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Perceptions of Built Environment Professionals on Intelligent Office Buildings: The interplay between technology and design for sustainability and responsiveness

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The confluence of technological advances, climate mitigation efforts, and evolving user expectations has significantly transformed how the built environment is conceptualised, designed, and delivered; Intelligent Buildings (IBs) are not an exception. The systematic literature review revealed that there have been limited studies exploring the perspectives of Building Environment (BE) professionals on IBs, along with divergent emerging descriptions of IBs, creating an ambiguity for their practical realization. To address this gap, this study aims to explore the intelligence in office buildings based on professionals' interpretations and its practical implementation through design features. An exploratory study was carried out by conducting semi-structured interviews with 63 domain professionals, and qualitative content analysis was utilised to identify emerging themes during the interviews. Nine themes were identified for describing Intelligent Office Buildings (IOBs). Professionals' perceptions were found to vary according to their nationality and profession. The original contribution of this study is that by reflecting the perspectives of building environment professionals worldwide through interviews and revisiting the existing debates in the literature, the current IOB design approach is delineated. The core IOB concept evolves around the occupant-oriented approach and the integration of climate-responsive design strategies with a balanced level of technology uniquely serving a well-defined purpose by taking advantage of regional conditions. Research findings have theoretical contributions by unravelling the IOB concept and design features, shedding light on the dual roles of technology and design principles. These findings on guiding principles for the design of IOBs can provide a valuable framework for BE practitioners.

Keywords

Intelligent Buildings, Smart Buildings, Intelligent Building Design, Intelligent Office Buildings

1. Introduction

The Intelligent building (IB) concept was driven by the scientific and technological developments in materials, electronics, Artificial Intelligence (AI), computing and communication [1] and its true origin was derived from AI [2]. Buildings are critical for the health, safety, and well-being of humans as well as for the fight against climate change. Advanced technological solutions have been developed to improve the performance of buildings, and terms such as smart, green, intelligent, and high performance have been used to describe buildings, lacking precise and distinct definitions for each term. What intelligence means within the context of the built environment and what makes a building intelligent remains dynamic, evolving over the years in response to changing conditions, such as demand and technology. Thus, IBs have been conceptualised from multifaceted perspectives, reflecting the requirements of different time periods such as the level of technology [3-6], the role of passive design [3, 7, 8]; the influence of automation on building occupants [9-11] and the contribution of IB to the sustainable way of living [3, 6, 12-14].

There are several studies about emerging IB definitions according to different geographical regions [15, 16, 17]. However, these definitions are too vague to use in design applications, limiting their development [18]. There is a lack of a shared understanding and definition of IBs, and no single and standardized definition worldwide [16, 19-21]. So and Wong [18] states that the existing definitions are very subjective. Not only the descriptions but also Alwaer and Clements-Croome [12] put forward that a typical, good, and excellent practice of IBs does not exist. A building's "intelligence" is often confused with building automation, and the definition of a smart building is very vague [22, 23]. Little consensus exists on what makes a building intelligent or how it assists the users of buildings [24]. Moreover, Himanen [25] emphasizes that the IB concept has its own internal tacit knowledge, which is shared verbally, and this limits the creation of a universal definition which will be valid for a certain period since the change is inevitable.

Becerik-Gerber et al. [26] conceptualise buildings as well as infrastructure and materials that compose the built environment as an “intelligent partner”, understanding and supporting human activities and needs while freeing people to engage in healthier, more productive, and creative pursuits. Intelligence within the built environment may differ based on the building type (e.g., home, office or infrastructure), as the expectations may change based on the partnership requirements and expectations. Office buildings are frequently named and promoted as intelligent, and they have been claimed to improve success and enhance occupants’ health and productivity [17, 27]. Hence, the specific focus of this paper is Intelligent Office Buildings (IOBs), particularly how intelligence in office buildings is perceived by professionals and the design approach to meet expectations from an IOB.

Among the research efforts on the IB description [2, 3, 5-8, 16, 17, 28-47], Kim [31] and Zağpus [34] investigated IOBs in Japan and Türkiye, respectively. Although some studies within the literature explored smart home technologies through experts’ interviews [48, 49], the lack of empirical data to explore the professionals’ perceptions of the IOB concept in the built environment is evident. This research intends to fill this gap in the existing literature by exploring the viewpoints of BE professionals regarding the interpretation and design features of the IOBs. In this regard, the notion of intelligence within the context of office buildings shall be conceptualized with the findings and revisiting ongoing debates. Further, the perspectives of each professional shall be examined in the light of their place of experience, nationality, and years of experience across diverse global settings. Through this investigation, the current interpretation of IOBs shall be uncovered and essential requirements for their effective design shall be delineated to provide a clear direction to the designers, design developers and practitioners.

The remainder of the study is organized as follows: first, a review of the recent literature was conducted, and the changes and debates in IB descriptions and design approaches over time were revealed. The following section describes the research approach and data collection through semi-structured interviews with BE professionals. Next, the analysis of the responses through qualitative content analysis and the discussion of findings about the debates in the literature are presented. The next chapter revisits the IOB concept as a result of professionals' insightful perceptions on identifying the IOB design principles and features. The conclusion section explains this study's limitations and recommendations, aiming to guide the designers in rethinking their design approach to the IOBs. In the next phase of this study, the expected design features of IOBs were further used to develop a tool for measuring the level of intelligence in IOBs. However, this paper is limited to the depiction of the initial findings of the research on the conceptualisation of an IOB [50].

2. Emerging definitions of intelligence in buildings

The notion of intelligence for buildings was first introduced and described as 'a new generation of buildings that almost think for themselves…' by New York real estate developers in 1984 [5]. The word 'intelligent' originated and was used interchangeably with the American term "smart" for the implication of the same abilities in materials, structures, and buildings at the beginning of the 1980s and the Hartford building in the USA was heralded as the first IB in the world [2, 16]. In the 1980s, the IB concept was closely associated with to the growth of Information Technology (IT) with sophisticated telecommunications, building management, and data networking services for shared tenant services [4]. This concept's early stage involved introducing technologies as a fundamental step towards intelligent building evolution.

Scopus was used to systematically identify the representative research studies that can answer "How IBs are defined?" In this regard, firstly, the keyword "intelligent building*" was searched using the filter of the years starting from 1990. The inclusion criteria for the selection of publications were articles, dissertations, books, and book chapters, and the exclusion criteria were the articles in the form of conference papers, posters, unpublished works and articles. The search was also limited to "English language" and "Engineering". Firstly, the titles and keywords of the identified 5632 articles were evaluated and the term "smart home" was deliberately excluded from this study, reducing the number of publications to 213. Finally, the publications which define or describe buildings as intelligent and smart were selected, and full texts were examined. Further, the snowballing method was applied, and the citations and references of the selected publications which defined or described the IBs or smart buildings were also included in the search domain. At the end of the research process, 22 journal articles, two books, three book chapters and one thesis were selected, and twenty-seven definitions of IBs spanning between 1989 and 2023 have been retrieved and depicted in the Appendix. The conceptualization of the IBs in different time periods is summarised in the following subsections.

2.1. First period (1989-1999): technology for efficiency

During this period, after the introduction of Building Automation System (BAS), the IB approach started to be highly related to the utilization of the BAS as a single control framework [29, 51] and the level of system integration [17] so that they can respond to their environment in a timely and cost-efficient manner. Thus, building intelligence was associated with facilities management via BAS [52], the extensive use of IT for building applications [28] and having advanced features for enhancing occupant productivity and energy efficiency [31] and the usage of digital technology [33]. In this period, the buildings that have IB technologies and building systems were framed as "electronically enhanced" [53].

