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Intelligent Buildings: Design & Implementation

LANDMARK RESEARCH PROJECT

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The Steering Committee contributed its time and industry expertise to the project during numerous Web conference meetings, offline sessions with the research team, and through interim and final review of the research processes, discussion guides, and this extensive report. The organizations and their representatives are:

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Project Background and Introduction

The Continental Automated Buildings Association (CABA) is a not-for-profit industry association dedicated to the advancement of connected home and intelligent building technologies. The Intelligent Buildings Council (IBC), a core working council of CABA, commissioned this landmark research project, titled "Intelligent Buildings: Design & Implementation", to obtain, on behalf of the Council members and the intelligent building industry stakeholders, a comprehensive understanding of the practices, challenges, process influencers and opportunities pertaining to intelligent building design and implementation. Traditional design and implementation processes are inadequate when catering to the needs of dynamic entities such as intelligent buildings. By undertaking this project, the IBC members sought to understand the importance and implications of adopting the right design practices and implementation methods that could bolster the adoption of the concept of intelligent buildings and the technologies and services associated with it.

The research examined the concept of intelligent buildings design and implementation processes from the perspective of building owners, occupants, vendors and service providers, industry associations, and think tanks. It referenced an existing body of literature in the public domain that pertains to this issue to corroborate findings obtained through discussions with industry participants and a comprehensive industry professionals' research survey. This executive summary offers a concise snapshot of the entire research project in a distilled manner, concentrating on the high-level and critical aspects of the findings. For easy reference, the key sections of the executive summary correlate to individual chapters in the body of the main report: Chapters 1-5.

The intelligent buildings industry is heterogeneous and fragmented by nature, and some segments of the industry are more open to adopting design practices and technology justification processes than others. Investment metrics, in relation to the efficiencies created by intelligent and integrated building design and implementation concepts, can significantly reduce ongoing operating costs and produce a timely return on investment for owners. Winning over project partners, service providers and key decision influencers, involved in technology procurement and fund allocations in the design, construction and operations processes, is often a complex proposition. The research confirms that in this highly complex and transitioning world of intelligent buildings, addressing core issues associated with pursuing the right design and implementation processes requires dismantling traditional silo based approaches, obtaining industry-wide consensus on change, and ultimately taking a strategic long term view of projects, beyond first costs.

CABA and Frost & Sullivan hope this report will drive attention to this key industry challenge and encourage effective dialogue among industry participants for creating awareness and exploring collective initiatives for driving optimal intelligent building design and implementation practices.

About the Report

CABA commissioned Frost & Sullivan to undertake this research project on behalf of the Intelligent Buildings Council (IBC), a working group of CABA. The project was funded by CABA and members of the IBC to understand the practices, challenges, process influencers and opportunities pertaining to intelligent building design and implementation (IBDI). The research commenced in May 2017, was conducted over a 20-week time period, and completed with a final webinar session in mid-2018.

The concept of intelligent buildings, and the value chain that caters to it, has expanded quite rapidly over the last decade. Encompassing players from a wide spectrum covering vendors, service providers, project execution partners and third-party professionals that help design, develop, fit-out, operate and continually service such an entity, this is a highly evolving landscape with a significant degree of fragmentation associated with its value delivery process. The challenge of keeping pace with technology has resulted in products and solutions often being incorporated in a sub-optimal manner, in additional to noticeable deviations in original design intent and ultimate outcome.

The outcomes of this collaborative research offer insights into the extent of these challenges, ways to alleviate inadequate practices, potential counter measures to be adopted and best practices identified that could help industry participants use design processes in a more favorable way. The findings will help vendors and service providers consider incorporation of design elements and implementation measures into their value proposition to create better buildings catering holistically to occupants' needs.

Role of the Steering Committee

The Steering Committee represents a cross-section of vendors, service providers, industry associations, utilities, and experts in the intelligent buildings marketplace. Representatives from each organization joined Frost & Sullivan and CABA on regular collaboration calls to guide the research scope and ensure that it met project objectives. Figure ES 1 shows the organizations that supported the project as Steering Committee members.

Figure ES 1: Project Steering Committee

About CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association, founded in 1988, dedicated to the advancement of connected home and building technologies. The organization is supported by an international membership of over 365 organizations involved in the design, manufacture, installation and retailing of products relating to home automation and building automation. Public organizations, including utilities and government are also members. CABA's mandate includes providing its members with networking and market research opportunities. CABA also encourages the development of industry standards and protocols, and leads cross-industry initiatives.

Please visit http://www.caba.org for more information.

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best-in-class positions in growth, innovation, and leadership. The company's consulting methodologies and strategic partnership initiatives provide clients with disciplined research and best-practice models to drive the generation, evaluation, and implementation of powerful growth strategies. The company leverages 50 years of experience in partnering with Global 1000 companies, emerging businesses, industry associations, and the investment community from over 40 offices on six continents. It collaborates with clients to leverage visionary innovation that addresses the global challenges and related growth opportunities that will make or break today's market participants. Frost & Sullivan's integrated value proposition provides support to clients throughout all phases of their journey to visionary innovation including: research, analysis, strategy, vision, innovation, and implementation. The 360° coverage includes industry convergence, disruptive technologies, competitive intelligence, visionary innovation research, breakthrough best practices, changing customer dynamics, and emerging economies. To learn more, visit www.frost.com.

The Project Consulting Team

Frost & Sullivan led the research project for CABA, with integral support from Frost & Sullivan's Customer Research Group. The core consulting team and report contributors are:

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Overview and Focus Areas

Intelligent buildings (IB) are prime examples of innovative applications of technology meant to enrich occupant experience, enhance operational efficiency and provide long term value justification to owners and investors. The true value of an IB is realized through successful concept planning, design and technology implementation, effective operation and management (O&M), and cost savings via predictive maintenance and optimization, all of which are typically realized when pursuing a fully integrated design and implementation approach. This, in turn, is reliant on the building industry's motivation to adopt open standards and integrated systems, selected on the basis of their ability to scale over time, and seamlessly incorporate technology advancements that will allow the IB to offer ongoing benefits and advantages to its owners, occupants and operators. In reality, however, IBs exhibit a myriad of flaws in terms of their planning and implementation process, in turn delivering subpar performance and limited technology advancements.

The key focus areas of the project included the following:

- Evaluating the benefits of adopting proper design and implementation practices
- Understanding various design processes currently in use and the ways to improve their adoption
- Addressing issues and challenges propagated by value chain participants and determining ways to mitigate them
- Determining opportunities for collaborations and partnerships to address common challenges

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Key Objectives

The key objectives of the research encompassed the following:

- **Evaluate the need and adoption influencers** for parametrically justified intelligent building design concepts
- **Understand the state of the market** and hindrance factors that lead to value engineering of core design elements based on cost, lack of knowledge or proven efficiency factors
- **Assess the positive and negative stakeholder influence** in the design and implementation process of intelligent building technologies, and ways to mitigate technical adoption barriers
- **Evaluate measures** that will allow design tools and methods to be incorporated early on in the process

Methodology

Frost & Sullivan used a combination of primary and secondary research methodologies to compile information for this project. This included both qualitative research and quantitative tools for analysis and projection of key issues.

Primary Research Process

Primary research formed the basis of this project, with two major components: an industry-focused research module and a survey module targeted at the intelligent buildings industry value chain participants. The description of each is provided below in Figure ES 2.

Figure ES 2: Primary Research Methodology Description

Item	Component	Description	Target Group Profile	Sample Size	Research Technique
A	**Intelligent buildings**	Selection of technologically advanced buildings and smart campus projects	Builder owner, developer, facility operator	n=8-10	Analyst Interviews
B	**Intelligent building technology vendors and service providers**	Vendors and product suppliers of IB technology, connectivity and IoT solution vendors and third-party service providers	Vice Presidents, Directors, Product/Sales Manager, R&D Specialists, Alliance Partners	n=120-130	Analyst Interviews
C	**Industry Influencers**	Codes and Standard Development Organizations, Industry Associations, Academic Influencers, Regulators	Technical committee personnel, academia, regulators	n=22-30	Analyst Interviews
Total sample target Interviews accomplished (Average across groups A, B, and C)				**n=150-170 73%**	

Item	Component	Description	Target Group Profile	Sample Size	Research Technique
D	Industry professionals survey	Building owners, occupiers, internal decision makers of large portfolio real estate clients, operators, contractors, EPCs, design build firms, architects, specifiers, ESCO, system integrators	Developers, building operators, consulting engineers, general contractor, master service integrator, technology contractor, project designer, ESCO, specifiers, commissioning agents	Target: n=600-650 Actual: n=655 US: 85% Canada: 15%	Survey by invitation to online panel

Frost & Sullivan adopted extensively structured and high-profile discussion techniques with target participants for the industry-focused primary research, involving single or multiple senior level personnel and Frost & Sullivan's team of analysts and consultants to engage in insightful deliberations on the subject. This resulted in maximum value output in terms of information exchange and excellent validation of findings from the industry professionals' research survey. Similarly findings of the survey were triangulated with insights from the industry-focused primary research process.

Research Instruments: Questionnaire/Discussion Guide

The discussion guides for both modules of the primary research process were developed by Frost & Sullivan in consultation with the steering committee. Draft discussion guides were reviewed at the early stages of the project and feedback was mutually exchanged between the project team and the steering committee. Thereafter, the discussion guides were run through a soft launch process for market testing. Subsequently, the two research modules were launched. The sample for both research modules were generated using Frost & Sullivan's vast repository of contact sources and databases. The industry-focused primary research accomplished an average 73 percent fulfillment of the target sample. The data obtained from these discussions were analyzed and distilled into the commentary of the report. The online industry professionals' survey was launched and remained active for a period of seven weeks in the field. A total of 655 responses were collected against an original target of 600-650. The data from these responses were then analyzed using various qualitative and quantitative tools for interpretation in the report.

Secondary Research

Secondary research comprised the balance of the research effort and included published sources such as those from government bodies, think tanks, industry associations, Internet sources, the CABA Research Library, and Frost & Sullivan's repository of research publications and decision support databases. This information was used to enrich and externalize the primary data. A listing of all works cited is in the appendix. References are cited on the first instance of occurrence. Dates associated with reference materials are provided where available.

Any reference to "Frost & Sullivan's research findings, industry interactions, and discussions" in this report is made in the context of primary research findings obtained from this project "Intelligent Buildings: Design & Implementation," unless otherwise stated. However, the analysis and interpretation of data in this report are those of Frost & Sullivan's consulting team.

