energy consumption by more than their older counterparts. The environmental goals of the companies directly impacted the number of installed IT4 as case 1 installed the most IT4, because they were more environmentally orientated than the other two cases. Moreover, the high capital cost to implement these technologies also determined the number and type of IT4 that were installed.

Table 1 below provides a summary of each case's GBCSA green star rating, total floor area, the date the building was constructed, the types of installed IT4 and the achieved energy savings of each case.

Table 1. Summary of each case studies GBCSA green star rating, total floor area, date the building was constructed, the types of implemented IT4 and their achieved energy savings.

Case	Green Star	Total floor area	Constructed	Implemented IT4	Energy Saving Percentage
Case 1	6 Stars	18,000m^2	2011	8 innovative technologies • Smart meters • Light occupancy sensors • BMS • Automatic shading system	23.59%

				• Server room heat capture system • Sea water cooling plant • Solar water heating system • PV plant	
Case 2	5 Stars	52,000m^2	2014	5 innovative technologies • Smart meter • Light occupancy sensor • BMS • Integrated CO2 room sensors • Centralized HVAC system	19.34%
Case 3	6 Stars	5,070m^2	2007	4 innovative technologies • Smart meter • Light occupancy sensor • BMS • PV plant	16.81%

The results of the analysis showed that installing IT4, not only improved the environmental and economic sustainability of the three case studies by reducing their energy consumption, but also enhanced the social sustainability of the case studies by improving the working environment. This had a positive impact on employee productivity.

5. Conclusions and further research

This paper examined the effects of IT4 on the environmental sustainability of South African commercial buildings through the reduction of energy consumption. The study identified different types of implemented IT4 in three green-rated star case study buildings and compared the level of energy consumption of these buildings with the recommended energy consumption for commercial properties by the South African National Standard (SANS 204).

It can be concluded from the study's findings that the level of knowledge and familiarity that building owners, designers and operating teams have about sustainability and IT4 are the main drivers behind the level of adoption of IT4 in commercial buildings. Furthermore, the significant energy reduction in the three selected case studies proved that there is an association between the number of utilized IT4 and the reduction in energy consumption in commercial properties. Therefore, commercial property developers and landlords should invest in IT4 to reduce energy consumption. This will provide financial savings regarding utility costs and reduce their carbon footprint as less fossil fuel-generated electricity is consumed.

Moreover, it was found that while the technologies themselves were focused on environmental sustainability, their implementation would positively impact the other two pillars of sustainability. This was seen in the economic pillar of sustainability, as participants described the implemented technologies in each case as providing positive financial returns. In addition, the rapid advancements in energy-saving technologies will result in more affordable installations and reduced payback periods. The technologies also positively impacted social sustainability by improving the working environment, resulting in increased employee productivity and comfort. These technologies improved environmental sustainability, as it was established that IT4 would reduce the energy consumption of a building, thus lowering carbon emissions. In conclusion, it was established that a positive relationship exists between IT4 and a reduction in energy consumption, reduced carbon emissions, and improved employee health. The results of this study, in respect to the energy savings of each case, was gathered in terms of the whole building's usage. Furthermore, the capital and operating costs of the implemented technologies in each case was not obtained due to non-disclosure of intellectual property by the FM's. Therefore, further research regarding the individual energy usage, capital and maintenance costs of each installed IT4 will generate a more accurate financial forecast model.

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