Towards the end of this period, the progression of the IBs moved from being thought of as a collection of innovative technologies via responsiveness to being a facilitator for business activities [27]. The definitions highlighted the importance of maximum occupant efficiency, worker productivity, and overall satisfaction with adaptable assembly of technologies [3, 17, 30, 32]. Shaviv [7] highlighted the optimization of three factors for thermal comfort, including the building structure, HVAC and lighting systems and controlling method. Country-specific conceptualisations were also presented. In the Asian context, the definition by So et al. [16] provided two dimensions, i.e., the needs of the building developer, owners, occupants (deliverable items) and the enabling technologies (systems and services). On the other hand, Harrison [24] described the IBs in a European context by three main goals of an organization: building management (environmental control of the building, user access to environmental systems), space management (management of change, the minimization of operating costs), and business management (the processing, storage, presentation, and communication of information). Therefore, as of the 1990s, the central theme was enhancing occupant satisfaction, and considering the business impact of buildings with the technology.

2.2. Second period (2000-2009): technology for sustainability

One of the earliest definitions of this period belongs to Chwieduk [54] who framed IBs as "energy-efficient buildings" with intelligent Building Management System (BMS) that control building systems to manage the energy consumption and enhance the comfort level within the buildings. Responsiveness, the ability to adapt instinctively to meet the occupant requirements in an energy efficient way [2] became the dominant theme describing IBs. Advanced technology and automation were highlighted for the IB concept as advanced hardware, such as building and personnel management systems and accommodating future technologies [6]; automatically managing ordinary works [34], and advanced technological facilities together with reduced maintenance [36]. Further, IB is conceptualized similarly to other intelligent agents such as humans, animals and robots [35].

During this period, to resolve global problems, Clements-Croome [38] provided a wider framework that the IBs should be sustainable. Minimizing the need to import energy was defined as one of the major functions of IBs [2]. In this regard, Ochoa and Capeluto [8] offered a different definition that IB should be a product of the design process with passive features while taking advantage of technological innovations. This theme appears to significantly impact the concept since the focus shifted from the dominating role of technology to the passive design strategies. Therefore, passive design, sustainability and advanced technology emerged as the main themes for this period.

2.3. Third Period (2010 to 2022): technology for learning and adaptation

In this period, the IBs were defined as integration of advanced building technology systems [5, 55], cyber-physical ecosystems that live and breathe with their surroundings [56] and complex cyber-physical systems with humans in the loop [43]. Moreover, the intelligence concept for sustainability was advocated [12], and the IBs were referred as “sustainable intelligent buildings” by Clements-Croome [38].

Emerged during this period, another terminology, smart buildings, explored by Buckman et al. [41], found out a clear difference between smartness and intelligence of buildings that smart buildings are adaptive and ready for a particular event and prepared ahead of time by leveraging accumulated information whereas the IBs are generally reactive. Further, three aspects of smart buildings are components (multiple interconnected pieces of technical building equipment and appliances), functions (intelligent and effective performance) and outcomes (health, comfort, productivity, and energy efficiency) [43]. Chang et al. [45] presented two separate definitions for smart buildings as energy efficient, comfortable, and reduced emissions and for intelligent buildings as physical and cyber structures satisfying users’ needs and optimizing resources’ efficiency by maximizing the technical functionality of BMS. Therefore, being fully integrated with ambient intelligence environments, the integration of technology that facilitates occupant monitoring [39] and the use of digital technologies to enhance performance and wellbeing [42] were reflected in the definitions in this period. The review by Mofidi and Akbari [44] highlighted the establishment of continuous communication with occupants, together with self-learning ability for the energy-related occupant behavior as well. Thus, hybrid intelligence enabling both reactions to the event in real-time and improvement by learning users’ needs simultaneously [57] and the adaptability to changing lifecycle circumstances according to the occupants’ requirements [38] became dominant theme in debates on the IBs.

Considering today’s technical and architectural evolution phase, adaptive building could be the definition of an IB [46]. In a more recent research, Fu et al. [58] highlighted a gradual increase in the application of deep reinforcement learning methods to IBs since the 2010s and refined the IB concept by embedding the criteria of AI [47] and the application of AI technologies [37]. Therefore, starting from 2020s, the focus is on the learning ability of the IBs achieved by machine learning techniques with AI applications.

In summary, with the advancement of technology in the last decade, particularly in information and communication technology [27], today’s IBs are being affected by the “tech push and market pull” scenario, high costs of intelligent systems, and the lack of widespread expertise for monitoring their operations [15]. Looking through the evolution of the IBs, their conceptualization has evolved with the integration of new technologies and heightened environmental awareness. Among the foremost considerations for IOBs is the degree of technology sophistication, which significantly influences building energy performance and occupant contentment. Additionally, a pivotal dimension pertains to design intelligence, defined as responding to the dynamic and unpredictable nature of its occupants and being in harmony with nature [1]. Within that perspective, intelligent façade [2] and passive design solutions [7, 8] emerge as an integral part of the IBs. Further, some researchers described the IBs as sustainable buildings [12, 14, 15]. The multifaced perspectives of the IB descriptions and interpretations in the existing literature led to the loss of focus and limited guidance for its design and construction. These discrepancies have sparked debates around the IB design approach and considerations on the level of technology integration, the role of passive design strategies, the level of individual occupant control and building's contributions to sustainability.

3. Research Objectives and Methodology

Some studies [48, 49] in literature critically evaluated smart home technologies from the experts' point of view. On the other hand, within the domain of the IBs, different research methodologies have been employed to examine the notion of intelligence in buildings, including inspecting case buildings [2, 3, 6, 30-32, 34], measuring intelligence in buildings [17], running building simulations for active and passive measures [7, 8], evaluating requirements of the occupants and their behaviour [16, 35, 39, 40], investigating intelligent building technology systems [5, 28, 33, 42, 43, 47], and conducting literature review [29, 36-38, 41, 44-46]. Thus, a gap exists in these diverse methodological approaches that specifically addresses the description and design features of the IBs, as perceived by professionals working in this field. Further, the systematic review of literature findings revealed that these studies, spanning over the last thirty years, present descriptions of IBs from varying perspectives. This diversity has created debates around the IB concept in terms of the level of technology sophistication, the role of passive design strategies, the level of individual occupant control and building's contributions to sustainability and constrained its design process and practical implementation.

In the light of these implications, this paper aims to delineate a holistic design approach for IOBs from the perspectives of BE professionals with different backgrounds and representing diverse geographical regions. The objectives are as follows:

- To explore the current conceptualisation and interpretation of the constantly evolving IOB concept by covering its key themes and identify expected design features based on varying perspectives of BE professionals.
- To revisit the debates in the existing literature to identify IOB design principles

Figure 1 presents the research methodology followed to achieve the stated objectives. Interpretivism, one of the epistemological approaches, was utilized in this study [59]. The research study started with a systematic review of the IB concept within the context of earlier descriptions. Then, interviews were conducted to achieve the research objectives and qualitative content analysis was used to analyse the interview data [60, 61]. Content analysis is described as a systematic and rule-guided techniques [62], within the context of verbal, visual and written documents [63]. There are two approaches, namely a quantitative and qualitative approach, which are applied either inductively or deductively based on the research questions and research design [64]. Firstly, the collected data are decontextualized by extracting the main ideas, namely the meaning units, which are considered as words, sentence or paragraphs [65]. Then, these units are categorized in terms of themes using open coding, meaning that notes and headings are written in the text while reading it [64]. Qualitative content analysis is applied inductively, where themes are derived from the data by careful reading [59, 66]. The coding reliability is assured by iterative cross-checking. Three main steps followed according to Elo and Kyngäs [64] are (i) preparing (being immersed in the data and obtaining sense of whole) (ii) organizing (open coding, grouping and categorization), and (iii) reporting (reporting the analysing process and results through categories).