Definitions and Industry Professionals' Survey Qualification Criteria

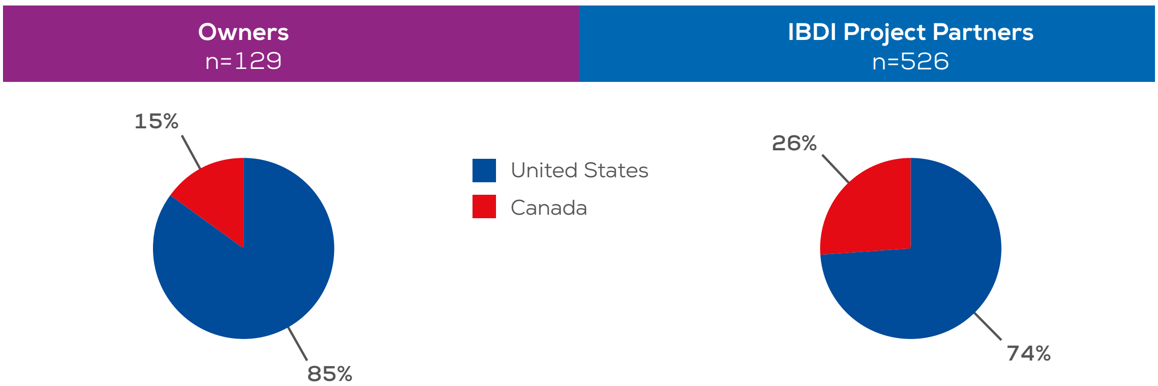
For the purpose of this research Frost & Sullivan adopted the following definition, in consensus with the project steering committee: "An intelligent building is characterized by the presence of two of more integrated and interoperable systems that aids in intelligent decision making regarding its operational state at present and in the future." Defining a rapidly evolving concept as IB with such a broad stroke provided the study participants a degree of flexibility in envisioning and discussing it. Based on the level of integration achieved, a building can move up or down the intelligence spectrum, with the corresponding benefits and key value drivers ranging considerably.

Participants in the industry professionals' survey were offered the same definition of an intelligent building; however, for easy understanding and screening purposes, a battery of screening questions was asked as part of the qualification criteria before allowing them to proceed with the survey. The respondent screening and qualification process entailed the following qualifiers:

- Country of organization
- Size of the firm
- Type of organization and the activities it is involved in
- Whether or not the participant played a role in designing, planning, or implementing the IB technologies
- The responsibility and accountability profile in the decision-making process
- Other qualifiers specific to the organization profile of the respondent

Accordingly, a respondent who did not fall within the requisite criteria was disqualified from the sample. Once the respondents were qualified to proceed further with the survey, they were taken through a series of questions. Several criteria within the set questions were looked at to classify respondents in relevant categories to aid resourceful analysis. The sample was broadly classified into building owners/occupants and project partners. Further sub-divisions were obtained within each broad category. The results of the respondent profiling process are illustrated below. Chart ES 1 shows the country classification of the broad category of respondents.

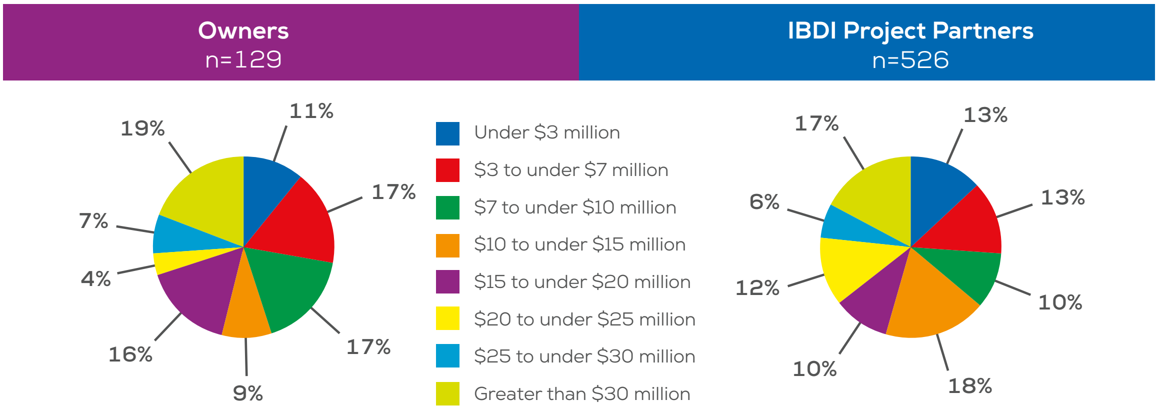
Chart ES 1: Country Classification within the Category of Respondents



Q: Country of organization

Respondents were geographically categorized for United States (US) and Canada. The US respondents comprised 85 percent of the sample, while the remaining 15 percent were from Canada. Of the total sample, 19 percent of owner-operated companies and 17 percent of project partner companies had revenue greater than USD $30 million.

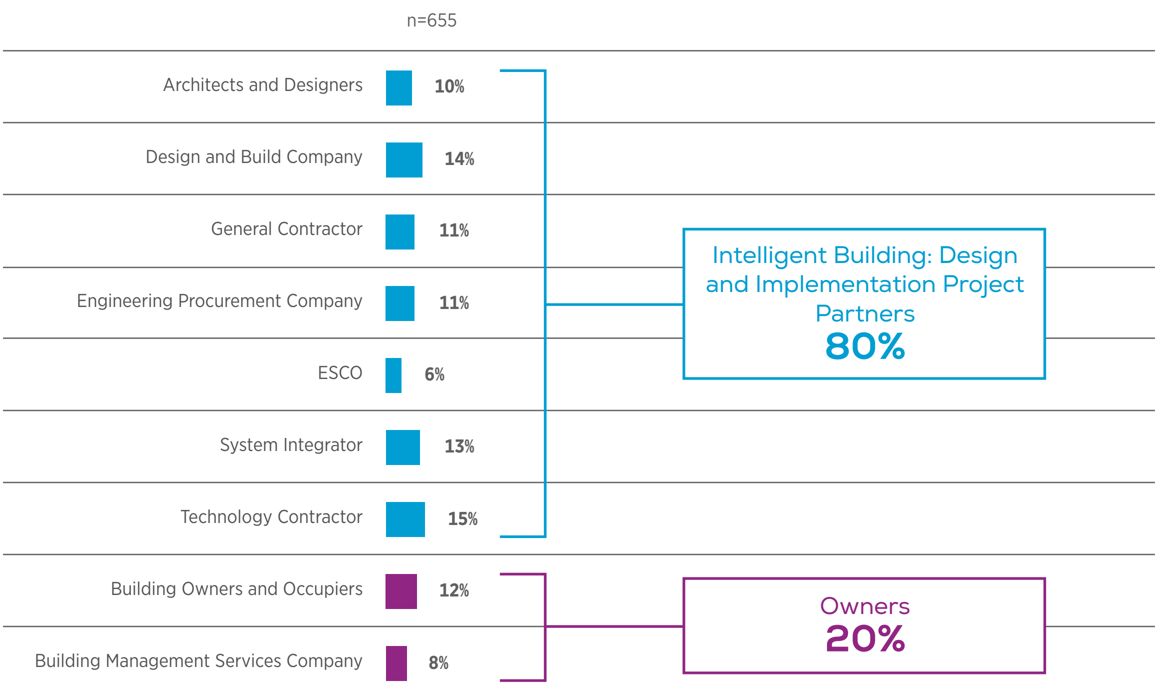
Chart ES 2: Annual Revenues of the Organization



Q: What was your company's total revenue for the last full fiscal year?

A significant 20 percent of respondents were building owners and 80 percent were project partners. The respondents were further categorized based on their job profile within the organization, thus allowing the research team to glean distinct feedback from key decision makers involved in such processes and their specific perceptions regarding various aspects of the design and implementation process.

Chart ES 3: Organizational classification of respondents



Q: What type of organization do you represent?

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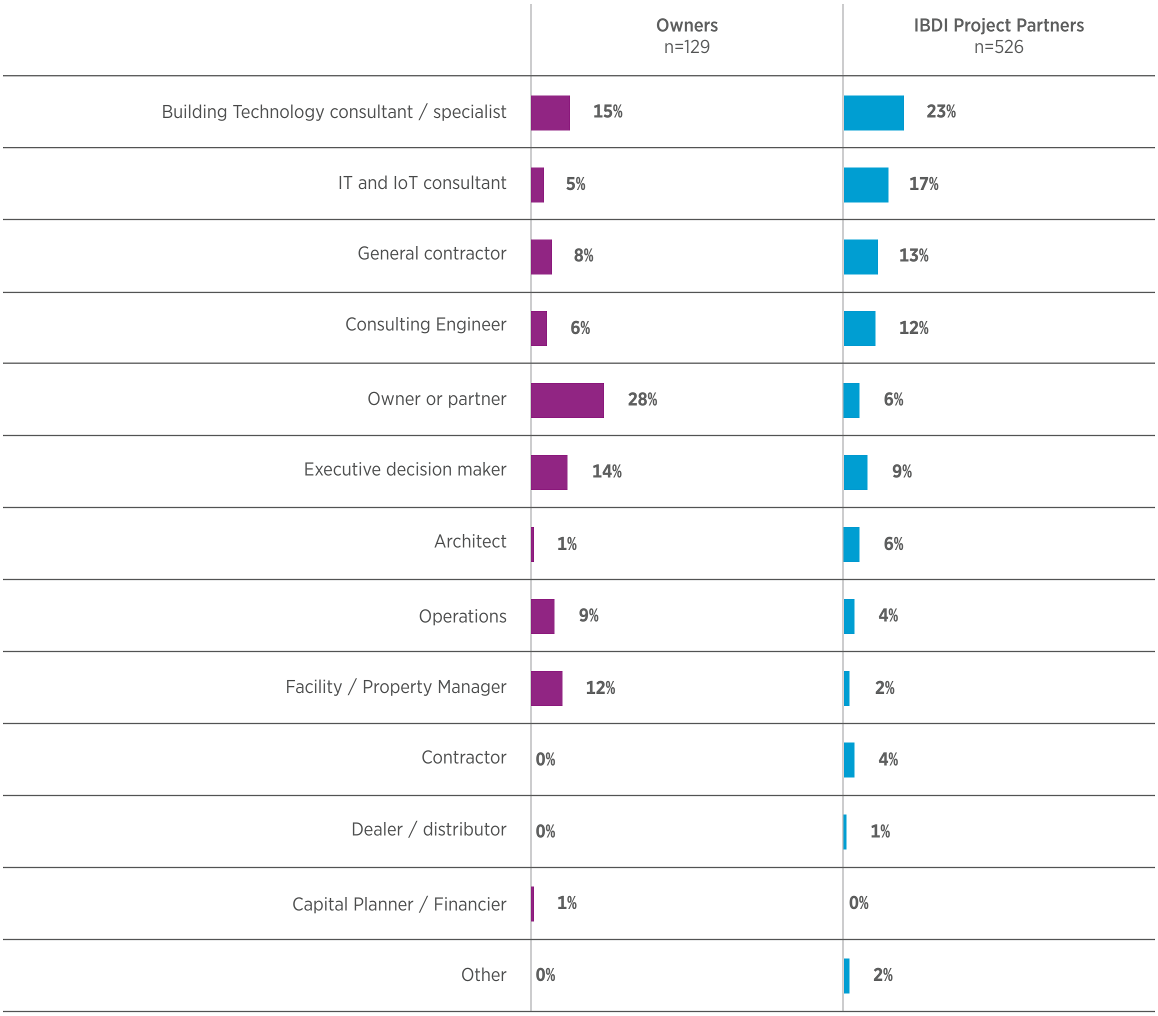
Chart ES 4: Profile of Respondents



Q: Which of the following best describes your job title?

Layout of the Report

The report is structured into five chapters with an executive summary outlining the overall objectives, research areas and findings, Chapters 1-5 and an appendix. Figure ES 3 provides a brief layout of the report to help navigate its contents.

