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Article

Smart and Green Buildings Features in the Decision-Making Hierarchy of Office Space Tenants: An Analytic Hierarchy Process Study

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Abstract: In the paper, we investigate the role of smart building or green building innovations on the Polish real estate market using the Analytic Hierarchy Process (AHP) method on the group of experts (consultants, managers, brokers) that are active on the office market in Krakow (study area). The findings point towards the highest relevance of the localisation factor, but also at the relatively low importance of the features of a sustainable building: building automation and information technology systems, as well as energy efficiency or certification. The findings suggest that despite the growing interest in sustainability and technological advancement amongst office market participants in Krakow, the relative importance of smart and green building features in their decision-making processes is relatively low. The study has some interesting practical implications. The knowledge regarding the relative importance of decision criteria can be valuable for developers and investors because the anticipation of tenants' expectations is directly linked with return on investment and innovation premiums.

Keywords: sustainable real estate; office market; smart building; green building; Industry 4.0; analytic hierarchy process; MCDM

1. Introduction

The economic literature has identified both positive and negative effects of Industry 4.0 in the service sector and industry. The potential benefits of the fourth industrial revolution include product benefits, operational benefits and spill-over effects (Dalenogare et al. 2018).

One of the major themes in the literature on the subject is the issue of adoption and diffusion of technological innovations in specific industries and services (Dalenogare et al. 2018, p. 384). The problem of diffusion of innovation has been an object of scientific research, at least since the breakthrough work of Hagerstrand (1953). Both economic and spatial threads appeared in the research because proximity (geographical, cultural, economic) is an important factor in the spread of innovation. In the literature, one can find a view that diffusion can be facilitated by several economic and institutional stimuli. It can also be slowed down by the existing market (strong competition) and legal barriers. There is also a dominant view that the process of diffusion of innovation most often takes place along the centre (developed countries)—peripheries (developing countries) axis; see Comin and Hobijn (2004) for more information. The impact of the revolution regarding innovative business models was analysed by Frank et al. (2019). Recently, there have also been systematic reviews describing the current state of research (Lu 2017). The degree of adoption of technological innovations significantly differs across industries and countries (Dalenogare et al. 2018).

It seems that despite prior research in this area, this problem has not yet been satisfactorily and comprehensively explained. Certainly, a significant knowledge gap in this respect can be observed

in the commercial real estate sector, where due to the processes of the globalisation of services and capital flows, these changes are very interesting and spontaneous. The question about the economic effects of diffusion of technological innovations, such as smart buildings or green buildings, for various stakeholders (market entities), i.e., investors, developers and users, also arises naturally. The research conducted so far shows that there is a demand for innovative solutions in office construction (e.g., green buildings), which translates into higher rents and smaller vacancies in innovative buildings (Costa et al. 2018). Even more revolutionary consequences of the 4.0 revolution for the real estate market are pointed out by other researchers (Erdogan 2019), who identify several organisational and spatial changes.

The motivation for the presented research was to assess the importance of sustainable and smart building features in the office tenant decision-making process. The paper aimed to investigate the preferences of decision-makers regarding selected features that can be related to smart and green buildings: building automation, quality of information technology (IT) services, building management systems, presence of green certificates (i.e., Building Research Establishment Environmental Assessment Method—BREEAM, Leadership in Energy and Environmental Design - LEED). In the empirical part of the paper, we investigate the key decision criteria considered when renting an office space in Krakow using the analytic hierarchy process (AHP). The technique allowed us to evaluate the relative importance of selected groups of criteria and belonging sub-criteria that contribute to the choice of an adequate office space for tenants in Krakow.

The rest of the paper is organised as follows: Section 2 discusses the economic literature on drivers and barriers of sustainable and smart building innovation diffusion; Section 3 discusses the AHP method, research design and study area; Section 4 presents and discusses the empirical results; and Section 5 discusses the findings and presents their practical implications.

2. Literature Review on Sustainable and Smart Office Buildings

2.1. Office Users' Preferences and Decision-Making

Factors influencing the choices of office tenants/users have been addressed in the economic literature. Prior studies used both qualitative and quantitative methods. The former include in-depth interviews and the Delphi method (Adnan and Daud 2010; Adnan et al. 2012; Gluszak and Zieba 2016), while the latter encompasses a broad range of analytical techniques, such as multi-criteria decision making (MCDM) methods (Adnan et al. 2015) or conjoint experiments (Zieba et al. 2013).

Amongst the various environmental, technical and economic features of a building, we can distinguish four groups of factors (Appel-Meulenbroek 2008; Remoy and van der Voodt 2014). Push factors are features of the current office that fail to meet the user's requirements. Pull factors refer to features of the alternative office that make it more attractive for a user. Keep factors are building features that make it reasonable to stay in it. Reject factors are generally all features that discourage a user from selecting the building. The literature acknowledges that office users' preferences are heterogeneous. The preferences regarding the location and building features may vary across industrial sectors, for example, banking and financial services, oil and gas, art and media, or IT (Remoy and van der Voodt 2014; Adnan et al. 2015). Differences regarding office users' preferences can also be attributed to cultural, climate or geographical factors. Previous studies suggest significant differences in office quality perception and requirements between groups of property market sectors, for example, occupiers and agents (Leishman et al. 2003). Ho et al. (2005) used AHP to investigate the preferences of various actors on the office market in Sydney regarding building functionality, services, design and management. More recently, Adnan et al. (2015) used AHP to analyse preferences of office tenants in Kuala Lumpur. Preferences of office users in Poland were studied by Celka (2011); Zieba et al. (2013) and Gluszak and Zieba (2016). (Marona and Wilk 2016) applied AHP to retail property users.