Once the codes were pinpointed, the themes and sub-themes were identified to deepen the analysis. The difference between theme and category are still discussed among the researchers. Graneheim and Lundman [65] states the main difference such that category gives the descriptive level of context and theme gives expression of the latent context (underlying meaning) through codes. This study uses the notion of theme for the first interview question (Description of the IOB concept) since the underlying meaning of codes is also considered in the analysis. Conversely, the notion of category is used for the second question (IOB design features) since the keywords are used directly from the transcripts without including latent context. Finally, the quantification of the analysed data was performed by counting the frequency of specific words or content [48, 49, 61, 67, 68]. The analysis is conducted manually, without using any software by one researcher and then validated by two professionals. The following section explains the data collection process via interviews in detail.

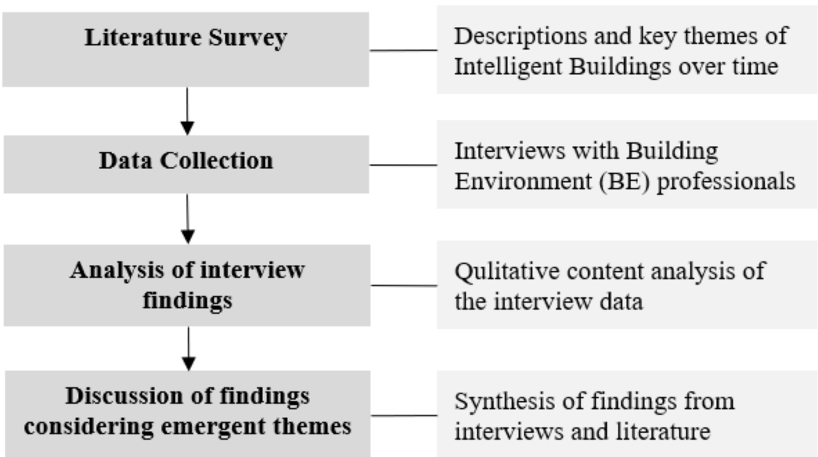

Figure 1. Research steps.

3.1. Data Collection via Semi-structure Interviews

Purposive sampling, a feature of qualitative research [69] was preferred in this study, with the highest priority of inviting professionals from different backgrounds and experiences. An interview invitation mail was sent to the eighty-nine BE professionals who are design-led professionals, researchers, and experts working on exemplary IBs worldwide. In response, sixty-three experts agreed to participate in the interviews. The sample size for interviews depends on the parameter called as the concept of saturation [70] and it should be consistent with the research question(s), the theoretical position and the analytic framework [71]. The point for the achievement of saturation is under debate in literature. Mason [70] states that at least 30 to 60 participants are needed when using semi-structured interviews to obtain a richness for qualitative analysis. The studies that use empirical data reached saturation within a range of (9 – 17) for interviews [72]. For qualitative research, data saturation occurs with a sample size of 12 among a relatively homogeneous population [73]. Overall, Marshall et al. [74] states that "a rough midpoint of suggested ranges for qualitative methodologist is about 30 interviews." In this study, the saturation point is accepted to be reached when new data did not shed light on the investigated issue, as suggested by [70]. Hence, the sample size of 63 interviews is considered representative for this study.

Depending on the circumstances, twenty-seven were conducted via online meetings, seven interviews took place through face-to-face interactions, and twenty-nine interviews were carried out via email correspondences. In this study, interviews were conducted with professionals from different parts of the world. Thus, alternative ways to face to face mode such as, online and e-mail correspondence are used due to geographical barriers, travel difficulties and financial constraints. This mixed-mode strategy of data collection strategy increases response rates [75]. While face-to-face interviews require long waiting time, e-mail correspondences enable the interviewees to answer the questions at their own convenience without noise disturbance due to independence of place and time [76]. Peasgood et al. [77] stated that using different modes such as face to face and online did not appear to have statistically significant impact on the result) similarly, while there were some variations in the depth and style of responses (e.g., full sentences vs keywords), the overall themes and conclusions through different interview formats remained consistent in this study.

The interviews were conducted between the years of 2020 – 2021 and recorded. Online and face-to-face interviews ranged in duration between 20 – 30 minutes. The interview content was structured into two components: (i) the demographic information of the professionals and (ii) two open-ended questions on the IOBs, which are:

Question 1: How do you define an intelligent office building?

Question 2: According to your practical experience, what features are usually considered in the construction industry to design and build an IOB?

These questions explore how building professionals interpret building intelligence and consider related design features based on their expertise and practical experience. Findings from this exploration facilitate revisiting the existing debates in the literature, leading to the conceptualisation of IOBs and the identification of design principles.

Table 1 presents the participants' demographics where the professionals working as smart city advisors, real estate advisors, climate engineers, and marketing managers were classified as “other.” Further, if a participant engaged in the projects across diverse continents, such as Asia and Europe, was considered as having worldwide experience.

Table 1
The demographic information of the participants.

Profession		**Percentage**
	Civil Engineer (N=11)	17%
	Mechanical Engineer (N=11)	17%
	Architect (N=21)	33%
	Other (N=20)	32%
Expertise		
	Designer (N=17)	27%
	Design Consultant (N=22)	35%
	Researcher (N=17)	27%
	Other (N=7)	11%
Experience		
	0-3 years (N=7)	11%
	3-5 years (N=12)	19%
	5-10 years (N=8)	13%
	More than 10 years (N=36)	57%
Nationality		
	Asian (N=24)	38%
	African (N=6)	10%
	European (N=22)	35%
	American (N=11)	17%
Place of experience		
	Asia (N=13)	21%
	Europe (N=7)	11%
	America (N=3)	5%
	Africa (N=4)	6%
	Worldwide (N=36)	57%

3.2. Analysis of the data collected from semi-structure interviews

The interpretation of interview data was explored through qualitative content analysis, and the key themes of the IBs were identified by considering the exact words of transcripts. Krippendorff [78] stated that the categories should be as mutually exclusive as possible, a viewpoint that remains contested [61]. Lindgren [79] argues that codes may be intertwined. In this study, it is acknowledged that the codes may not be mutually exclusive. In accordance with the guidelines provided by several studies (e.g., [64, 66-68, 78], the steps are followed manually to indicate the consistency and trustworthiness of the approach:

> Step 1. Decontextualization - Carefully reading the interview transcripts to familiarize with the data and obtain a sense of whole considering the open-ended questions.
> Step 2. Coding - Taking notes of the meaning units derived from the data by also including the latent context, such as “reducing carbon emission”, “using Internet of Thins (IOT)” or “maximum passive functionality”.

Step 3. Creating themes - Grouping similar ideas into themes and giving a first label such as “responsiveness” or “energy efficiency” until all aspects of the text have been covered. Then, gradually revising, developing and finalising the categories and sub-categories by scrutinizing the text carefully.
Step 5. The compilation – Rereading the transcripts and controlling whether the ideas fit into the finalized categories to prevent discrepancies.
Step 6. Reporting – Describing and calculating the frequency counts of themes and subthemes.

4. Analysis of Findings

Several inferences are obtained from the two open-ended questions, including key themes of IOBs and related design features.