Figure ES 3: Intelligent Buildings: Design and Implementation: Layout of the Report

Sections	Title	Content
Preface	Executive Summary	Background and introduction; objectives, methodology and definition, overview of top findings
Chapter 1	Intelligent Buildings: Design & Implementation – An Overview	Overview of intelligent buildings industry, definitions, IBDI methods, participants' roles and responsibilities, issues and challenges, areas to be addressed

Sections	Title	Content
Chapter 2	Industry Perception Analysis	Introduction and methodology, sample classification; IBDI adoption potential analysis; benefits and outcomes; expectations from vendors and project partners; key takeaways
Chapter 3	Addressing Key IBDI Adoption Challenges	Issues and challenges in IBDI adoption; consensus development on core issues; process optimization needs
Chapter 4	Evaluation of Process Optimization Requirements	IBDI process optimization: key elements; best practices; value chain interdependency evaluation
Chapter 5	Conclusions and Recommendations	Conclusions of the research and key recommendations
Addendum	Appendix	Glossary of terms; references

Summary of Key Findings

The key findings of this research as discussed through Chapters 1-5 are outlined subsequently. Discussion under each heading represents a synopsis of the chapter corresponding to it in the report. For example, ES-CH 1 corresponds to executive summary of Chapter 1.

ES-CHAPTER 1 INTELLIGENT BUILDINGS: DESIGN & IMPLEMENTATION–AN OVERVIEW

Overview of the Intelligent Buildings Industry

The term 'intelligent building' (IB) has had a variety of definitions and terminologies since the early 1980s. The definitions cover differing levels of importance given to various aspects and measuring parameters that contribute to building intelligence. Commonly, IBs are characterized by the presence of devices, controls, and systems that interconnect and communicate with one another to enable an environment that is responsive and adaptive to occupants' needs and comforts. The degree of "intelligence" varies by the sophistication underlying the software-aided applications and communication network that helps these devices and systems function in an interoperable manner and share operational data. This ultimately forms the backbone of this evolving concept. The evolution and transition in buildings has led industry experts to dwell upon various terminologies such as green, automated, intelligent, smart, and high performance to define these buildings.

Defining an Intelligent Building

For the purpose of this research Frost & Sullivan adopted the following definition, in consensus with the project steering committee: "An intelligent building is characterized by the presence of two of more integrated and interoperable systems that aids in intelligent decision making regarding its operational state at present and in the future." Defining a rapidly evolving concept as IB with such a broad stroke provided the study participants a degree of flexibility in envisioning and discussing it. Based on the level of integration achieved a building can move up or down the intelligence spectrum, with the corresponding benefits and key value drivers ranging considerably.

Figure ES 4 depicts a building's characteristics associated with its corresponding level of system integration and intelligence, as progressively tracked by Frost & Sullivan over the last decade.

Figure ES 4: IB Characteristics and the Level of System Integration

Building Profile	Design and Spec Approach	System Integration Specialist	Integration Determinants	Limiting Factors
Non-integrated	• Segregated approach divided across different participant groups • Performance specs with minimal design documentation	• Overtly dependent on contractors	• Availability • Low cost • Relationships • Lack of open standards • Difficult to accomplish system integration	• Least conducive to occupant needs • Long-term maintenance contracts of manufacturers • Engineering-by-design not adopted as a norm • Costly upgrade contracts
Partially integrated	• Combination of segregated and integrated approach • Some design documentation, but generally standalone system/hardware intensive • Meets the minimal criteria of achieving an IB status	• Dependency on contractors and system integrators	• Advocacy of open standards to some degree • Cost still overrides decisions • Benefits of integration not fully exploited	• Hardware intensive with multiple communication interfaces/gateways making the switch to full integration cumbersome • Proprietary strongholds persist • Partially responsive to occupant needs, though features significant gaps
Fully integrated	• Technology contracting or integrated consulting approach with a sole source contractor assigned • Design documentation is a mandatory norm • Sub-system integration at the control network level	• Collaborative approach and accountability shared by multiple stakeholders with the building owner at the center of decision making	• *Features an integrated design and execution process* • *Specs dictated by compatibility and interoperability* • *Demonstrates lowest life-cycle cost*	• Variances in cost estimation • Perception issues with regards to cost and time consumed • Lack of skilled professionals • Lack of project partner coordination

The IBDI Methods and Practices

This research found that there are no clear cut methods or implementation processes that specifically exist for IB projects. However, various permutations of widely used and traditional design and procurement methods, such as bid-and-spec and construction management, currently serve as the "go-to methods" for IB projects.

Given the undefined and informal nature of this space, it was imperative to start by isolating such processes embedded within these traditional methods that can conform to IB project planning and delivery requisites and adopting a separate nomenclature that can help appropriately position them as "IBDI methods". Accordingly the following methods were identified, as depicted in Figure ES 5.

Figure ES 5: IBDI Methods Prevalent in the Industry

IBDI Methods	Description	Key Highlights
Design-bid-build	• The design-bid-build method, when used for IBDI, works on similar principles, as when used in a non-IB context. • It starts with the building owner's selection of a design build or a consulting engineering firm. • IB design and procurements tasks, specific to each technology or process, are initiated sequentially with limited overlaps. Typically the building owner or occupant contracts with separate parties for the design and for the implementation of the project.	• Clear vision of technology requirements to be fulfilled • Demarcation of roles and responsibilities by design, procurement and implementation
Design-build and implementation	• In this method the building owner or operator contracts with a single party who takes charge of the design, procurement, integration and implementation of the IB technologies and processes that are contracted to this party. • This method can potentially reduce the project delivery time by overlapping the design and implementation phases of the project.	• Single point of contact enhances overall accountability • Simultaneously execution ensures better coordination of technology integration needs and processes
Performance-linked implementation	• This is essentially a variation of the "design-build and implementation" method in which a performance guarantee is linked to the technology or process implementation that is contracted from such service providers. • For example, guaranteed energy saving, compared to a baseline performance, is expected to be delivered under such contracts from the contracted party. • This has often been an instrumental way of adopting IB solutions, entailing zero, or negligible upfront investment in certain cases.	• Assured guarantee stipulations increases the onus and accountability of the service providers contracted • Considered the most effective way to fast track technology implementation in IBs in recent years
Collaborative implementation	• This method essentially combines best-of-breed processes and practices that are already inherent to the preceding three methods, in addition to provisioning the ability to incorporate specialists, new industry entrants, and outside industry entrants as needed. • The purpose of such collaboration is to facilitate a robust delivery and implementation process that is closely aligned with the owner's or occupant's vision and future expectations from the building.	• Proper coordination and collaboration ensures better technology and process integration • Ensures low life-cycle costs • Offer scalability of initial investment

In practice, it is quite common for some of these methods to be used in conjunction. Additionally, sub-classifications of these methods have tended to proliferate in response to market demand. The research revealed the following key imperfections that characterize the current value delivery process associated with majority of IBDI projects as discussed below.

Extreme Fragmentation Creates Polarization of Goals

OEMs, product vendors, and technology vendors work, either directly with the building owner, or through any of their supply chain partners. These partners generally include their own line of agent representatives, distributors, and system integrators. Unless working directly with building owners, often times these partners either interface with a contractor, architect, or a project management agency that takes on the responsibility of fulfilling the project execution and installation. As a result, a single project can have up to three different layers of supplier representatives and assigned integrators who liaise with the contractor, often creating conflict of interest, and jeopardizing their own prospects.

Multiple Decision Makers Lead to Fulfillment Nightmare

While the contractor typically assumes all technology procurement responsibility, actual decisions on what to procure are often incumbent upon what the project fulfillment partners, such as consulting engineers (CEs) or energy service companies (ESCOs), decide in conjunction with the building owner. There is a further fragmentation of the value chain at the general contractor level where electrical, mechanical, and other sub-categories start interfacing with the general contractor.

Static Model with Limited Dynamic Intervention

Linear and orchestrated as it may appear, the reality of conducting business within this value chain presents some critical challenges for all parties involved. Managing costs, expectations, project objectives, and ensuring that all parties understand and deliver to those objectives poses a major hurdle in each step of the process. However, a significant constraint arises in that the structure of the value chain has remained fairly static, despite the fact that technology and operational requirements of buildings have undergone considerable changes. Clearly the processes have not kept pace with these changes, thus resulting in situations where transactional practices have taken over what should have been a seamless delivery process.

Lack of Design Flexibility Eliminates Technology Integration Prospects

Each group in the value chain has a role to play in ensuring timely and quality design implementation, construction and installation in any project. However, due to the staggered nature of contracts awarded, it is not possible to involve all groups during the initial design phase. It is imperative that the architect be flexible enough to make the requisite changes as they often emerge down the road with key IB technologies. For example, integrating lighting systems that might require supplemental natural lighting for energy-saving methods may call for changes in the architectural design and clearance from the architectural design partner. These changes are often never factored in, nor budgeted for in advance, leading to futile negotiations and delays during the implementation phase.

ES-CHAPTER 2 INDUSTRY PERCEPTION ANALYSIS

The research survey conducted among industry professionals provided important insights into the overall adoption, issues and challenges associated with IBDI processes and methods from the perspective of value chain participants. The imperfections in design process integration, technology deployment using such processes, and the expectations of owners and occupants from project partners was obtained from this research. The top findings and strategic messages that can be drawn from the survey are highlighted below.

Growth Potential

Significant growth potential exists for the adoption of an IB design and implementation practice or method. The research indicates this trend could witness an average of 46 percent penetration within the next three years, pointing to a dynamic and fast-evolving market. Due to the application of different technologies in an IB, it is essential to have proper integration and interoperability for a successful outcome. The inclusion of lighting, security, fire alarms and HVAC systems in the design and planning phase of an IB is expected to witness five to 12 percent penetration in the next two years. Therefore, it can be concluded that the future demand for IB technology will feature the inclusion of smart lighting systems, robust security systems, and energy management equipment. Accordingly, in the immediate term, safety and security; energy efficiency; reduction in operational expenses; and better ROI management will continue to be key drivers for the adoption of IB technologies. The ability to quantify energy savings, create ways to reduce operational expenses, increase comfort and convenience, and, most importantly, maximize space utilization by offering compact interoperable systems will be instrumental in maintaining market demand for IB solutions.

Practices and Outcomes

A complete analysis of an IB project and having positive execution practices in place are the most important criteria for successfully designing and implementing an IB. Building owners and project partners should have a unified view of all the smart technologies included in the project. They should participate in every aspect of design and work as a team towards the constructive implementation of an IB. The favorable cost-benefit ratio associated with adequate planning are motivating factors for the adoption of proper design and implementation practices. Having a universal view of the design and implementation plan and active collaboration between project partners, such as design companies, architects, technology consultants, and system integrators (SIs) from the onset of the project will lead to the desired outcome. The benefits of adopting IB best practices, including financial management and through energy efficiency management, building operation optimization, and comfort and convenience, will lead to overall tenant satisfaction.

Distinctively disjointed value chain partners lead to poor IB execution. Haphazard inclusion of design partners and a lack of teamwork are the primary attributors to poor implementation processes in an IB project. Poor design, over reliance on outsourced partners such as contractors, a lack of communication between key stakeholders, and non-cooperation between workers and project partners are some of the top negative practices resulting in an undesired and delayed outcomes.

Adherence to Best Practices

Currently, only 30 percent of respondents follow best practices; however most respondents have a strong desire to implement key best practices. The incorporation of good building design ensures value propositions such as proper space utilization, energy management, and smooth operation of systems installed in an IB project. The trend of collaboration between design consultants and relevant parties helps minimize design changes and reduces project deadlocks. Clearly conveying the design process to various participants helps develop a roadmap for proper integration of the various technologies involved in an IB. This practice was significantly perceived as the most valuable process not only by project partners, but also by building owners. Other valuable practices include having an experienced internal team that can clearly understand project needs, managing project costs through the timely incorporation of technology solutions and respective vendors, and having good communication and teamwork. On the other hand, respondents who rely on the contractor to help implement the design are perceived to be using fewer best practices because this tends to cause significant delays and cost overruns.