Based on the literature review (Rymarzak and Siemińska 2012), we conclude that various characteristics that affect the office location decisions of tenants/users can be divided into three broad categories: (1) location, accessibility and neighbourhood; (2) office building attributes; and (3) lease

agreement clauses and conditions. This general classification will be operationalised in Section 3.1 and used in the empirical part of the paper (Section 4).

2.2. Green and Smart Buildings' Features and the Preferences of Office Tenants

Since 2000, several important innovations have emerged and been adopted by the real estate industry across the world. Arguably, two of the major technological innovations in building construction and management are green (sustainable) and intelligent (smart) design.

The sustainable (green) building is a fuzzy concept but it can be defined as a responsibly created and managed construction environment, complying with the guidelines of natural environment protection and the efficient use of natural resources (Kibert 2007). Typical features of a green building include a selection of environmentally friendly technologies in the building construction and design, maximum use of daylight and high indoor air quality; individual climate control of the indoor environment; low energy consumption; water and energy efficiency; and building life-cycle orientation (Gluszak 2015). The adoption of the innovation was particularly visible in the commercial property market (office, retail and hotel sectors). Since Hagestrand's path-breaking work on the mechanisms of spatial diffusion of innovation (1953), the problem has been discussed theoretically and investigated empirically. Like many others, green and smart building innovation diffusion is a spatial phenomenon. In the recent two decades, one could observe a hierarchical/cascade or contagious dispersion of technological advancements as the green building innovation spread from mature to emerging property markets worldwide. The drivers and barriers of the diffusion of sustainable buildings have been identified in the business and economic literature (Livingstone and Ferm 2017; Darko et al. 2017). Theoretical links between sustainability and property market behaviour were identified by Eichholtz et al. (2009). They argue that there are four possible explanations for the increase in the demand for sustainable office space. The first category encompasses direct economic benefits, including lower operating costs and lower energy consumption. Most prior studies report that green buildings have relatively lower maintenance costs (Pivo and Fisher 2010). Second, there are indirect economic benefits that can be related to an improved image of the user's organisation. Green building users may experience increased employee efficiency, lower turnover and lower absenteeism. The third category includes risk avoidance. Due to the evolution of the office market and possible institutional and legal changes, the early adoption of technological innovation (like a green or smart office) can be perceived as a safer option for a user, especially in the long term. Finally, interest in green buildings can be driven by ethical or environmental concern. Many organisations adopt principles of corporate social responsibility (CSR), or responsible property investing. Eichholtz et al. (2009) noted that CSR is reflected in corporate decisions regarding the property market (e.g., in decisions to lease LEED-certified office space). Similarly, non-profit and government organisations display a higher propensity to rent office space in an ecological building, guided strongly by legal considerations.

As discussed earlier, according to economic theory, the higher utility of green and smart offices should translate into tenants' willingness to pay for a better workspace, and finally higher office rents. Various empirical studies quite consistently report economic premiums for a sustainable office space. Findings suggest that sustainable buildings command higher rents, lower vacancies, and finally, higher values (Pivo and Fisher 2010; Fuerst and McAllister 2008; Wiley et al. 2010).

In the case of sustainable design, the process has been facilitated by the emergence of independent third-party governance institutions and the development of green building certification systems. The positive role of multi-criteria green building certification by independent institutions has been advocated by Sedlacek and Maier (2012). They argue that independent assessments of building quality performed by the third-party organisation can mitigate tensions between developers, investors and users/tenants. Information on building quality reduces the asymmetry of information typical in the real estate market and provides positive incentives to increase the quality of the built environment (Sedlacek and Maier 2012). The most popular green building certification systems in Europe are:

- Building Research Establishment Environmental Assessment Methodology (BREEAM), created in 1990 by the Building Research Establishment (BRE).
- Leadership in Energy & Environmental Design (LEED), created in 1998 by the United States Green Building Council (USGBC).
- Haute Qualité Environnementale (HQE), created in 1992 by Association pour la Haute Qualité Environnementale (ASSOHQE).
- Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), created in 2007 by Deutsche Gesellschaft für Nachhaltiges Bauen e.V.

Available statistical data, as well as prior research on competition between sustainable building rating systems (Gluszak 2015), show that two certification systems have a strong competitive position in most European countries. Arguably, British BREEAM green certification systems possess a dominant competitive position in Europe, especially in the United Kingdom, France, Poland, Belgium, Netherlands, Lithuania and Slovenia. The American LEED system has a strong competitive position in Italy, Greece, Switzerland and Finland. It is worth noting that other major European systems are less popular outside their domestic markets. DGNB certification is popular in Germany and Austria, where it was created and developed, and to date, it has a dominant competitive position, whereas HQE is relatively rarely utilised outside France.

Smart buildings are a fairly new concept and has only recently drawn attention from researchers and industry (Chamoso et al. 2018). Similar to a green building idea discussed previously, there is no consensus regarding the definition of a smart building (Omar 2018, p. 2905), although its features often include intelligent, automated and adaptive management systems; indoor climate control; and energy efficiency. One of the definitions states that an intelligent building is any building that provides a responsive, effective and supportive environment within which the organisation can achieve its business objectives (Li et al. 2005).