4.1. Key themes of the IOB definition through experts’ perceptions

Following the steps above, the open coding process produced 9 themes and 21 sub themes. Some responses produced more than one subtheme. Table 2 tabulates the themes by including the illustrative quotes expressed by the professionals in their original responses. The occupant centered design methodology and energy efficiency themes may relate to the sustainability theme; however, as mentioned above themes are not mutually exclusive. The energy efficiency theme is divided into subthemes of minimum energy use (referring to requiring less energy) and energy saving (referring to reducing energy use by applying some strategies). The automation theme is expressed by two sub-themes: operation itself (relating to adapting the changing conditions based on the collected data) and automated systems (referring to automatic control of the operations based on pre-set target parameters). The responsiveness and automation themes may seem not mutually exclusive. The basic differentiation is that responsiveness is considered to be an adaptation to changing conditions, whereas automation is more concerned with the pre-set values of the system's operation. Finally, the less technology theme is divided into two subthemes: minimum technical installation (expressing the use of minimum amount of technology) and low-tech solutions (referring to the technologies that are not advanced or latest technology).

Table 2
The identification of IOB themes.

Themes	Key Quotes	Code Counts
1. Theme: Intelligent monitoring and control		**28**
Learning ability and prediction of occupant preferences	"Predicting user needs to create a comfortable environment", "Learning preferences and comfort levels of occupants optimize the energy", "Comfort levels according to predicted occupant needs", "A building where spaces for individuals notes their preference and adjusts lighting, temperature control and window sun control", "Buildings learn to adapt", "Self-learning algorithms"	6
Real-time monitoring (Environmental conditions and occupant behavior)	"Use of online applications to extract real-time operating data from BMS", "Monitoring of data on real time basis to achieve well defined desired outcomes, "The data from interior conditions: number of people, room climate, the required lighting conditions at the moment, and exterior conditions: climate, solar radiation".	12
Remote control of smart features	"User control with cell phones or mobile apps to control HVAC and security systems", "Having objects connected to each other on a network, so that one may control things remotely".	10
2. Theme: Occupant centered design methodology		**24**
Occupant comfort	"Comfort", "Right comfort conditions", "Comfortable and productive environment for its users", "Providing optimum comfort to all users".	18
Occupational wellness (health and safety)	"Occupant health", "Occupant safety", "Well-being of occupants", "Safer environments".	6
3. Theme: Responsiveness		**20**
Responding the changes	"A Building and its systems' ability to respond to changes based on external environment", "Continuously responding to the life happening inside it", "Responding to its context in physical, operational, social and environmental terms", "Incorporates a control system that responds to more than just indoor and outdoor temperature."	11
Adapting in real time	"Feedback loops adjusting building energy performance to a variety of factors, including environmental conditions and occupant behaviour," "Adaptability according to the real-time occupancy schedule", "A reactive capacity to adjusted building elements to meet changing conditions."	9

Table 2. The identification of the IOB themes (continued).

4. Theme: Sustainability		**20**
Smart use of resources	"A minimum of resources (energy, working hours for operation)", "Using resources carefully", "Using minimum natural resources", "Recycle and reduction of water".	8
Environmental considerations	"Carbon emission targets" / "Greenhouse gas emission reduction targets" / "Carbon neutral targets", "Reducing the waste".	5
Sustainable in general	"Sustainable building", "To be sustainable", "Sustainable design", "Sustainable lifecycle".	7
5. Theme: Energy efficiency		**18**
Minimum energy demands	"Low energy services", "Minimized energy demand", "Minimum energy performance", "Little energy requirement".	6
Energy saving	"Recovery of energy and generating energy from renewable resources", "Efficient use of energy" "Avoiding wasteful use of energy", "Energy saving, minimizing excessive use of energy".	12
6. Theme: Automation		**14**
Operation itself	"Operates based on the data collected from the IoT devices/sensors/users; automated with the parameters like temperature, humidity and daylight"; "Adjust their operations according to the data they are retrieving from building itself, including occupants and environment", "Adapt to the environment per time".	8
Automated systems	"Automatic electrical and water switches", "Uses automation to its management and performance", "Automatic control of the operations", "Automation of different mechanical, communication, and electrical systems", "Most of its accessories automated".	6
7. Theme: Climate based design		**13**
Climate adaptive	"Climate responsive building structure and envelope to enhance occupant comfort with less environmental impact", "Climate responsive façade".	6
Passive environmental features	"Maximize the use of passive functionality", "Inclusion of passive environmental features".	7
8. Theme: Advanced technology		**12**
Advanced Systems	"Advanced digital infrastructure and control systems, "Advanced fire / security / vertical systems", "Advanced HVAC and lighting control systems".	5
Smart Technology	"Smart electrical provisions", "Smart devices", "Smart appliances".	7
9. Theme: Low technology		**10**
Minimum technical installation	"Use technical solutions supportive", "The simpler the better", "Minimum technical installations and controls", "Suited and minimized systems to serve that with elaborated controls", "installation of only the real necessary equipment".	6
Low tech solutions	"Without big technology works as a thermodynamic organism", "Low-tech solutions can also make buildings very adaptable too".	4

Interviews yielded valuable insights into potential view differences among BE professionals considering the salient themes as depicted in Table 3 in terms of frequency. Table 3 demonstrates that the interpretation of IB concept may differ according to nationality, geographic context (country) and years of experience, as also highlighted in previous studies [15, 17]. The most significant disparity emerged concerning technology perspective. Specifically, Asian professionals emphasized the importance of "occupant centered design methodology", "automation" and "advanced technology" mentioning them ten, six and five times, respectively; only one mentioned "low technology". This finding aligns the Asian context's definition of the IBs proposed by So et al. [16], which presented two dimensions, i.e., the needs of the building developer/owners/occupants (deliverable items) and the enabling technologies (systems and services). On the other hand, European professionals highlighted "low technology" nine times and mentioned "automation" only three times.

Table 3
The frequency of IOB themes mentioned by the professionals is based on demographic information.
(1: Intelligent monitoring and control, 2: Occupant-centered design, 3: Responsiveness, 4: Sustainability, 5: Energy efficiency, 6: Automation, 7: Climate based design, 8: Advanced technology, 9: Low technology)

Demographic Info.	**# of participants**	**Themes (# of mentioned)**								
Nationality		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
European	22	14	8	5	6	6	3	5	5	9
Asian	24	8	10	9	11	8	6	7	5	1
American	11	5	1	5	3	2	2	1	1	0
African	6	1	3	1	0	2	3	0	1	0
Place of Experience		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Europe	7	3	1	2	0	2	3	1	2	0
Asian	13	4	7	5	7	4	4	3	4	1
Africa	4	1	1	1	0	1	3	0	1	0
America	3	1	0	1	1	0	1	0	0	0
Worldwide	36	19	13	11	12	11	3	9	5	9
Years of experience		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0-3 years	7	3	2	1	3	0	3	1	3	1
3-5 years	12	6	3	6	2	6	5	1	2	0
5-10 years	8	3	3	4	4	1	3	1	2	0
More than 10 years	36	16	14	9	11	11	3	10	5	9
Expertise		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Designer	17	5	4	5	8	2	2	3	4	2
Consultant	22	10	8	3	6	7	3	7	4	6
Researcher	17	8	6	9	2	7	4	3	2	2
Other	7	5	4	3	4	2	5	0	2	0
Profession		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Civil Engineer	11	8	4	4	5	5	4	0	5	0
Mechanical Engineer	11	2	2	3	2	2	1	5	1	4
Architect	21	6	10	8	9	6	4	6	3	4
Other	20	12	6	5	4	5	5	2	3	2

Notably, civil engineers did not mention “low technology” and “climate-based design,” whereas mechanical engineers and architects strongly supported these themes for the IOB concept. While intelligent monitoring and control emerged as the prominent theme among civil engineers, architects focused on responsiveness to changes and occupant needs. Additionally, an intriguing finding was that the professionals with worldwide experience and more than ten years of experience are the most frequent proponents of “low technology” and “climate-based design” compared to other groups. It is essential to recognize that these findings reflect the opinions of a limited number of professionals, and varying responses belonging to each demographic group are evident. In this study, qualitative research is conducted to provide new insights based on the subjective reality of individuals rather than drawing a universal truth and thus no statistical measures is not required to assess the results [80]. Similarly, qualitative data are not usually amenable to counting or measuring [81]. Thus, in this study no analysis was conducted to identify whether the differences in the perspectives of participants are statistically significant; hence, no generalization is intended. Nevertheless, notable disparities in the responses and the qualitative insights obtained shed light on the trends, distinctions, and boarder comprehension of the IOB concept within the community of BE professionals.