Role of Value Chain Participants

The architect, design build contractor, and technology consultant are the top partners in determining the standards and specifications of an IB project. However, the influence level of these partners changes with the type of construction. These partners have the highest level of influence in new construction and renovation projects. Nevertheless, due to significant involvement of building owners and occupants in retrofit projects, they have less power in determining the standards. The role of project partners is not just to deploy and specify what goes into a building, but to also educate the value chain participants (such as consumers and building owner) about the benefits associated with proper design and implementation. Technology consultants must be able to demonstrate the value of implementing smart technologies from the very beginning. Project partners and building owners were involved in major initiatives to educate end-users, such as in producing informative videos and courses on how to correctly use and install the new technology and understand the benefits associated with proper implementation.

Overall, this research confirms that the practices currently followed during the design and implementation of an IB are not well-integrated by all value chain partners. Only 30 percent of respondents adopted a structured and systematic method of utilizing best practices in their IB processes. Because of this, most organizations have fundamental issues and challenges that need to be addressed in order to mitigate project completion delays and meet customer expectations.

ES-CHAPTER 3 ADDRESSING KEY IBDI ADOPTION CHALLENGES

The core issues that challenge incorporating IBDI processes revolve around broad themes of communication, capital expenditure (CAPEX) versus operational expenditure (OPEX), conflict resolution, improper expectation setting, and the inadequate training of resources. These affect both adoption rate and project execution processes for IBs. The resulting impacts include significant cost overruns and project delays. In certain cases, drastic deviations from the original vision and objectives are responsible for recurring maintenance challenges of these buildings and ongoing downtimes. Addressing these concerns involves navigating a myriad of critical issues and challenges for all stakeholders involved.

In this regard, some key issues and challenges for the industry stakeholders are shown in Figure ES 6.

Figure ES 6: IBDI Domain Issues and Challenges

Issues[1]	Challenge and Impact	Propagated By
Value Engineering of Components	• Driving project decisions on cost • Declining vendor interest for innovation	• Contractors, SIs, EPCs, Owners
Absolute Control of Contractors	• Lack of product incorporating knowledge • Driven by cost and schedule to complete and move on • Hindrance to the installation of other requisite systems as the project progresses	• General and mechanical contractions; sub trades
Inadequacy of Tools and Standards	• Lack of specific IB design tools • Generic elements and broad framework of design specification Master Formats • Inadequately defined specifications for rating quality and functionality of IB technologies	• Design Tool Developers; Specification Standard Developers; Professional Bodies
System Interoperability and Integration Issues	• Static design and inability to incorporate future innovative solutions • Limited control over processes and outcomes • Cost implications	• Vendors and SIs
Exclusion of Owners and Occupants	• Faulty structure of task allocation and communication flow • Lack of feedback loop • Vision and strategy mismatch with final outcome	• Design build firms; CEs; Vendors

Issues[1]	Challenge and Impact	Propagated By
Training and Certifications	• No institutionalized options • Training costs can be a deterrent • Consensus on qualifications to certify • Keeping pace with technology advancements • Maintaining a qualified resource pool	• Academic Institutions; Professional Certification Bodies; Vendors
Credits and Incentives	• Takes years to develop • Compliance cannot be enforced • Biased towards passive components • Lack of comprehensive treatment of IB technologies and practices	• Associations and Accreditation Agencies; Utilities

In addition to these challenges, the continued advancement in IB technology is increasingly creating a new generation of technology and services enabling participants. These participants will link users, suppliers, and intermediary channels in innovative ways and open up new communication flows. As a result IBDI practices will need to keep pace with such disruptions in this marketplace. Chart ES 5 provides an overview of the key contributing factors for IBDI breakdowns and failures.

Chart ES 5: IBDI Breakdowns and Failures: Key Contributors

IBDI projects fail to deliver on their strategic goals in four key primary areas. While secondary contributing factors propagate these failures further, these primary factors are often the triggers that perpetuate a cycle of process breakdowns, typically with little scope for course correction in place.

Lack of Partner Alignment	Unclear Vision & Strategy	Disjointed Planning & Processes	Inability to Monitor, Test & Adapt
49% of participants experienced the impact of this factor in negative project outcomes	**51%** of project participants agree to this as a key contributor to IBDI failure	**56%** of the overall respondents attribute IBDI breakdowns to this factor	**58%** agreed to the inability to rectify problems or change course during the execution phase

Remediation of such challenges calls for consensus building among IB value chain partners, including owners and occupants, to deploy corrective techniques and comply with them in an objective manner. The best practices identified in successful IBDI projects point to the fact that given strong will and commitment from the project partners, these are highly achievable and are easily instituted for the IB industry at large. In order to make these mainstream components of the IB industry, it is important that these are adopted more commonly across projects, as opposed to being experimented on some. Given the tangible benefits and outcomes that can be attributed to the adoption of these measures, there is little doubt that the IB industry has more to gain from their swift incorporation.

ES-CHAPTER 4 EVALUATION OF PROCESS OPTIMIZATION REQUIREMENTS

When evaluating the strength of an IBDI value proposition, the research found that the following elements must be considered: process optimization, interdependency of value chain partners during implementation, and best practices that stakeholders should adopt.

Figure ES 7 provides an overview of inadequacies found in traditional processes and the focus areas identified to achieve optimization and cutting-edge practices.

Value Chain Interdependency in Implementation

To optimize processes and successfully implement an IB, value chain partners share a common responsibility to understand the project objectives in detail and address the issues of coordination, communication, and project control across the entire value chain. This value chain interdependency during IB implementation is evident in the typical and collaborative models that exist in this industry. For successful execution of IBDI projects it is imperative that a collaborative approach be adopted that permits early involvement of various participants, including different contractors and systems integrators (SIs), which positions them to understand the project goals, objectives, and design specifications, while empowering them with extra room to devise creative solutions and engage in the intensive exchange of ideas that is missing, yet needed, to help them better approach the project design and implementation of an IB.

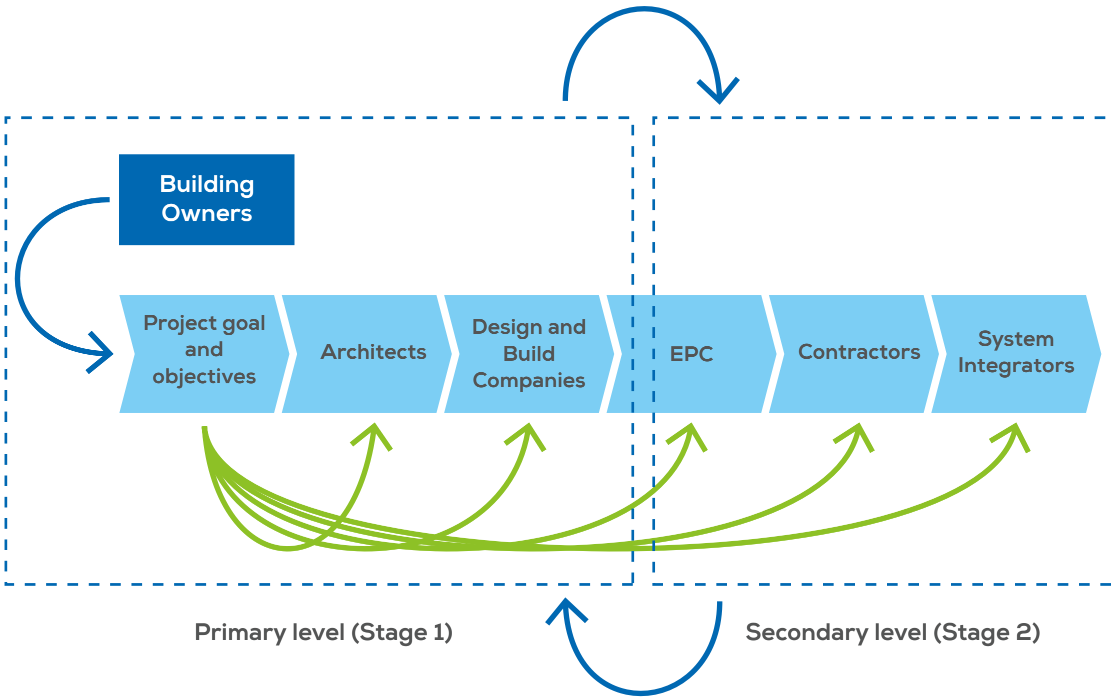
Figure ES 7: Challenges in Traditional Processes and Area of Focus

Stage	Challenges in Traditional Processes	Areas of Focus
Design and Planning	• Disconnect among value chain partners • Cost-driven approach by owners • Inadequate efforts to understand stringent project specifications leading to poor design • Lack of awareness about IBDI benefits • Lack of understanding of technology advancements • Team inexperience • Over-reliance on contractor	• Collaborate with project partners. Even earlier involvement of contractors, technology partners and operation and maintenance team is needed to provide feedback during the initial phase. • Building owners should focus more on long-term and operational costs. • Insist on establishing a complete and detailed understanding of the desired goal(s) and project specifications to ensure a strong design plan. • Stay updated on the latest technological advancements and associated benefits. • Have an experienced and multi-disciplinary team to generate the perfect design plan. • Understand the functionality of various technologies.
Execution	• Identification and allocation of resources • Slow to comprehend interoperability and integration of technology • Lack of communication and collaboration among project team, vendors, and owners • Lack of in-depth knowledge of technology	• Precise material and manpower should be allocated for specific activities. • Establish an experienced team for execution. The resources should be able to quickly grasp the integration and interoperability of the devices. • Maintain open communication with all project partners, including building owners. • Education and training is needed on the application of particular technologies to ensure contractors and system integrators provide solutions as per the project standards and specifications.

Stage	Challenges in Traditional Processes	Areas of Focus
Control	• Weak project monitoring and control	• Building owners, consultants, and contractors should regularly monitor and use tools to control the progress and cost performance of the project.

Chart ES 6 illustrates the collaborative approach.