Although several ideas related to the intelligent built environment have been introduced in the industry, some scholars argue that smart building innovation has not been successfully implemented to-date (Jia et al. 2019). Batov (2015) suggests that in many cases, the intelligence of the building is confused with building automation. One of the key technologies in the development of smart building is the Internet of Things (IoT). IoT may have several applications (Jia et al. 2019; Stojkoska and Trivodaliev 2017): location of users and resources tracking, energy management, facility management, indoor comfort management (heating, ventilation and air conditioning (HVAC) systems), security and safety. Another feature is related to artificial intelligence, automation, analytics and big data computing.

Prior research has focused mostly on the technical side of the smart building technology, i.e., mostly on the design and efficiency of particular solutions. Serious economic and social evaluation has not been made to date. In particular, it is not clear whether smart buildings generate higher demand from users, thus command lower vacancies, and higher rents compared to their conventional counterparts. In a recent study, authors argue that the market adoption of smart buildings depends on the user perception of benefits (such as superior energy management) and risk (mainly lower control over building operation) related with the technology (Wilson et al. 2017).

As it can be easily seen, smart and green building share several features (such as sophisticated HVAC, information processing and building management systems). It seems that currently, their development is an indirect manifestation of the technological change introduced by Industry 4.0.

3. Materials and Methods

3.1. Analytic Hierarchy Process Method

The employed research method was the analytic hierarchy process (AHP) developed by Saaty in the 1970s and described through an example application in (Saaty 2008). In AHP, the managerial decision is achieved with the use of expert judgments. Highly qualified specialists in the decision problem's field compare all decision criteria on an each-with-each basis. In every such pairwise comparison task, a statement of preference towards one of the criteria with regard to a parent

criterion or a decision alternative is expressed. The final results of rankings of all experts are combined through the aggregation of individual judgments or the aggregation of individual priorities (Russo and Camanho 2015).

In the 1990s, the AHP was subject to a wave of criticism, related mostly to: (i) the appropriateness of application of the pairwise comparison matrix's eigenvector for the ranking of decision criteria, and therefore, the resulting choice of the decision alternative; (ii) the bias of Saaty's fundamental comparison scale; (iii) potential inconsistency of experts' opinions; and (iv) the risk of rank reversal. A discussion of the shortcomings of the AHP method can be found in Prusak and Stefanow (2011) and in Gawlik (2019). A consideration of AHP's criticism about most recent developments of the method was provided by Franek and Kresta (2014) and seemed to have settled in favour of the method.

Valipour et al. (2018) state that in an AHP framework, the decision problem is hierarchically decomposed into a linear top-to-bottom structure, assuming a one-way hierarchy relationship among decision levels. Therefore, as the choice of the office space that is adequate for business process outsourcing (BPO) activities (like the one analysed here) is usually based on a set of independent criteria, AHP is the proper method for the enhancement of such a decision-making task.

Following the AHP methodology, the study consists of three levels:

- The main goal level, where the aim of the decision-making is determined.
- The decision criteria level, where a hierarchy of groups of criteria, associated sub-criteria and their descriptors are formed; when composing a hierarchy of criteria, one should ensure that its lower elements do not interact with the upper ones.
- The decision alternatives level, where potential variants of decisions are identified.

In the research, we follow the standard AHP routine (Gawlik 2019):

1. Formulation of a decision-making hierarchy, where the decision problem is identified, goals of the decision-making are formulated, and key stakeholders of the decision-making process are acknowledged.
2. Selection of experts, where the team of evaluators needs to be composed of people that possess expertise regarding the decision problem.
3. Expert evaluations stage 1 (decision criteria), where expert judgments are collected through pairwise comparisons of groups of criteria, sub-criteria and their determinants.
4. Expert evaluations stage 2 (decision alternatives), where the process from Step 3 is repeated, with the inclusion of available decision alternatives. As a result of Steps 1–4, a ranking of the significance of decision criteria and alternatives arises.
5. Consistency checks of expert opinions, where the judgments obtained from experts are tested for their individual and group consistency with relation to other pairwise comparisons. Saaty proposes an empirically drawn random index (RI) that is used for calculating the consistency ratio (CR) of expert evaluations. The most common approach suggested is to treat them as consistent when the inconsistency of expert opinions is lower than 10%. In this research, we accepted consistencies that did not exceed 10% (including those equal to 10%), which is still acceptable from a methodological perspective. Interesting discussions on AHP's inconsistency can be found in (Jarek 2016).
6. Evaluation of decision alternatives, where the decision alternative that fulfils all decision criteria to the possibly greatest extent at the same time appears.
7. Sensitivity analysis, an additional step proposed by French (1986) that aims at defining which criterion and which measure of performance are most susceptible to cause the reversal of the initially obtained hierarchy of decision alternatives.

3.2. Experts Selection and Study Design

We were interested in the preferences and decision criteria of potential office tenants in the Krakow Metropolitan Area. This particular population has the following common features: tenants are mainly corporate organisations from business process outsourcing (BPO) and shared services

centres (SSC) information technology (IT) sectors, most of them being branches of multinational companies.

Results from the AHP depend on the choice of experts, who evaluate decision criteria and decision alternatives. In our study, experts (evaluators) have been carefully chosen through the arbitral choice procedure, which aims at creating a nearly representative research sample. There were three general expert selection criteria: (i) having a high level of expertise in real estate investments for potential BPO clients, (ii) being currently employed in an institution of the real estate market in Krakow, and (iii) an active practitioner in the field of real estate management, brokerage or consultancy. Our experts came from the Institute of Analysis Real Estate Market Monitor (Instytut Analiz Monitor Rynku Nieruchomości), FYI Commercial Consulting, Knight Frank, CBRE Group, Skanska Property Poland Ltd., MRICS Avestus Real Estate Ltd. and Buma Group. From the initial sample of 10 experts, one was rejected due to an unacceptable level of inconsistencies of evaluations and 4 due to incomplete evaluations. The final set of 5 experts falls into Saaty's 5–9 interval and is therefore entirely sufficient.