4.2. Design features of IOBs through BE professionals’ perceptions

54 professionals participated in responding to the second question. The responses of nine professionals to the first questions are included into the identification of IOB themes, notwithstanding their non-response to the second question. This approach is predicated upon meticulous control of their contribution to the frequency of the themes. It has been determined that their input exerts negligible impact on both the frequency distribution and overarching trends for the themes describing the IOB concept.

The gathered data was analysed inductively through qualitative content analysis. The categories are used to express the interview data since the intelligent features articulated by the professionals are directly listed without the latent context of data. Hence while some design features might be overlapping, the formulation of the categories resulted in six categories coalesced into two overarching themes: design and technology (Table 4).

The design theme covers the design-related comments, especially the climate responsive design, adaptability and flexibility. Indeed, the building envelope design, passive design solutions including natural ventilation and daylighting and adaptable and flexible features and layout strategies are highlighted. Some exemplary quotes of the interviewees for an IOB design approach are:

> Simulate the building at early design stages to reflect very realistic scenarios and implement passive design strategies, for instance, thermal activation of concrete structures (A Climate Engineer from Germany).

> Reduce energy requirement first (done already by building codes), then, design mechanical equipment to meet the remaining requirement (load). Internal gains, especially from IT, can be used. Heat pump(s)/chillers can be utilized to heat and cool down the building, if possible, in

combination with geothermal/ foundation piles /wastewater heat exchanger/ice storage (A Mechanical Engineer from Germany).

This pertains environmental considerations, especially carbon emissions. Energy demand can be diminished with a good insulation, external shading, and proper building configuration. This is a way to reduce carbon emissions (An Architect from the USA).

The building has a well-designed facade potentially with an automated and motorized external shading and a separate internal glare protection device to control solar gain, probably a heat pump to be all electric, energy saving appliances and installation of photovoltaic panels to generate energy (An Architect from the USA).

The IOB must include passive environmental features to begin with and then low energy consumption services, water collection mechanism, some sensors to monitor energy use can be utilized. Adjustability of all services to minimise excess energy use, try to establish a natural environment as close as possible (An Architect from Australia).

Table 4
Themes and categories identified for the IOB design features.

Categories	Code Counts	Themes group
Category: Climate based design		Design
Passive design	8	
Natural ventilation	2	
Natural daylight	2	
Excellent envelope	5	
Category: Adaptability and flexibility		
Flexible and adaptable construction features	6	
Flexible and adaptable internal layout	2	
Category: Controllability		Technology
Automation	7	
Automated shading	5	
Automated doors	2	
Advanced HVAC control	9	
Lighting control	10	
Remote control	6	
Category: Building systems		
Building Management System (BMS)	14	
Advanced security and safety system	4	
Advanced lift system	4	
Digital communication network	14	
Renewable energy production	8	
Category: Sensors		
Lighting sensors based on daylight and occupancy	4	
Indoor sensors for ambient monitoring and measuring environmental parameters	11	

The technology theme primarily encompasses controllability, building systems, and sensors. The automated controls, BMS, advanced digital communication networks, advanced systems (particularly those related to security, lift systems), sensors, are frequently mentioned in the responses. Statements from two professionals underscore the pivotal role of technology in this context:

> An IB uses IoT technology to coordinate the operation of different building components in response to user wishes and ambient climatic conditions (An Architect from the USA).

> With active systems we employ smart occupancy sensors and power saving techniques in collaboration with renewables (A Mechanical Engineer from India).

5. Discussion of findings

This section revisits and critically discusses themes describing the IOB concept and design features drawn from BE professionals' perspectives to resolve the existing debates.

5.1 Balance of automation and individual control

When it is allowed to be controlled in a 'smart' manner, the building is considered intelligent [7]. The word "intelligent" brings an expectation of higher controllability, which created a debate around the extent of technology intrusion: whether the building intelligence should be aligned with automated control or prioritize user preferences since the automatic control could interrupt the individual occupant. "Automation" was the first definitive word to describe building intelligence in the existing studies and emerged as a theme mentioned fourteen times in the IOB descriptions by the professionals. Finley et al. [30] pointed out that a building cannot be considered intelligent unless automation helps create an environment that fosters creativity, productivity, dynamic intellectual stimulation, and information exchange, as well as mental and physical good health. Further, the intelligent control of HVAC and lighting systems is frequently mentioned as an IOB feature during the interviews. In contrast to fully automated building functions, which make all decisions themselves without providing any control opportunity to the user, professionals highly emphasised the theme of "occupant-centered design methodology" as a foundational concept of the IOB design. During interviews, two opposing arguments are elucidated:

> The prevalent perception of heavily automated is detrimental to the creation of truly intelligent buildings of the future (An Architect from India).

> Occupant control should be avoided where it is possible. Occupants do not know what is best, and this leads to distress, confusion, and disharmony (An Architect from Australia).

"The end of all design is human satisfaction" [82], and user satisfaction is a crucial and integral requirement for IOBs [83]. Many researchers mentioned the impact of individual controllability on occupant satisfaction [1, 84, 85]. It is also evident in the study conducted by Guillemin and Morel [9] that the users became frustrated with the automatically controlled blinds when their long-term (lasting more than one hour) preferences were not taken into account. Similarly, Meistad [10] put forward that automated systems which restrained individual adjustment options, lead to increased complaints in energy-efficient office buildings. A recent study by Tamas et al. [11] indicated that occupants were dissatisfied with automation and preferred more manual controls. This occupant-centric perspective was reflected during the interviews, including:

> The intention of the IOB design should focus on providing individual occupant control over their environment, rather than a complete takeover by a BAS. Automation is essential, but only in specific situations for a specific purpose (An Architect from India).

> The occupant becomes the agent of change (An Architect from Europe).

Maintaining a delicate equilibrium between individual user controllability and automation may be a pivotal challenge for the IBs due to crucial role of occupant behaviour on the energy-efficient building performance as evidenced in the studies of Nguyen and Aiello [39], Shaikh et al. [86] and Timm and Deal [87]. In the responses, this perspective is reflected as:

> Each building serves a distinct purpose and has a unique behavioral need, and the intelligence embedded must cater to this in a certain bespoke manner (A Mechanical Engineer from Malaysia).

The IBs should always allow for flexibility in the way occupants want to "live their life" in the building [15] and provide more rational and personalised solutions [13]. The findings may support the IOB design approach that the focus of intelligent control should be on the appropriate level of automation and individual control of the occupants by including them in the design process.