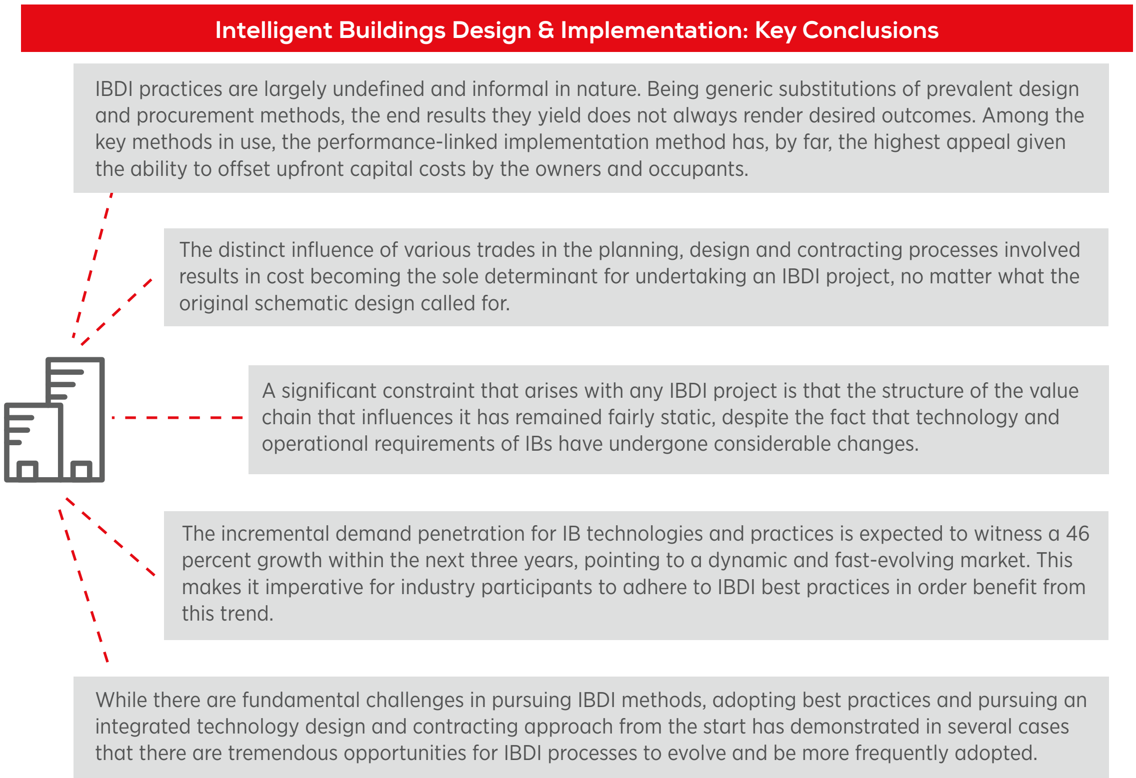
Chart ES 6: Collaborative Approach of Value-Chain Partners



ES-CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

The top findings of this research validate some of the early hypotheses around the nature of complexities associated with the IBDI process, and the triggers that cause it to either fail, or perpetuate subpar project delivery. If not addressed appropriately, such faulty practices will continue to hinder market adoption rates of IB solutions and services, despite a desire of owners and occupants to experience and invest in IBs. Creating proper process flows, collaborative engagements and education will help drive focus to the right practices that both owners/occupants and the industry can adopt to bolster the market acceptance of IB solutions and IBDI practices. Figure ES 8 summarizes the key conclusions.

Figure ES 8: Intelligent Buildings: Design & Implementation: Key Conclusions



The key recommendations of this research include the following:

- Standardize requirements for design inputs and technology specification parameters to conform to IB principles for streamlining processes
- Engage with owners, occupants and operators to capture project vision, long term goals and IB technology orientation for their cohesive inclusion
- Develop partner strategies in working with the IBDI value chain, lay down stringent guidelines, and expect satisfactory compliance from peers in implementation
- Promote better communication flow, including project records, feedback loop, and incorporation of neutral project advisors to ensure transparency at all times
- Collaborate on industry initiatives around education, training, standards, and policy

1. INTELLIGENT BUILDINGS: DESIGN & IMPLEMENTATION – AN OVERVIEW

1.1 INTELLIGENT BUILDINGS INDUSTRY OVERVIEW

From the early 1980s, there have been a number of definitions and terminologies used for describing the term 'intelligent building' (IB). The variations in the definitions depend on the different priority levels provided for various attributes, and the yardsticks used to estimate the building's "intelligence". Some attributes that contribute to characterizing IBs include the presence of integrated devices, sensors and control systems, that can intercommunicate. As a result of this, they would be expected to enable an environment that is responsive and adaptive to the needs and comforts of the building occupants and other stakeholders. For further detail on factors determining the degree of building intelligence and other terminologies used in conjunction with the term, please refer to Section ES-Chapter 1 of the Executive Summary.

Examples of IBs in North America range widely, starting with structures where some degree of system automation and control strategies have been implemented to achieve significant reduction in energy and resource wastage, to a comprehensive enterprise-wide integrated platform that eliminates all silos. No matter how robust the vision of an intelligent building is today, there are some distinct functionalities and applications that have come to exist within its domain, and others that may be prominent as part of its future evolution.

An IB typically consists of multiple devices, systems, and control mechanisms that have a high level of integration and inter-device/system communication to effectively and dynamically cater to the requirements of various stakeholders in the building ecosystem, such as occupants, facility management teams, energy service companies, and emergency responders. A key component that makes a building intelligent is an integrated communications infrastructure that supports wired and wireless networks and applications[1].

1.1.1 Defining an Intelligent Building

In consensus with the project steering committee, Frost & Sullivan adopted the following definition for the purpose of this research: "An intelligent building is characterized by the presence of two of more integrated and interoperable systems that aids in intelligent decision making regarding its operational state at present and in the future." The building's position in terms of intelligence is heavily dependent on the level of integration achieved. Figure 1.1 depicts a building's characteristics associated with its corresponding level of system integration and intelligence, as progressively tracked by Frost & Sullivan over the last decade.

Figure 1.1: IB Characteristics and the Level of System Integration

Building Profile	Design and Spec Approach	System Integration Specialist	Integration Determinants	Limiting Factors
Non-integrated	• Segregated approach divided across different participant groups • Performance specs with minimal design documentation	• Overtly dependent on contractors	• Availability • Low cost • Relationships • Lack of open standards • Difficult to accomplish system integration	• Least conducive to occupant needs • Long-term maintenance contracts of manufacturers • Engineering-by-design not adopted as a norm • Costly upgrade contracts
Partially integrated	• Combination of segregated and integrated approach • Some design documentation, but generally standalone system/hardware intensive • Meets the minimal criteria of achieving an IB status	• Dependency on contractors and system integrators	• Advocacy of open standards to some degree • Cost still overrides decisions • Benefits of integration not fully exploited	• Hardware intensive with multiple communication interfaces/gateways making the switch to full integration cumbersome • Proprietary strongholds persist • Partially responsive to occupant needs, though features significant gaps
Fully integrated	• Technology contracting or integrated consulting approach with a sole source contractor assigned • Design documentation is a mandatory norm • Sub-system integration at the control network level	• Collaborative approach and accountability shared by multiple stakeholders with the building owner at the center of decision making	• *Features an integrated design and execution process* • *Specs dictated by compatibility and interoperability* • *Demonstrates lowest life-cycle cost*	• Variances in cost estimation • Perception issues with regards to cost and time consumed • Lack of skilled professionals • Lack of project partner coordination

The true value of an IB is realized through successful concept planning, design and technology implementation, effective operation and management (O&M), and cost savings via predictive maintenance and optimization, all of which are typically realized when pursuing a fully integrated approach. This, in turn, is reliant on the building industry's motivation to adopt open standards and integrated systems, selected on the basis of their ability to scale over time, and seamlessly incorporate technology advancements that will allow the IB to offer ongoing benefits and advantages to its owners, occupants and operators. In reality, however, IBs exhibit a myriad of flaws in terms of their planning and implementation process, in turn delivering subpar performance and limited technology advancements.

Often such negative or sub-optimal outcomes are propagated by various solution providers who come together in a highly transactional design and delivery process that lack in overall vision, is cost driven, and characterized by a lack of accountability and collaboration. Adding to these fundamental flaws are issues related to lack of technology knowledge, inadequate skill sets, and inability to integrate the right parts of the value chain when required to deliver a comprehensive IB design, delivery and implementation process. However, before proceeding to analyze such issues and drawbacks, it is important to understand what constitutes an IB design and implementation process and the ecosystem of key players associated with it.

1.1.2 The IBDI Methods and Practices

IB projects do not currently have any clearly demarcated implementation processes. Please refer to Section ES-Chapter 1 of the Executive Summary for additional information on methodology and definitions used throughout the study to describe Intelligent Building Design & Implementation (IBDI) methods and practices. The following methods were identified by this research, as depicted in Figure 1.2.

Figure 1.2: IBDI Methods Prevalent in the Industry

IBDI Methods	Description	Key Highlights
Design-bid-build	• The design-bid-build method, when used for IBDI, works on similar principles, as when used in a non-IB context. • It starts with the building owner's selection of a design build or a consulting engineering firm. • IB design and procurements tasks, specific to each technology or process, are initiated sequentially with limited overlaps. Typically the building owner or occupant contracts with separate parties for the design and for the implementation of the project.	• Clear vision of technology requirements to be fulfilled • Demarcation of roles and responsibilities by design, procurement and implementation
Design-build and implementation	• In this method the building owner or operator contracts with a single party who takes charge of the design, procurement, integration and implementation of the IB technologies and processes that are contracted to this party. • This method can potentially reduce the project delivery time by overlapping the design and implementation phases of the project.	• Single point of contact enhances overall accountability • Simultaneously execution ensures better coordination of technology integration needs and processes
Performance-linked implementation	• This is essentially a variation of the "design-build and implementation" method in which a performance guarantee is linked to the technology or process implementation that is contracted from such service providers. • For example, guaranteed energy saving, compared to a baseline performance, is expected to be delivered under such contracts from the contracted party. • This has often been an instrumental way of adopting IB solutions, entailing zero, or negligible upfront investment in certain cases.	• Assured guarantee stipulations increases the onus and accountability of the service providers contracted • Considered the most effective way to fast track technology implementation in IBs in recent years

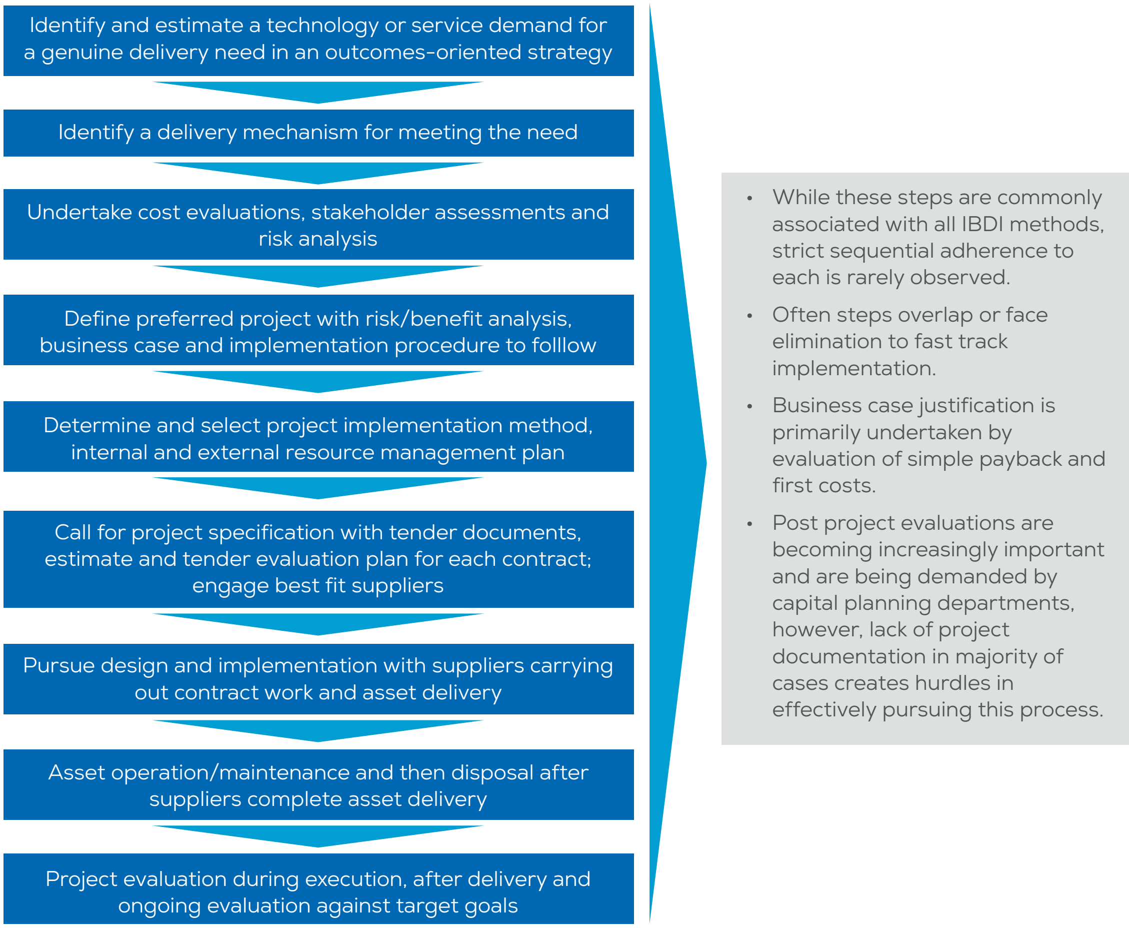
IBDI Methods	Description	Key Highlights
Collaborative implementation	• This method essentially combines best-of-breed processes and practices that are already inherent to the preceding three methods, in addition to provisioning the ability to incorporate specialists, new industry entrants, and outside industry entrants as needed. • The purpose of such collaboration is to facilitate a robust delivery and implementation process that is closely aligned with the owner's or occupant's vision and future expectations from the building.	• Proper coordination and collaboration ensures better technology and process integration • Ensures low life-cycle costs • Offer scalability of initial investment