Selected experts addressed the preferences and choice processes of potential office tenants in Krakow by evaluating the hierarchy of decision criteria. The selection of criteria and sub-criteria was based on the literature review. Table 1 presents the hierarchy of criteria employed for AHP evaluations.

Table 1. Groups of decision criteria and their sub-criteria for choosing the office space in Krakow.

Criterion	Explanation
Localisation	
Distance from the city centre	Location inside or close to the actual city centre (i.e., the centre of urban services and functions) or to a central business district (CBD)
Access to urban amenities	Accessibility in the nearest neighbourhood to such services as restaurants, shops, simple services (e.g., hairdressers), banks, post office, doctors, etc.
Access to public transport	Public transport availability—tram, bus, suburban trains, bus stops, train stations, connection frequency
Neighbourhood image and reputation	The business neighbourhood, prestigious environment, high quality of architecture, representative area
Market proximity (clients, suppliers)	Location close to business centres—advantages of agglomeration, accessibility from outside town (airport, train, highway)
Building	
Building automation and IT services	Presence of building management systems (BMS)—management automation of building's infrastructure) and their quality, the quality of building's IT infrastructure
Security and safety	Building access control, security service, fire protection and other similar services
Workplace quality and internal comfort	Quality of ventilation, heating ventilation and air conditioning (HVAC), humidity, daylight intensity, noise protection, the functionality of internal design, quality of finishing materials and its standard
Sustainability and energy efficiency	Energy efficiency, waste management, water efficiency, eco-friendly and healthy finishing materials
Functionality and space	Size of offered rent space, the possibility of adaptation of rooms and space to various working styles (open space or separate rooms), parking places for bicycles, cloakrooms with showers, canteen, relax space, amount of car parking places or the possibility of parking in the proximity of the building
Lease Agreement	
Occupancy cost	Monthly occupancy cost net per square meter of rented office space, rent indexation method
Maintenance fee	Monthly maintenance costs covered by tenants
Fit-out cost	The sum of all finishing and space adaptation costs covered by tenants
Length of lease	The total length of lease period agreement, contract termination conditions
Flexibility within tenure	Possibility of expansion or limitation of leased space, preparation of office space for the tenant and adaptation cost, availability of additional services (facility management)

Source: own elaboration.

Additionally, using the AHP framework, we analysed the decision alternatives. The decision alternatives were three types of office buildings for BPO/SSC tenants:

- A type A building is an A-class office building located in the centre of Krakow, about 1 km from the main market square. It is close to the railway station, bus and tram stops (including fast tram) at a distance of 200 m away, and near Galeria Krakowska. The building is ecological (LEED or BREEAM certificate). Minimum office module is 100 sqm. Available office space is 1500 sqm. Lease cost is 14.50 EUR/sqm/month and the service charge is 15 PLN/sqm/month. The parking space cost is 100 EUR/space/month.
- A type B building is a B-class building located in the southern part of Krakow, at a distance of about 5 km from the main market square. It is located near the local transport junction/public transport stop/tram or bus within 200 m and near the suburban transport junction. The building is near the Krakow ring road and intercity transport stop (train, suburban buses or intercity bus) up to 500 m away. The minimum office module is 140 sqm. The available office space is 3000 sqm. The lease cost is 13.5 EUR/sqm/month. The service charge is 14 PLN/sqm/month. A parking space costs 70 EUR/space/month.
- A type C building is a B+ facility, constructed in the north-eastern part of Krakow, about 4 km from the main market square, near the accompanying functions (business services, restaurants), additional (shops, park) and easy to access by public transport. Tram and bus stops are at a distance of 200 m away. The building is ecological (LEED or BREEAM certificate). The minimum office module is 140 sqm. The available office space is 2000 sqm. The lease cost is 14 EUR/sqm/month. The service charge is 13 PLN/sqm/month. A parking space costs 80 EUR/space/month.

Using the AHP methodology, we evaluated the decision-making model. In particular, we investigated the role of two sub-criteria for choosing the office space in Krakow: building automation and IT services, and sustainability and energy efficiency. The former sub-criterion is linked with smart buildings, and the latter corresponds to green building design.

3.2. Study Area

The office market in Krakow makes an interesting study area for two interrelated reasons. First, the office market in Krakow has been booming for several years. As a result, an important number of modern office buildings appeared on the market, most of them equipped with sophisticated smart building technologies and are certified within one of the major green building certification schemes (LEED or BREEAM). Simultaneously, the expectations of tenants regarding the standards offered by these types of buildings evolved. One of the reasons for the mentioned market growth was a constantly rising interest of tenants from the business process outsourcing (BPO) and shared service centres (SSC) in the localisation of their offices in the city of Krakow and surrounding business areas. Krakow is the biggest regional office market in Poland, second only to Warsaw. Modern office space in Krakow is estimated to be approximately 1,257,500 sqm.

Second, Krakow is also one of the regional leaders in implementing sustainable practices in the real estate sector, in the cases of both building construction and operation. According to the Polish Green Building Council (2019), as of May 2019, the total number of 499 office projects have been certified in Poland in one of 5 sustainable buildings rating systems (BREEAM, LEED, DGNB, HQE, Well). Amongst them, 493 projects have been certified in BREEAM or LEED (Table 2).

Table 2. Office buildings projects certified in BREEAM and LEED in Poland in 2019.