Further, another problem might arise because occupant behaviour and preferences are not properly considered during the design [41, 88-90]. The suggested solutions include involving occupant representatives at the beginning of the design process [1], considering user as an integral part of the system's dynamic behaviour [91] and providing necessary information to the occupants so that they can easily adapt [41]. Another solution is modelling occupant behaviour and better management of building systems with the advances in big data technologies, sensing technologies and AI applications. Recently, as an occupant-centric and autonomous approach, researchers elucidated not to standardize or generalize the occupant behaviour, instead they suggested using data-driven or demand-driven approaches with occupant feedback in the BAS [92, 93]. Moreover, recent studies focused on adaptive control systems through AI algorithms by processing the data collected through user interaction [14]. The new challenges for the future include AI-based controllers, climate-adaptive and occupant-centric control for thermal comfort and energy savings [94]. Thus, promising research has been concentrating on balancing occupant comfort with building energy consumption.

In the responses, the theme of real time monitoring was mentioned twelve times. Intelligent systems operating based on real data have the potential to better satisfy the occupants and achieve higher energy efficiency compared to manually controlled systems [57]. Real time learning algorithms significantly improve the performance of the building [35]. The important role of communication with occupants in real time is underpinned as follows:

> Building systems gathers real time information and analyses the data. This continuous monitoring enables automated adjustments and control throughout the building (A Researcher from Belgium).

The "learning ability" of occupant behaviour (e.g., [22, 40, 44]) comes forward as another prominent feature so that the personalized comfort conditions could be created for occupants with minimum building energy consumption feature. A quantitative information in literature has been supported this finding. The benefits of learning occupant behaviours are evidenced by the researchers that saving energy between 7% and 52% compared to the conventionally scheduled cooling systems [95]; savings up to 72% in lighting systems by learning user preferences [96]; saving energy up to 9% of the energy in HVAC systems in office buildings by learning occupants' personalized comfort profiles [97]. This learning ability brings an extensive IOB description by the professionals as:

> A building more intelligent than its occupants (A Consultant from Turkey).

> An adaptable building to its surroundings, including interior conditions: occupancy levels, room climate and lighting requirements and to exterior conditions: climate factors (wind, solar radiation) with the help of connected hardware (IoT). It continuously learns through AI algorithms from the building usage patterns and enhances its operations resulting in minimum cost and energy (A Civil Engineer from Germany).

In summary, the interaction of the buildings with the occupants and their role is integral to the intelligence of buildings and constitute fundamental components of building intelligence. Two quotes from the professionals reinforcing this idea include:

> An IB should ideally encourage (and create) intelligent users that operate and occupy the building the way it was (or even better than) intended by its designers (An Architect from India).

> It’s all about motivating the people (Construction material market manager from Germany).

5.2 Role of technology for building intelligence

The benefits of technology are evident, primarily in terms of energy conservation [39], on-site energy production [43], and in creating secure and healthful environments for inhabitants [5], as also reflected during the interviews:

> IBs integrate technology and IoT solutions to address the age-old issues of overspending and inefficiencies in building construction and operation such as reducing energy consumption, predictive maintenance, enhanced productivity, and optimized resource utilization (A Quantity Surveyor from Ghana).

If a house is considered as “a machine for living in” [98], it might be reasonable that early IB concept was centred on pure technology [99] and developed largely as containers of intelligent technologies [1]. Further, Gao et al. [100] noted that “smart” refers to the development, integration, and utilization of intelligent systems based on information and communication technologies. The use of new technologies, such as sensor deployment, big data engineering and analytics, cloud and fog computing, software engineering development, and human-computer interaction algorithms, is a fundamental prerequisite to realising smart buildings (also known as intelligent buildings) [55]. Previous studies highlighted: (i) the IBs have advanced features to promote occupant productivity [31] (ii) the IBs recognize and reflect technological advancements [5], (iii) a probable stereotype of an IB is that it is a possession of technologically advanced countries [6], (iv) IBs could not exist without the involvement of technological systems, particularly IT within the modern building environment context [20]. In addition, the employed level of technology is used as a measurement of building intelligence: (i) AIIB (Asian Institute of Intelligent Buildings) Index has an indicator of high-tech image; (ii) the implementation of advanced technology was an indicator in the evaluation system developed by Huang [101]; (iii) the intelligence of buildings was measured and labelled as “low-tech” or “high-tech” by Harrison et al. [4]. Against this common descriptions of IBs with high-tech images, many researchers presented their arguments that (i) IBs can be simple or technologically sophisticated depending on the circumstances [3]; (ii) technologies alone do not make a building intelligent [21]; (iii) an IB does not have to include high levels of technology [27]; (iv) the sole inclusion of high-tech and sophistically controlled services systems does not make a building intelligent [17]; (v) intelligence cannot be achieved by incorporating sensors or other systems alone [102]. One of the experts criticized the role of technology:

> I think the construction industry regards the use of advanced systems as intelligent (An Architect from India).

Parallel to these disparities in the literature, the opposing themes “low technology” and “advanced technology” are mentioned ten and twelve times, respectively, in the responses. Further, BMS, sensors especially for lighting, and digital communication network are mentioned fourteen times as one of the IOB design features. This finding is in line with the existing studies that consider the use of sensors fundamental for intelligent environments [103] and as a part of IBs [104]. The benefit of digital innovation is undeniable when it comes to meeting occupant needs while saving energy, as elucidated by a professional:

> Real-time data tracking plays a crucial role in achieving desired outcomes including minimising energy and water consumption, meeting greenhouse emission reduction targets and carbon-neutral targets (A Smart City advisor from the USA).

On the other hand, the excessive use of sensors and mechanical equipment might cause problems, resulting in more energy consumption and occupant dissatisfaction if it is not properly applied. This was also argued during the interviews:

> Intelligence cannot be confined to specific features, such as sensors being in the market; intelligence is a constantly and vivid search for optimized processes which is not linear and not necessarily efficient but always effective in a particular situation (An Architect from Germany).

As also supported by research evidence, if technology systems in the buildings are not working correctly, they will not make the buildings intelligent [20]. The improper operation of intelligent buildings systems leads to more energy consumption and negative economic implications [105]. Further, Meistad [10] adds that modern energy-efficient buildings are more fragile in their performance due to increased complexity. The upgrading and updating of information collection devices in the IBs will increase the amount of data and lead to a rise in the complexity of control problems [58] and future prospects of the trade-off between complexity and predictive/control performance [94]. Although IBs are seen as complex, they should be easy to operate, energy and resource-efficient, easy to maintain, upgrade, modify and recycle [1]. The challenge lies in the complexity of intelligent systems because intensive planning and arbitration are required [43]. Otherwise, realising expected-potential benefits from intelligence may be hindered [27]. The proposed solutions include (i) design for manageability by avoiding unnecessary complexity [106]; (ii) focusing on simplicity as an ultimate object [38]; (iii) reconsideration of low-tech and low-cost solutions as opposed to high-tech short-term solutions [107] and (iv) providing for unique and changing assemblies of recent technologies in appropriate physical, environmental and organizational settings [32]. When discussing this matter with the professionals, the key design approaches were described as:

> All the technology used in a building should have a precise purpose; it should not be used as a budget because too much nonsense technology always ends up in little benefits for efficiency or user operation (An Architect from Italy).

> The technology should be simple, robust and easy to understand as much as possible (An Environmental Engineer from Germany).

> Technology adoption is influenced by contextual issues such as country and sector firm specific barriers, and these issues may foster or restrain the IOB concept; therefore, awareness, better understanding of influential contextual issues, and efficient readiness to adopt is required to promote the concept (A Quantity Surveyor from Ghana).