In practice, it is quite common for some of these methods to be used in conjunction with others. Market demand has also encouraged the usage of sub-classifications of these methods. There are numerous variants of these commonly adopted IBDI methods. For example the General Services Administration (GSA) in the United States, in their procurement guidelines, identifies more than eight variants of the design-build and implementation method.

The IB industry has witnessed the development of a plethora of steps and stages formulated to successfully deliver IB projects using the above IBDI methods. An evaluation of these methods, and the stages embedded in them, confirms the presence of certain key elements with varying degrees of detail and sophistication, dictated by the complexity of the project at hand. The research determined a set of key elements or stages that can be condensed from the review of the above methods pursued in fulfilling

IBDI projects. Chart 1.1 lists these key stages present across IBDI methods.

Chart 1.1: Key Stages Embedded in IBDI Methods



1.1.3 The IBDI Value Drivers

Building owners and occupants are increasingly looking at buildings as an extension of their primary function, rather than a separate entity providing an environment to operate in[2]. There are unique value drivers that are associated with pursuing IBDI methods by owners and occupants, combining both tangible and intangible components. From a tangible perspective, the evolution of building functions is primarily being driven by three factors, discussed as follows:

- **Development of underlying or enabling technologies:** For this industry, the primary technology enabling evolution has been communication and control. The introductions of new communication standards and reduced costs associated with microcontrollers have been major driving influences.
- **Impact of fluctuating energy prices:** Considering operation costs typically form approximately 50 percent of a building's life-cycle costs, energy price fluctuations play a significant role in driving the need to reduce energy dependency using efficient automation methods.
- **Impact of the Internet of Things (IoT) on user expectations:** Given the rapidly evolving impact of the IoT, occupant preferences and owner/operator expectations stresses the need for connected experiences and smart outcomes from their built environments. As the physical technology realm increasingly transforms to one with information technology (IT) and IoT

enabling all aspects of its functioning, the experience and value derived from inhabiting such environments increases with it, making the need for the right design and implementation methods for creating such an environment all the more necessary.

- **Intangible benefits:** Beyond the tangible drivers that help justify the investment in IBs, there are certain key intangible benefits that are increasingly being upheld by IBs such as: productivity gains, occupant comfort and satisfaction with their work environment, reduction in sick days; which further drives the interest in planning and design of IBs with the right set of technologies that combine to deliver such benefits.

The above value drivers have been instrumental in creating the need for the right design and implementation methods to be adopted that can enable an IB, its owners and occupants to harness the full benefits of owning and occupying such an entity.

To understand the IBDI methods, and how they impact various aspects of technology implementation in buildings, it is important to review the IB industry landscape and the value chain of solution providers that inhabit this space. Based on the definition of IB followed for this research, the IB industry encompasses participants from a wide spectrum covering vendors, service providers, project execution partners and third-party professionals that help design, develop, fit-out, operate and continually service such an entity. Given their roles and responsibilities in executing projects via the IBDI methods, a closer look at this value chain is necessary to understand how each player influences these methods, and practices associated with them. Figure 1.3 illustrates some of these key participants of the IB value chain, and the roles and responsibilities they have assumed.

Figure 1.3: Major Participants3 of the IB Industry Value Chain: Key Roles and Responsibilities

Participant	Roles and Responsibilities
Owner/Developer/ Occupant	• Defines technology requirements and approves capital budgets • Defines the project requirements for the design and/or contracting/ construction team • Reviews proposals and selects original equipment manufacturers (OEMs), consulting engineer, design/build firm, or construction management firm, as required • Works with select partners to develop plans that meet the project's goals, budget, and requirements • Reviews selected subcontractor bids and approves selection • Executes contract with general contractor, if directly dealing with contractor • Oversees all contract relationships, including continued service agreements, maintenance, and commissioning
Consulting Engineer (CE)/ Design Build Firm/ Architect/ Designer	• Works closely with owner/real estate developer to identify project requirements • Responsible for completing a final project design and providing detailed construction drawings, technology specifications, and supporting documents • Reviews bids from subcontractors to ensure they meet all requirements and seeks clarifications from bidders when required • Advises owner in regard to the most suitable bids • Provides some construction administration to ensure contractors delivery process meets design intent

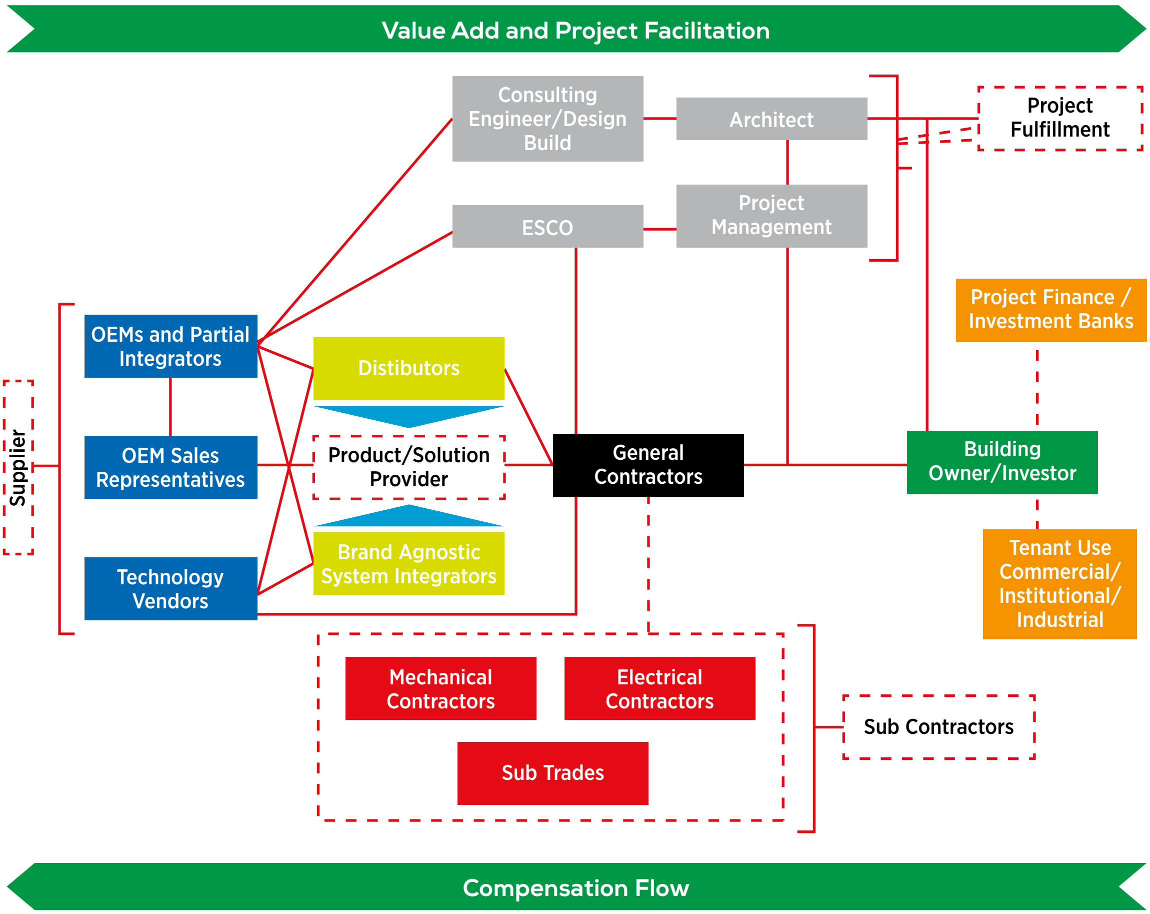
Participant	Roles and Responsibilities
Contractors and System Integrators (SI)	• Responds to requests for bids by submitting proposals that offer the best value and meet criteria • Works with distributors to obtain pricing needed to submit a bid • Procures systems to meet the consultants' design and fulfill the installation process • Responsible for constructing the facility in accordance with the design and the budget • Ensures construction is completed on time
Distributors	• Responds to request for quotes from contractors • Sends request to the manufacturer representative or directly to the OEM to get pricing information • Sends purchase order to the agent representative or directly to the OEM • Coordinates shipment of the equipment to the job site or the contractors shop
OEMs, IT, Telecom and IoT vendors	• Works closely with manufacturer representatives to assist in the equipment delivery process • May continue to be involved via manufacturer representatives, or directly, in the delivery of additional products and services to assist the installation process • Educates the industry through their manufacturer representatives about new technologies and products
Energy Service Company (ESCO)	• Conducts detailed assessment of existing conditions • Proposes measures to meet the client's specific energy and performance goals • Works with owner to establish the measures that will be adopted and determines a baseline energy performance for the purpose of comparing energy savings and ensuring delivery of guarantees • Responsible for completing a project design and providing detailed construction drawings, specifications, and supporting documents • Reviews bids from subcontractors to ensure they meet all requirements and advises owner in regard to the most suitable bids • Responsible for commissioning measurement and verifications to determine energy savings against baseline
Utilities	• Offer a facilitator role in provisioning energy services • Are becoming increasingly involved in offering demand-side management via smart grid deployment initiatives • Also involved in helping pilot IB solutions, either directly, or in collaboration with OEMs and third party service providers

Technology vendors and OEMs have traditionally interfaced more with building owners directly to propose their products and solutions. However, building owners have mainly relied upon consulting specification engineers and design build organizations to make the right technology selection. Given this situation, a clear mismatch between the specified and delivered technology arises, which creates a divide between the original project vision and the final outcome. Nevertheless, industry participants have continued to work within their defined domains to create optimal value propositions for the building owner and occupants, which they often strive for, no matter what challenges they face in dealing with value chain partners in the delivery process.