City	Office Stock (sqm)	Number of Projects Certified in	
		BREEAM	LEED
Poland	N/A	353	140
Warsaw	5,480,000	222	63
Krakow	*1,257,500*	*51*	*18*
Wroclaw	1,054,200	14	25
Tricity	775,000	18	6
Katowice	519,300	10	4
Poznan	478,100	11	9
Lodz	468,900	11	4

Source: (Polish Green Building Council 2019; Savills 2019a, 2019b). Krakow's data is in italics for ease of reference.

The vast majority of certified office projects are located in major cities, mainly Warsaw and Krakow. Currently, 51 office projects in Krakow have been certified in BREEAM and 18 in the LEED system. From a statistical perspective, these numbers make Krakow a regional leader in sustainability, second only to the capital city Warsaw. An increasing number of green offices in Krakow corresponds with the growing role of building automation, and demand for intelligent features of office space (mostly security and HVAC). Unfortunately, the diffusion of smart building innovation within the office market in Poland has not been addressed empirically yet. Thus, it is extremely difficult to cite relevant statistics.

4. Results

4.1. Presentation of the Results

Experts provided their evaluations through online software (Expert Choice Comparion 2019). Each evaluator received an e-mail with a personalised link. Obtained rankings of the significance of criteria, sub-criteria and alternatives were aggregated and normalised. As the structure of the group of experts was homogenous, and no conflict of interests was found (Ossadnik et al. 2016), we used the aggregation of individual judgments (AIJ) through a weighted geometric mean method (WGMM). Figure 1 presents the aggregated results of experts' evaluations with prioritisation of groups of criteria related to the decision alternatives.

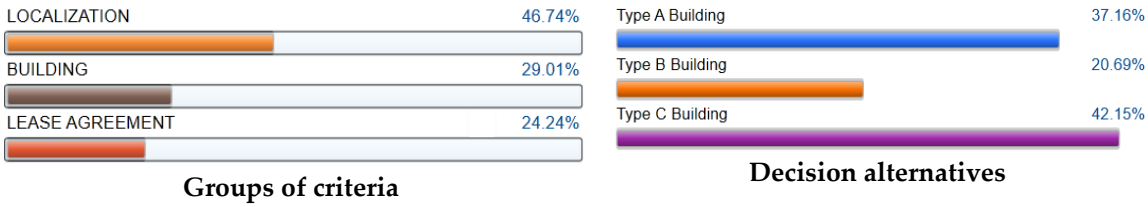


Figure 1. Aggregated results of experts' evaluations with prioritisation of groups of criteria related to the decision alternatives (%).

As shown in Figure 1, the group judgments of all involved experts about the possibly most adequate office space for a potential tenant from the BPO sector pointed at the localisation as the most important group of criteria, with a 46.74% relevance for the choice of the decision alternative. Considerably less important was the group of criteria related to the features of the building (29.01%) and the lease agreement being the least relevant with 24.24%. Such prioritisation of groups of criteria and their belonging sub-criteria resulted in a ranking of decision alternatives pointing at the type C building as the one that meets all decision criteria at the same time to the highest possible extent (42.15%). The type A building came second with a score of 37.16% and the type B building was last (with 20.69%).

There were at least two interesting outcomes of these results: first was that in the eyes of experts, the localisation of the office space plays the most important role when searching for an adequate place for renting. Second, that the lease agreement was judged as the least relevant. This can be due to the existence of a lease agreement standard for such office spaces (in the BPO/SSC sector), which results in relatively similar lease agreement rent offers on the local market in Krakow.

The direct outcome of our research is a ranking of the importance of particular criteria related to the choice of an adequate office space for tenants from the BPO/SSC sector. As a result, employed experts pointed to the type C building as the one that fulfils all tenants' expectations (decision criteria) to the highest possible extent at once. In order to give a deeper insight, Figure 2 presents, once again, the hierarchy of decision alternatives with additional relevance of particular groups of criteria for each alternative.

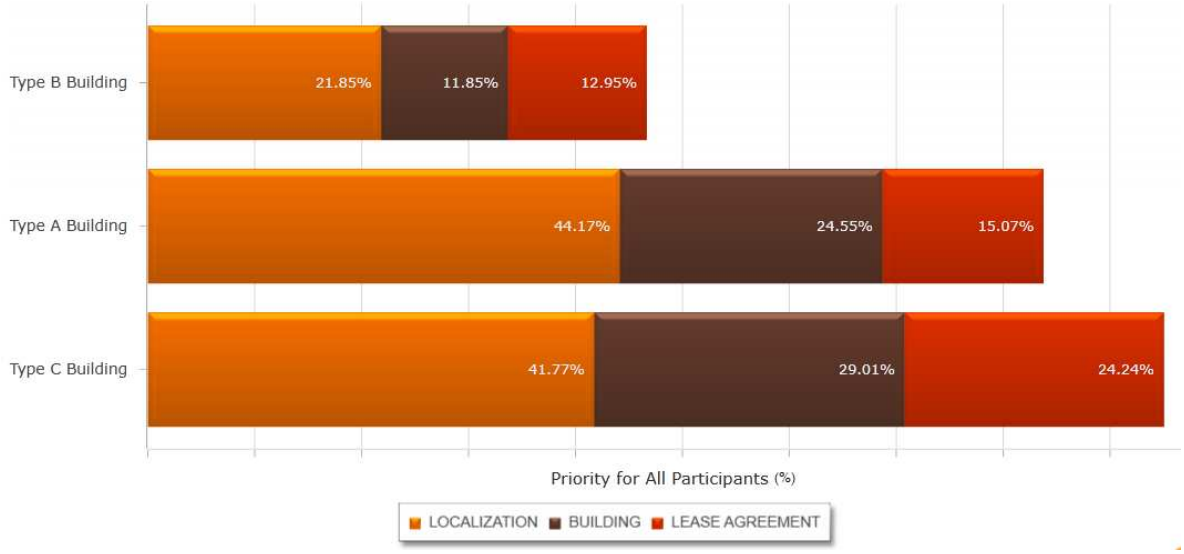
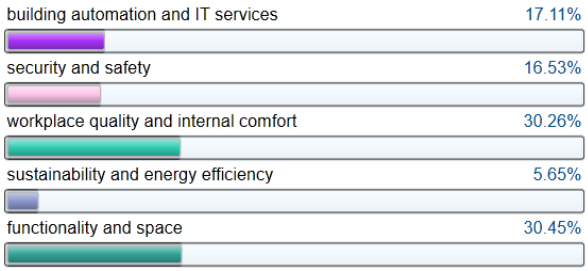