In conclusion, empirical evidence derived from interview data suggests that rather than measuring or labelling the buildings as high-tech or low-tech, the thoughtful selection and implementation of technology may be a critical approach to the IOB design. This approach entails considering regional context, avoiding unnecessary complexity, and aligning technology with specific purposes.

5.3 The role of passive design

The following statements of the professionals corroborated the critique by Kroner [1] who introduced the terms intelligent and responsive architecture, that architecture is disconnected from the intelligence of the systems and the inhabitant to the point where there is a little interaction between three.

> A building can't be intelligent; it is the design of the building, which is intelligent (A Climate Engineer from Germany).

> There is no "intelligence" in dead matter like material, construction, etc. It is the exchange between people (designer, builders, user, etc.) with their tools (computer, software, network, etc.) and their environment (desk, office, building, etc.) that make a building intelligent (An Architect from Germany).

Even though advanced building systems were mentioned as features of IOBs, some professionals highlighted the critical role of climate responsive design. This perspective is also evident in existing literature, which advocates that building design should be attuned to the climate [19, 32]. Due to the diverse climate factors in different regions of the world, varying IB design concepts can be observed [83]. Passive design solutions, including natural ventilation, thermal mass, and natural daylight utilization, are mentioned as features of IOBs and have also garnered substantial support from multiple authors [1, 8, 38] in enhancing building intelligence. This sentiment was expressed by a professional:

> I worked in a building where minimally processed materials were used, and passive ventilation strategy was implemented. I consider this building as intelligent despite the absence of sensors and

complex systems. I believe active systems alone do not define building intelligence. Instead, the prudent utilization of resources is the underlying concern (An Architect from India).

Scholars [1, 38, 108] noted that vernacular architecture is a sign of intelligence by skilfully utilizing the form, structure, and internal arrangement of buildings. As a similar approach, during the interviews, the professionals expounded upon the concept of climate responsive design:

> A building on its own, without any big technology, should work as a thermodynamic organism. Perhaps, an intelligent control system could support the building for an adaptive response; however, it is a good point for a discussion during the integrated design process which is the key (A Climate Engineer from Germany).

> An IB utilizes resources efficiently and adapts to the specific conditions where it is located by getting benefit from what is available and shielding undesirable external conditions (An Architect from India).

> An IOB can be responsive by tailoring based on the local climate and placing the users at the core of the design process (A Mechanical Engineer from France).

Although passive design can result in occupant dissatisfaction due to the limited user controllability ([8, 84], it brings more advantages, as supported with a quantitative data from the literature as (i) the right combination of active and passive features can save up 50-50% compared to a conventional situation [8]; (ii) passive is better than active [106] and (iii) enhancing building energy performance cannot be accomplished by only technologically active systems because passive strategies hold greater potential for savings [109]. Moreover, passive design strategies (e.g., high efficient building envelope) simplifies the mechanical systems significantly [110]. The façade design especially plays an important role in IBs [7]. Different expressions include “intelligent façades allow the occupant to determine the degree of indoor environmental parameters” [1]; “intelligent skin is similar to human skin” [2]; “intelligent envelope is the active adaptation to the particular climate, site, and building function” [108].

The intelligent design approach can be summarized through the perception of one professional:

> Priority should be given to thoroughly exploring passive design strategies to minimize the energy consumption. Active design approaches can then complement this effort by optimizing equipment to meet the loads with less technology. For instance, integrating heat pump systems with a well-designed envelope can achieve this goal. These considerations can be extended to all technology available within the building footprint including infrastructure services (A Mechanical Engineer from Malaysia).

Another professional also affirms this as:

> IBs maximize the use of passive functionality and only uses technical solutions supportive (A Mechanical Engineer from Germany).

In view of these contemplations, although emerging technologies do influence architectural practices, the essence of building intelligence lies not in amassing an array of intelligent technologies but rather in crafting an intelligent design. Passive design strategies play a crucial role in ensuring that the IBs remain adaptable to the dynamic environmental conditions without solely relying on automation technologies. In summary, implementing climate-responsive strategies – achieved through a meticulous analysis of local microclimate conditions – reduces the reliance on mechanical equipment (and even allows for its omission). Furthermore, the judicious integration of only essential technology into architectural design concepts emerges as a pivotal finding, advocating for a holistic approach to IOB design.

5.4 Interplay of intelligence and sustainability

The pressure on natural resources in the built environment was reflected in the themes of IOB description as energy efficiency, smart use of resources, and environmental considerations eighteen, eight and five times, respectively. The quintessential hallmark of an IB lies in its ability to operate without any additional energy requirements from external sources. This defining feature aligns with the assertation made by Wigginton and Harris [2] who posit that self-sufficiency is the epitomic of true intelligence. Further, Kolokotsa et al. [91] reinforced this notion by chracterising the IBs as intelligent net zero and positive energy buildings.

In addition, the significance should be directed towards flexibility and the ability to change the architecture and facilities [111]. IBs must be able to respond to individual, organizational and environmental requirements, cope with changes [21], and be flexible and responsive to different usage and environmental contexts [112]. The IBs can cope with social and technological change and are adaptable to short-term and long-term needs [3, 38]. The flexibility of construction features and internal layout emerged as a prominent design feature during the interviews, and were advised by the professionals:

> An IOB should be an adaptable structure so that it can be resilient to changes in social dynamics and environmental conditions at its site (An Architect, Designer from the UK).

> Construction features should exhibit ergonomic design and flexibility to facilitate the operation of intelligent systems (A Consultant from Turkey).

The IB design approach relates to sustainability which mentioned twenty times in the interview data. Various researchers have echoed similar sentiments regarding the alignment of IB concept with sustainability: (i) the IBs must stem from a belief in sustainability [3]; (ii) many concepts pertaining to the IBs have inherent relevance in sustainable building [12]; (iii) emerging technologies with sustainable design maximize occupants' comfort and well-being [15]; (iv) IBs should be used to promote total sustainability (ecological, economic, and social-cultural) in the built environment [6]; (v) buildings cannot be 'sustainable' but can support sustainable patterns of living [85]; and (vi) the smart intelligent buildings and sustainable building concepts are expected to merge [13]. In summary, empirical evidence supports that IOB design fosters sustainability throughout its lifetime by being flexible, remaining adaptable and responsive to changes with minimum energy requirements and carbon footprint.

6. Revisiting the IOB concept

The BE professionals used some analogous terms to express intelligence, such as smart, high performance and green building, during the interviews. Some of them even argued that "intelligence cannot stick to one feature" (A Construction material market manager from Germany), "using the term intelligent building is a hype that discourages thoughtful design" (A Climate Engineer from the USA) and "attaching a functional name to a building could limit its life and thus its sustainability" (An Architect from the UK). Expressing a building by an adjective might lead to underestimation of the profound impact of design and thus limit its performance. That`s why, in this study, the IOB design approach is debated around climate-responsive design and the level of technology then it was juxtaposed with the sustainability imperatives. In light of these implications, the IOB concept is elucidated through its basic design principles and its behaviour rather than providing a definitive list of features to provide a holistic and directional perspective, allowing for adaptability and context awareness in the IOB implementations:

> The core idea of the IOB evolves around the occupant-oriented approach and the integration of climate responsive design strategies with a balanced level of technology uniquely serving a well-defined purpose by taking advantage of regional conditions.
>
> The behavior of IOBs is described as a) adapts and responds to the changes in its environment, b) creates a healthy and comfortable environment for its occupants, c) pursues the optimal design performance for the least consumption of energy, d) communicates with its occupants to include them into building management process and e) learns occupants' preferences to improve its performance with their feedback.