As further corroborated by the industry professionals' research survey, conducted as part of this project, the most important motive driving the business value proposition for any of these participants is the ability to retain strong margins on any design and implementation project they deliver. However, the intensity varies by the type of participant. For instance, ESCOs and design build firms are more inclined to keep tasks in-house, as opposed to subcontracting to other entities, because they assume the majority risk in any project delivery. This ensures that they complete projects with higher margins than their counterparts. Furthermore, depending upon the type of IBDI method under consideration, the interaction and task details of these participants could vary. Consequently, this may imply that the responsibility assumed by a particular type of participant could be more, or less, based on the process followed.

Chart 1.2 provides a snapshot of the IB industry value chain[3] involving all aspects of design and implementation.

Chart 1.2: Intelligent Building Design and Implementation: Industry Value Chain



Encompassing all critical supply points within the design and delivery process, the value chain of the IB industry assumes a fairly robust sequential flow with value added components moving from suppliers on the left to the building owners and occupants on the right as shown on Chart 1.1. However, given the relatively nascent development of a full-fledged IB implementation process, clear definitions for the scope of responsibilities of various participants can vary from project to project. It then becomes incumbent on the project management office to define a specific demarcation of scope boundaries at the start of the project, in tandem with the overall consulting engineer or design build firm. This helps reduce delays in execution and coordination issues that can cause the project to exceed its timeline or result in a sub-optimal quality of construction. The research revealed the following key imperfections that characterize the current value delivery process associated with majority of IBDI projects. Additional descriptions of these are provided in the executive summary chapter.

Extreme Fragmentation Creates Polarization of Goals
Given that OEMs, product vendors, and technology vendors work, either directly with the building owner, or through any of their supply chain partners, there are instances of conflicts of interest and, at times, jeopardizing of prospects of participants. Often this factor is the root cause of deviation from a project's original intent and vision.

Multiple Decision Makers Lead to Fulfillment Nightmare
Even though the responsibility for technology procurement lies with the contractor, the final decisions on procurement are taken by the building owner in consultation with participants such as consulting engineers (CEs) or energy service companies (ESCOs). Additionally, general contractors have to interface with a further fragmented value chain comprising of electrical, mechanical and other sub-categories.

Static Model with Limited Dynamic Intervention
The structure of the value chain for this industry has remained fairly static, despite the fact that technology and operational requirements of buildings have undergone considerable changes. As a result, transactional practices dominate the overall project delivery process.

Lack of Design Flexibility Eliminates Technology Integration Prospects
There is an unfulfilled requirement of further flexibility in building design to accommodate changes required during the implementation phase. In particular, most design and implementation practices do not have a way of integrating new upgrades to technology, service innovation and new players.

1.2 IMPLICATION OF IBDI PROCESS ADOPTION BY TECHNOLOGY TYPE

It is the design and implementation process that supports a well-connected and integrated network of building systems and controls. The technical design stage is when most important decisions should be made that will influence how the IB operates. Generally, lighting systems, fire and life safety, HVAC, and security systems are the top four technologies in almost all IB projects. For a building to be intelligent it is imperative that its physical systems integrate and intercommunicate. Project partners involved in the design and delivery of IBs, such as engineering consultants, building owners, and SIs, are required to have a holistic view of what the building is expected to deliver, and more importantly what its occupants and owners desire from it. A comprehensive design and an implementation roadmap are essential when evaluating building expectations and when attempting to cater to the future needs of changing technologies and occupant demands. Therefore, an intelligent design and implementation framework is the first step in this process.

The design and implementation processes followed in the industry for any particular type of IB technology do not vary significantly. However, depending upon the type of value chain partner involved or responsible for influencing the procurement process, there appears to be subtle differences.

Considering that the fulfillment partners, comprising CEs, design build, architects, ESCOs, and project management companies are directly responsible for incorporating the requirement for such technologies, it is not surprising that they enjoy a distinct influence in technology selection across the board. They, along with the contractor and the system integrator, determine what goes into the project. The SI is particularly important for technologies such as; building automation, energy monitoring, fault detection and diagnostics, and analytics. Most system integrators (SIs) agree that they are able to ensure that their represented products get considered the majority of the time. However, it is always a battle to justify pricing. It is also additionally required to ensure effective education and exposure of fulfillment partners with regard to available innovations and new product offerings. Marketing activities such as seminars, targeted whitepapers, exposure in trade fairs, etc. play a significant part in ensuring that participants such as OEMs and technology vendors are able to include their technologies for consideration during the planning and design stage.

Communication technology, IoT and other digital transformation related projects are usually procured via a separate design and delivery process, and therefore, work independently of other building technology design processes. Although the influence of any particular value chain partner is difficult to establish, it is clear that this category of vendors does work more closely with the fulfillment partners and building owners and are relatively immune to value engineering and price pressures, owing to the nature of products and services they offer.

Figure 1.4: IBDI Process Adoption by Technology Type

Technology	IBDI Value Add	Key Influencers	Drawbacks
HVACR	• OEMs work through SIs and distributors to meet the design and operational requirements. • OEMs and OEM reps would escalate to the building owner or facility manager in case of conflicts during implementation.	• Their relationships with building owners, facility managers, and contractors influence methods of working and adjustments in commissioning schedules. • Price is a key determinant, though energy efficiency attributes are equally gaining importance as owners/facility managers look to save on operational costs.	• There is limited or no interface during the initial design phase. OEMs typically have to customize their designs, sometimes at the cost of efficiency, to meet design requirements. • Internal business strategy needs to be examined and unified, to showcase adjunct products effectively to end-users for ensuring allowances for adjunct products during the design phase.
Lighting and Energy Efficiency	• OEM representatives work for lighting design inputs with architects and end-users during the design phase.	• Architects and their lighting designers are the key project influencers for the design phase. • If ESCOs are involved, their in-house consultants become key influencers in terms of efficiency and smart lighting requirements.	• Custom design needs are a requirement so OEMs need to have a higher involvement with the distributor/project fulfillment partners for ensuring smoother coordination. • Educating SIs on appropriate product innovations for ensuring effective integration and troubleshooting is required.

Technology	IBDI Value Add	Key Influencers	Drawbacks
Building Automation	• OEMs, agent reps and SIs are key coordinating participants.	• SIs appear to be key influencers for the final integration stage. • SIs are the key touch points for contractors, facility managers, and project management firms during implementation given their interaction with multiple system providers.	• There is limited or no involvement during the design stage. • Technology silos need to be removed. • Further education of OEMs with changes to construction specification practices and master format categories is required to ensure compliance during construction.
Energy Information Monitoring, Management, Diagnostics	• SIs are key to ensuring effective implementation and would be a key participant during requirement discussions.	• Suppliers are required to coordinate with SIs for effectively incorporating their products into the overall solution. • Reporting mechanisms developed in consultation with owners and facility managers determine usefulness.	• More interaction during design phase with fulfillment partners is required. • Education of end-users about various features would ensure optimal design and usage.
Telecom, Communication Infrastructure, IoT/IT	• Vendors work directly with fulfillment partner or building owner/ facility manager. • IT infrastructure to support various systems would also require interaction with fulfillment partners.	• As compared to suppliers of other technology offerings, vendors here have a higher level of interaction with project fulfillment partners due to the networking aspects of the technology. • Price, in addition to reliability is a key aspect for owners and facility managers. • Ensuring connected technology nodes as a part of the IoT ecosystem is also a key aspect.	• Creating a single point of responsibility with regard to both, the products and subsequent installation is required, which would need collaboration of these vendors with system installers/integrators.
Fire & Life Safety	• OEMs and SI serve as the key touch points in the stages. • These suppliers work directly with the fulfillment partners or building owner.	• The key influencing factors for this area are fire codes. Scope for design variations is minimal given the adherence required to these codes. • Price determines selection, as other aspects require adherence to the codes. • Owners would ensure the monitoring of any attributes for adherence to the respective codes.	• Creating awareness about possible innovations in products or customization options within the ambit of the codes is required to be provided during the design phase.

Technology	IBDI Value Add	Key Influencers	Drawbacks
Physical Security	• OEMs, SIs, and distributors of physical security products serve as the key participants. • They can work either through association with the fulfillment partner, or with the building owner/facility manager.	• Relationships of OEMs with building owners and facility managers are key to determining requirements are adhered to and installation is in line with expectations. • Security concerns and the need for better access control and monitoring makes the inclusion of these products necessary. • Integration aspects are important for ensuring centralized control and monitoring.	• Products need to be made with open protocols to prevent technology silos and integration issues. • Vendors need to coordinate directly with design engineers to ensure adherence to the overall plan.
Building Infrastructure, Structural Elements, and Other Services	• Contractors appear to be the main point of contact for this group of suppliers and service providers. • However, this group does enjoy direct interaction and relationships with the building owner and facility managers.	• Fulfillment partners, particularly CEs and project management firms, will have high influence in determining aspects requiring adherence. However, these vendors will primarily coordinate with contractors during the implementation phase. • Logistics, material quality and coordinated fabrication are key aspects for this area.	• Higher involvement during the conceptual planning/ design stage is required to ensure all aspects for constructability is considered. • A better understanding of the master format spec process is required.

1.3 IMPLICATION OF IBDI PROCESS ADOPTION BY VERTICAL INDUSTRY SEGMENT

The IBDI methods and practices followed across key vertical industry segments of the IB industry are determined by the end objectives and purpose governing their use by such clientele. This research reviewed the adoption of IBDI methods in segments such as commercial (office, retail, hospitality, mission critical facilities), industrial (manufacturing plants, warehouses), and institutional (public building, education). Commercial buildings are generally tenanted facilities; therefore, occupancy and fast-leasing prospects drive the need for new technology design integration, interim fit-outs and major renovations/retrofits by the building owners and operators. Short-term gains play a key role in decision making. Energy savings and smart labels have gained relative importance among building owners in this category, as it helps in differentiating their properties. However, longer paybacks from investment in smart technologies are not attractive. Technology incorporation is also partly constrained by budget issues, limited availability of institutional finance, and performance-linked implementation options for this segment. The SIs act as the key influencer category and work closely with the contractors to facilitate technology and design implementation needs. An OEM's direct relationship with the building owner is also instrumental, primarily when working on renovation and retrofit projects.

The industrial buildings segment has similar characteristics to the commercial segment. However, contractors operate as the most important touch point throughout the design and implementation process. Additionally, the duration of projects in the industrial segment tends to be longer than in others. This prolongs the involvement of the contractor in the project and gives them influence over design changes during the execution phase of the project.

Institutional buildings appear to be the only category where budgets and pricing do not exert an overwhelming influence on technology and design process adoption or vendor selection. Owing to the fact that this segment has access to performance contracting, and has set some stringent energy efficiency goals for their facilities, their appetite and adoption rate of IBDI solutions is relatively better than the other two vertical segments. This segment also operates on direct OEM and vendor relationships, and sole source contracts, eliminating the risk of low-priced competitive bids taking away from the objective and vision of the project. Figure 1.5 depicts the implications of IBDI adoption by key vertical industry segments.