Figure 2. The hierarchy of decision alternatives (criteria sensitive, %).

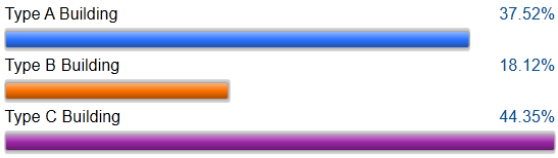
The results in Figure 2 confirm the highest relevance of the localisation, no matter the final type of building chosen. In two out of three types of building, the features of the building itself were judged as second in their relevance for the choice of the appropriate office space. However, the lowest significance of this criterion in the type B building differed from the lease agreement only by 1.1%, which is a relatively low difference.

What becomes interesting from the perspective of the 4.0 industrial revolution is that the features of the building are perceived by the experts (and potential tenants) as relatively relevant (second place with a result of 29.01%). Therefore, a closer look should be undertaken regarding the composition of this group of criteria. The group of criteria "building" was described by the following sub-criteria: building automation and IT services, security and safety, workplace quality and internal comfort, sustainability and energy efficiency, and functionality and space.

Figure 3 presents the original expert evaluations of sub-criteria belonging to the group of criteria "building" regarding their relevance for the choice of one of the decision alternatives (type A, B or C buildings).



Sub-criteria of the group of criteria "building"



Decision alternatives related to the group of criteria "building"

Figure 3. The original evaluations by experts (%) that provide a relevance ranking of sub-criteria of the group of criteria "building" with regard to the choice of adequate office space for BPO tenants.

Figure 4 shows a radar map of the significance of these sub-criteria with regard to the upper node of the AHP hierarchy, i.e., the group of criteria "building". The percentage shows to which extent a particular sub-criterion is significant for the choice of a given type of building (A, B or C).

The two most important sub-criteria from the perspective of the conformity of chosen office space with the requirements of industrial revolution 4.0 are "sustainability and energy efficiency" and "building automation and IT services". Therefore, the sensitivity analysis will be devoted to these two factors.