7. Conclusion

This study explored the notion of intelligence for office buildings through semi structured interviews with 63 professionals from diverse countries. The qualitative content analysis of the interview data yielded nine salient key themes: intelligent monitoring and control, occupant-centered design, responsiveness, sustainability, and energy efficiency emerged as the top five discernible themes. Notably, the findings also underscored the diversity of professional viewpoints in interpreting the IOB concept, particularly concerning technological sophistication and climate-based design, influenced by their respective roles and national affiliations.

The synthesis of empirical evidence drawn from the interview data and revisiting the prevailing debates in the existing literature led to delineate the main IOB design approach by moving beyond the prescriptive descriptions or definitions of the concept. Further, design principles that underpin the intelligence in buildings are identified:

1- The intelligence begins with its design, where passive design strategies are harnessed to minimize the reliance on mechanical and electrical equipment and continues with the judicious integration of essential technology into architectural design concepts.
2- Technology should be selected and tailored based on regional contexts and guided by a deliberate purpose by avoiding complexity.

3- Personalized occupant comfort conditions, which might require balancing automation and individual controllability, are imperative to enhance well-being and productivity.
4- Efficient resource utilization, adaptive design, and being resilient to the changes for long-term viability are needed for sustainability.

As a result, this study offers practical implications for building professionals and designers by providing a clear direction and guidance for decision making in building intelligence. The research outputs have the potential to pave the way for the development of tools for assessing intelligence in buildings and the creation of design guidelines for building intelligence.

There are some limitations of this study that should be considered in the interpretation of the findings. Only the Scopus database was used to find the previous IB definitions, articles, dissertations, books, and book chapters included in the research. The scope of this study is limited to intelligence in office buildings, as gleaned from insights provided by a group of professionals. It is important to acknowledge that that the participants were representative of the broader population, allowing for an exploration of trends and variations in IB comprehension. These findings could encourage future empirical studies with a high number of participants to test the validity of identified themes and provoke more discussion on the debates in relation to the IOB design. In this study, we have used different modes for the semi-structured interviews, enriching the breadth of experts' perspectives. Although no noticeable difference in responses is observed due to the diversity of interview formats, future research can be performed to analyse specific impact of a wider range of interview formats. Moreover, future research is recommended to expand the content of the study for all building types. Since the building intelligence evolves with technological advancements, user needs, innovations and sustainable practices, and developments in multi-faceted research fields, the approaches towards the IB concept will remain an open challenge.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

No	Ref.	Year	Definition
1	[28]	1989	Buildings that make extensive use of information technology for building applications, and business applications, and that are responsive to organizational and technological change.
2	[29]	1991	A building which creates an environment that maximizes the efficiency of the occupants of the building while at the same time allowing effective management of resources with minimum lifetime costs.
3	[30]	1991	An IB offers a coherent set of facilities to both the building managers and to the occupant, to the building manager, an integrated set of management, control maintenance, and intra- and inter-building communication facilities that allow efficient and cost-effective environmental control…
4	[31]	1996	Office buildings having advanced features such as communication systems, intelligent cards for security, credit transactions, use of office facilities, BMS and building automation that promote occupants’ productivity and the efficient use of energy and resources.
5	[3] [32]	1997	An IB provides for innovative and adaptable assemblies of technologies in appropriate physical, environmental and organisational settings, to enhance worker productivity, communication and overall satisfaction.
6	[17]	1997	An IB can be used to create the personal, environmental, and technological conditions necessary for building occupants to maximize their individual capabilities, productivity, and satisfaction.
7	[16]	1999	An IB is designed and constructed based on appropriate selection of Quality Environment Modules to meet the users' requirements by mapping with the appropriate building facilities to achieve long-term building value.
8	[33]	1999	An IB utilises computer technology to autonomously govern the building environment so as to optimise user comfort, energy-consumption, safety and monitoring-functions.
9	[7]	1999	An IB provides thermal comfort by optimizing the following factors: the building structure, particularly its external envelope. i.e., walls and windows, its HVAC and lighting systems and the method in which the building is controlled.
10	[2]	2002	An IB has the ability to know its configuration, anticipate the optimum dynamic response to prevailing environmental stimuli, and actuate the appropriate physical reaction in a predictable manner.
11	[6]	2002	An IB can support advanced hardware, such as the building and personnel management systems, as well as accommodate future technologies and the anticipated level of long-term user requirements.
12	[34]	2002	An IB is described as automatically managing ordinary works, in case of unexpected situations operating security system, able to establish communication between outside and inside users and electronic equipment with the help of software and automation systems.
13	[35]	2004	An IB is itself recursively composed of other agents and on a conceptual level, similar to other intelligent agents such as humans, animals and robots.
14	[36]	2006	An IB can help building owners and occupiers reduce operating and occupancy costs whilst providing an environment, which is more flexible, convenient, and comfortable for occupants.

No	Ref.	Year	Definition
15	[8]	2008	An IB should be a product of design process with passive features while taking advantage of technological innovations.
16	[37]	2010	Application of AI technologies to buildings results in so-called "IBs".
17	[5]	2010	A smart building involves the installation and use of advanced and integrated building technology systems, including building automation, life safety, telecommunications, user systems, and facility management systems.
18	[38]	2011	IBs need to be sustainable (i.e., sustain their performance for future generations), healthy and technologically up to date; meet regulatory demands; meet the needs of the occupants, and be flexible and adaptable enough to deal with change.
19	[39]	2013	IBs refer to buildings equipped with technology that allows monitoring of their occupants and/or facilities designed to automate and optimize control of appliances, in particular, lights, HVAC system, and home appliances, with the goal of saving energy.
20	[40]	2013	An IB is able to manage its indoor environment via computer techniques to optimize energy efficiency, occupants' wellbeing, safety and productivity.
21	[41]	2014	The buildings which integrate and account for intelligence, enterprise, control and materials and construction as an entire building system, with adaptability; not reactivity, at its core, in order to meet the drivers for building progression: energy and efficiency, longevity and comfort and satisfaction.
22	[42]	2015	An IB uses digital technologies to enhance performance and well-being, to reduce costs and resources and to engage more effectively and actively with its residents.
23	[43]	2018	Smart buildings are emerging as complex cyber–physical systems with humans in the loop which are aimed at providing safe, healthy, comfortable, affordable, and beautiful spaces in a carbon and energy-efficient way.
24	[44]	2020	An IB should (1) perceive its environment through indoor environment monitoring system; (2) communicate with occupants and know their needs; (3) make energy-related decisions by its energy management system (EMS); (4) take energy-related actions through its energy management and control systems (EMCS), (5) have a learning capability to improve its performance, and (6) have a proper communication to the grid.
25	[45]	2020	Smart buildings are designed, constructed, and operated by integrating innovations of technology, process, organization, and knowledge in order for (1) energy and resource security and efficiency, (2) comfort and satisfaction, and (3) CO2 emissions' reductions or decarbonization during their life cycle while providing inhabitant and stakeholders with interactive and adaptable management systems in real time. IBs are physical and cyber structures satisfying users' needs and optimizing resources' efficiency by maximizing the technical functionality of BMS.
26	[46]	2021	In the today's phase of technical and architectural evolution, adaptive building could be the definition of IBs.
27	[47]	2022	iBuilding distributed artificial intelligence embedded into IBs or Smart Buildings in an Industry 4.0 application that enable their adaptation to the external environment, learning from its users and monitoring its functionality in terms of assests, space and energy, therefore assissting building managers or developers to make comercial or operational decisions.

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