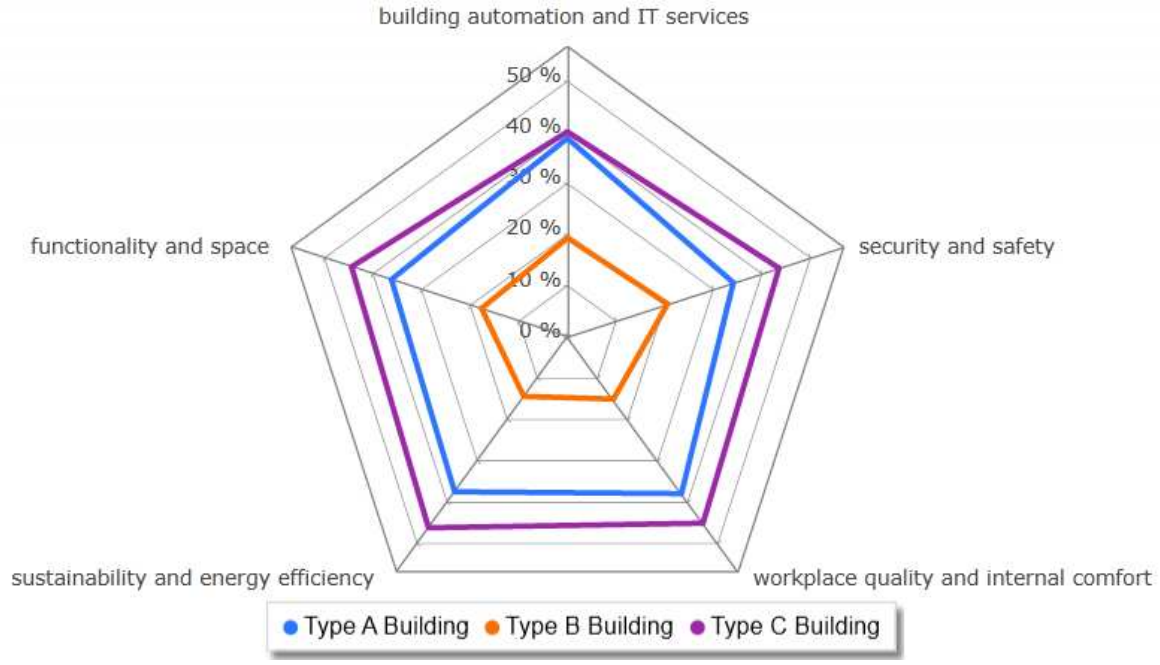


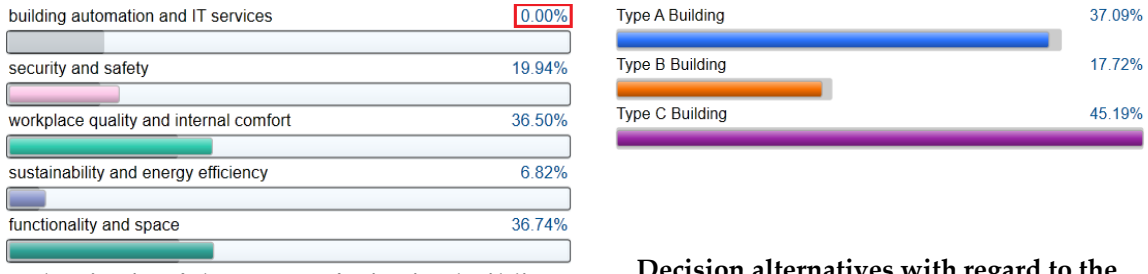
Figure 4. The hierarchy of decision alternatives (criteria sensitive, %).

4.2. Sensitivity Analysis

This research is a part of a larger research project focusing on the industrial revolution 4.0, where sustainability achieved through innovative IT systems plays a crucial role. Therefore, instead of providing a typical AHP sensitivity analysis, we decided to focus on the features of a smart and green building. Hence, the sensitivity discussion will take a graphical form, with special regard to two sub-criteria most relevant from the sustainability perspective, i.e., "sustainability and energy efficiency" and "building automation and IT services".

Figure 5 presents the same ranking of importance as Figure 3. However, the relevance of sub-criterion "building automation and IT services" was manually changed to 0% (not relevant at all, the minimal extremity of the scale). This change, however, did not cause any rank reversal in the

prioritisation of decision alternatives. Also, the change in the strength of the first-choice decision alternative (type C building) was almost unnoticeable.

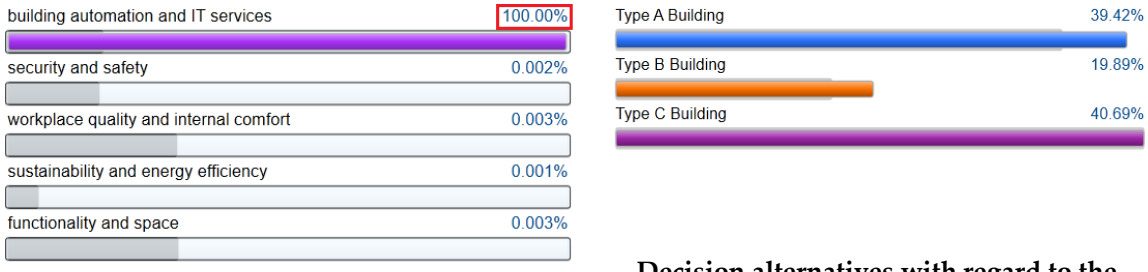


Sub-criteria of the group of criteria "building"

Decision alternatives with regard to the group of criteria "building"

Figure 5. Relevance ranking (%) of sub-criteria of the group of criteria "building" with regard to the choice of adequate office space for BPO tenants with "building automation and IT services" ranked at 0%.

Figure 6 again presents the same ranking of importance as Figure 3. This time the relevance of the "building automation and IT services" sub-criterion was manually changed to 100% (most relevant, the maximal extremity of the scale). This change weakened the superiority of the type C building but did not cause a rank reversal in the prioritisation of decision alternatives. Nevertheless, the type A building became a very close alternative (second best solution). For increasing the precision of such decision-making situations, when two or more decision alternatives are very close to each other, the Modular MUlticriteria MAnagerial DEcision-Making Model (MMUMADEMM) model can be applied (Gawlik 2019).

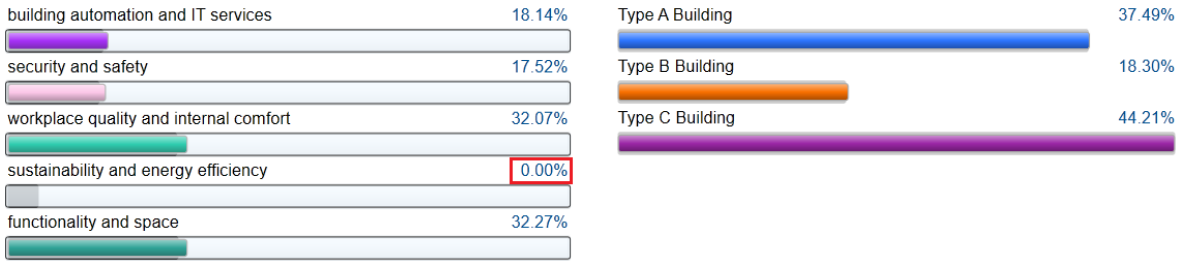


Sub-criteria of the group of criteria "building"

Decision alternatives with regard to the group of criteria "building"

Figure 6. Relevance ranking (%) of sub-criteria of the group of criteria "building" with regard to the choice of adequate office space for BPO tenants with "building automation and IT services" ranked at 100%.

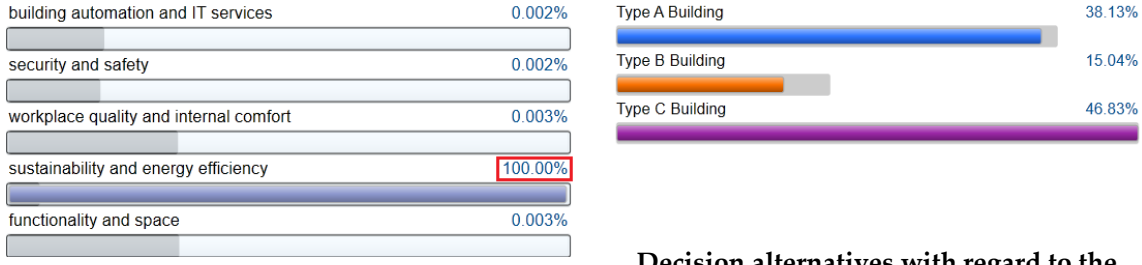
The same analysis for the sub-criterion "sustainability and energy efficiency" follows. Figure 7 presents the same ranking of importance in Figure 3. However, the relevance of the last-mentioned sub-criterion was manually changed to 0% (not relevant at all, minimal extremity of the scale). This change did not cause a rank reversal in the prioritisation of decision alternatives. The change of values of priorities of particular decision alternatives was even smaller.



Sub-criteria of the group of criteria "building" | **Decision alternatives with regard to the group of criteria "building"**

Figure 7. Relevance ranking (%) of sub-criteria of the group of criteria "building" with regard to the choice of adequate office space for BPO tenants with "sustainability and energy efficiency" ranked at 0%.

As stated previously, Figure 8 presents the ranking of importance from Figure 3. Here, the relevance of sub-criterion "sustainability and energy efficiency" was manually changed to 100% (most relevant, the maximal extremity of the scale). This change strengthened the choice of the type C building, but still did not cause a rank reversal in the prioritisation of decision alternatives. The change in prioritisation values was much lower as could be expected for such an important change of the sub-criterion (by 94.35%).



Sub-criteria of the group of criteria "building" | **Decision alternatives with regard to the group of criteria "building"**

Figure 8. Relevance ranking (%) of sub-criteria of the group of criteria "building" with regard to the choice of adequate office space for BPO tenants with "sustainability and energy efficiency" ranked at 100%.

The above shows a very low sensitivity of both analysed sub-criteria. Changes in the prioritisation of neither "building automation and IT services", nor "sustainability and energy efficiency" caused any rank reversal in the prioritisation of decision alternatives. Therefore, the type C building remained the best solution for BPO office space tenants, at least from the perspective of those two sub-criteria. The Discussion section below aims at explaining these research results from the perspective of the industrial revolution 4.0 framework.

5. Discussion and Conclusions

One of the effects of Industry 4.0 in the real estate industry is the diffusion of technological innovations. We addressed the role of smart buildings or green buildings innovations on the Polish real estate market using the AHP method with a group of experts (consultants, managers, brokers) that are active on the property market in Krakow (study area).

In the paper, we investigated the preferences of tenants from BPO/SSC regarding the specific features of an office space. We categorised relevant decision criteria into three major groups: location related, building features and lease agreement clauses. The research findings seem plausible. We found that location was the most important decision criteria. Building characteristics were less important than location, but slightly more than lease agreements.

Further investigation yielded several interesting findings. We explored the role of two features of an office building that could be related to Industry 4.0: "building automation and IT services" (smart building) and "sustainability and energy efficiency" (green building). According to expert assessment, either of these two sub-criteria can play a major role in the decision process. In contrast, they were ranked below other building sub-criteria evaluated. Functionality and space, workplace quality and internal comfort, as well as security and safety, were considered more important when choosing an optimal office. We used sensitivity analysis to check whether the different prioritisation of green band smart building features would initiate any rank reversal in the prioritisation of decision alternatives (buildings A–C). The test yielded negative results, as the results again suggest a very low sensitivity of both analysed sub-criteria. The results seem to be surprising when contrasted with the accelerating diffusion of sustainable building innovation in Poland (a growing number of BREEAM and LEED-certified office projects). On the other hand, prior research in Poland is not conclusive either. Although an early quasi-experimental study of Zieba et al. (2013) suggested a significant premium for LEED or BREEAM certification, following qualitative study based on in-depth interviews by Gluszak and Zieba (2016) did not fully support previous findings.

Empirical data on office rents is available, and further research should focus on addressing rent premiums for smart and green building features using revealed preference data. Therefore, cross-validation of research results obtained within this study carried out with the use of alternative research methods seems to be a natural field of future research. Another potential field of future research are the implications of the disappearance of barriers between humans and machines (which is the core concept of Industry 4.0) on the decision-making processes of office space tenants. Will the rental decisions augmented by artificial intelligence or even become fully automated? Will the tenants' requirements remain the same? Will the criteria determining the class of office buildings stay unchanged? These questions remain to be answered.

There are some limitations to our study. The research was focused on one particular group of tenants representing BPO/SSC. This particular category of users plays a major role in the office market in Krakow and has the strongest impact on office space demand. For this reason, we were not able to test for differences in the relative importance of key decision criteria for various groups of tenants. One could argue that the relative importance of building criteria could be different for representatives of other important categories of tenants such as IT and public administration. Other limitations can be attributed to the AHP method used and are extensively covered in the relevant literature.

The research fills the knowledge gap on sustainability within the real estate market in Poland. Compared to mature economies, emerging markets in Central and Eastern Europe has been relatively understudied. The study has some interesting practical implications. The knowledge on the relative importance of decision criteria can be valuable for developers and investors. The findings suggest that the innovation diffusion process has not been completed on the office market in Krakow, and the relative importance of green and smart building features is still limited compared to other factors considered in the decision-making process.

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