Figure 1.5: IBDI Process Adoption by Vertical Industry Segment

Market Segment	IBDI Process Flow and Influencers	New Construction versus Renovation/Retrofit*	Issues to be Addressed
Commercial (office, retail, hospitality, mixed use/ multi-dwelling)	• Key stakeholders can vary as per specific building types. For example in the case of a showroom, lighting vendors can have a more prominent role. • Contractors and trades people have more authority during the planning phase to determine technology selection. • OEMs and SIs are key coordinators during implementation.	**New construction** • Contractors are key decision makers and coordinators with suppliers. • There is a limited ability to influence detailed design aspects. **Renovation/retrofit** • Initial coordination would be with the building owner and facility manager and vendors would have more authority. • Ability to cater to operational requirements has higher weightage compared to price.	• Building owners need to be further educated about the value and operational cost saving aspects of IB adoption. • Awareness of various features and innovations in IB technologies needs to be increased for owners and facility managers. • Owners excessively rely on credits and rebates for investing in such projects. • More stakeholder integration during the design and planning stage is required.
Industrial	• This segment has a high number of projects with a client nominated contractor as the overall custodian of the project during design and implementation. • OEMs and SI work through the contractor to cater for technology requirements.	**New construction** • Projects typically have a longer duration than other vertical segments. **Renovation/retrofit** • Past relationships and project exposure, including continued service offerings, help in better coordination during retrofits.	• Issues of coordination and expectation mismatches between owners and contractors are common. • Included margins of the nominated contractor create cost challenges. • Further education for owners required regarding non-industry process specific IB technologies.

Market Segment	IBDI Process Flow and Influencers	New Construction versus Renovation/Retrofit*	Issues to be Addressed
Institutional	• OEMs and SIs are the key coordinators at the system level. • Construction or project management firms act as the key link between owners and suppliers. • One of the key criteria in design aspects is energy and operational savings.	**New construction** • A larger variety in architectural design aspects leads to more complexity in vendor types. **Renovation/retrofit** • Past relationships and project exposure, including continued service offerings, contribute to better coordination.	• Awareness of new innovations in technology and features available is needed.

1.4 CHALLENGES IN TECHNOLOGY INTEGRATION IN IBDI PROJECTS

Currently, IB technologies are not being effectively used due to challenges within the industry. Limited time for design and technology implementation leads to premature finalizing and ordering of equipment to meet construction deadlines. Some major challenges that need to be considered while adopting an optimal design are functional efficiency, ease of maintenance, operating costs, delivery time of the design concept, and the technology solution delivered as part of it. Chart 1.3 depicts the most cited challenges in pursing IBDI projects and a few corresponding success stories observed by this research.

Chart 1.3: IBDI Projects: Common Challenges and Resolutions Achieved

IBDI Projects: Common Challenges		Resolutions Achieved
Dismantling technology silos	• IB products undergo third-party value additions as they navigate their way from the OEM into the project specs. • However, delivery of such embedded intelligent products requires the use of specialized technology contractors. • *Ad hoc* inclusion of such specialists and overt dependence on OEMs propagates technology silos and continued selection of proprietary products.	In 2016, Intel created its first IoT-enabled smart building in Bangalore, India. The office building was outfitted with approximately 9,000 sensors for monitoring and optimizing aspects such as temperature, lighting, energy consumption and occupancy. However, the legacy building management system that Intel was using in the rest of the buildings of the campus had a proprietary interface making integration cumbersome. As a result, Intel then designed its own scalable smart building solution to collect and analyze data.[4]

	IBDI Projects: Common Challenges	Resolutions Achieved
Contractor's control of the buying process	• Disconnect between value chain participants makes it far easier for the fulfillment partners, as well as the building owner, to overtly depend of the contractor to carry out the buying process. • For the CEs and architects, this minimizes the onus and accountability, once the spec is put down. • Thus past relationships and ease of install dictates technology selection, even when the right design process was originally adopted.	Strictly following a performance-linked implementation project, the operations team at the Harker School in San Jose, California, partnered with master energy consultant, California-based Serious Energy to identify an intelligent energy management solution for enhancing energy efficiency and reducing operating costs through real-time energy information monitoring. With constant collaboration and a combined design approach, the school authorities, Serious Energy, a local system integrator, smart server provider Echelon and the local utility completed the project successfully, with less than two-year payback for all capital expenses incurred.
Piecemeal integration of a technology contractor	• What characterizes the technology contractor and; therefore, who typically assumes this role, is a shifting perception. • However, for a successful IBDI project the technology contractor is a critical prerequisite. • The difficulty in compartmentalizing such entities easily into one or more categories often leads to their incorporation in projects on a piecemeal basis.	The Michigan-based Van Andel Cancer Research Center incorporated technology leaders right from the start to meet it objective of achieving centralized management of operations with tracking, monitoring and reporting capabilities, and above all technology scalability in the future. Working closely with their IT solutions provider and smart lighting solutions provider Legrand, advanced system integration and open information communication was achieved facility-wide, with computerized control of lighting from a central software application. This resulted in annual operations and energy savings of up to $130,000.

Research undertaken among IB solution providers and owners/occupants indicates that these challenges were commonly experienced in the design and implementation of security systems, HVAC, and lighting systems. In general, OEMs have concentrated their efforts on developing cost-effective and energy-efficient systems that comply with green energy regulations that impact the system selection in an IB. The ability to quantify energy savings and offer an interoperable system is a key factor driving equipment choice in an IB. Consequently active involvement of such suppliers prior to, and during, the design and implementation phase can help ensure a clear understanding of the end solution and the related integration of components required to add it to the building's design and technology portfolio. Furthermore, this will help the contractor and building owner navigate the vagaries of challenging applications and the specific specialists that need to be involved to ensure appropriate fulfillment of the project.

1.5 COMPARATIVE REVIEW: PROJECT DELIVERY AND IMPLEMENTATION MODELS

Various project delivery and implementation models can have different effects on the design and implementation processes of a project. With the exception of the collaborative implementation method, all others have key drawbacks and functional challenges that continue to deliver sub-optimal projects. These challenges have been compared in Figure 1.6 below.

Figure 1.6: IBDI Methods: Comparative Review of Functional Challenges

Design-Bid-Build	Design-build and Implementation	Performance-linked Implementation
• There is a longer delivery time due to the multiple stakeholders used for different project phases. This increases the likelihood of conflicts when changes/approvals are required. • Costs and potential issues with constructability can be identified only after the completion of the design and project planning phases. • Assigning responsibility and resolving issues becomes the owner's responsibility, requiring dedicated resources and time allocation.	• This approach runs the risk of designs being created in a sub-optimal manner in order to ensure ease of construction. • Possibilities of low energy savings targets being set in the case that energy management of the building is the responsibility of the single-point company. • Involvement of the owner is restricted to the requirements phase and overall plan, with possibilities of a mismatch in expectations due to the owner's interests not being represented during the execution phase. • Solutions can possibly focus more on reducing capital expenditure than on operational control and maintenance costs.	• This can incur added overall expenditure because of additional margins of the performance guarantor. • Less direct involvement of the owner due to performance guarantees being the contracted criteria can result in sudden downtime in case of non-performance of the vendor. This can be detrimental to the owner's interests, especially in the industrial vertical.

1.6 KEY CHALLENGES AND AREAS TO BE ADDRESSED

There are multiple reasons projects could turn out sub-optimal, have execution delays, or end up failing. These ranges from improper spec gathering, unrealistic expectations, and inefficient conflict resolution processes. Some common areas of concern to be addressed have been provided below:

- Technology silos, where certain suppliers provide technology systems through proprietary technologies, can be challenging to integrate with other systems. This can cause project delays due to integration issues and cost overruns due to an increased workload of system integrators. In some cases, system controls are required to be isolated for systems, and this can result in sub-optimal building operation.
- A higher level of interaction between OEMs and the project design team is necessary to ensure that required design changes are clearly communicated and accounted for. Comparatively, OEMs communicating through contractors/owners might not be able to effectively resolve issues or suitably cater to design requirements.
- The inadequate training of contractor and supplier's employees with regard to system integration requirements and rapidly evolving smart building technologies can result in

issues and delays during the execution stage.

- An undefined or poorly defined conflict escalation mechanism for design issues that occur during project execution or negotiations can hinder progress or cause cost overruns due to material wastage/reverse logistics for components.
- An improper or inadequate handover mechanism can result in unplanned scenarios that a standard operating procedure does not account for. It can also result in repeated building maintenance requirements.
- Inadequate communication of project requirements in terms of the level of intelligence required for a building by the owner can get distorted as it passes through various project partners involved in the process, thus necessitating design changes and cost and time overruns.
- Inadequate communication between a partner's internal project fulfillment teams could lead to errors in compatible system selection.

2. INDUSTRY PERCEPTION ANALYSIS

2.1 INTRODUCTION AND METHODOLOGY OF THE SURVEY PROCESS

Industry Research Module

The industry perception research module was designed to understand and capture valuable insights regarding the critical challenges and concerns involved in the design and implementation process of an intelligent building (IB) for various vertical uses. The intent of this research module was to capture the perceptions of various IB industry value chain operators and to corroborate, or further supplement, the general notions and viewpoints that currently prevail in this industry.

Key Objectives of the Customer Research Survey

The survey addressed the following:

- Current practices prevalent in the industry with regard to adoption, implementation, and value optimization from various aspects of an IB
- The benefits of adopting proper design and implementation practices that lead to better outcomes from such buildings for owners, occupants, and operators
- Design processes currently in use and the ways to improve their adoption
- Issues and challenges experienced by various stakeholders in pursuing such design and implementation processes
- The role of key adoption drivers and restraining factors in either promoting or impeding such practices
- Scope for justifying design-backed investments in IBs and the perception of value gained from it
- Prospects for making design and implementation best practice a key feature of this industry

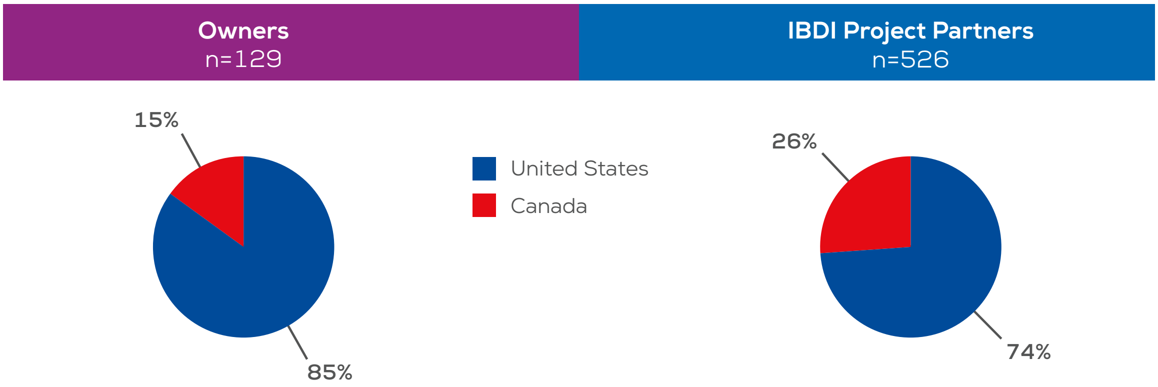
Research Instruments: Questionnaire

Frost & Sullivan developed the discussion guide for the industry perception research process in consultation with the steering committee. The process of approval and obtaining data consisted of multiple stages, which have been detailed in the methodology section of the Executive Summary of this report. The data from these responses were then analyzed using various qualitative and quantitative tools for interpretation in the report.

2.2 ORGANIZATIONAL AND INDUSTRY-BASED PROFILING1

A few screening questions were asked as a part of qualification criteria before allowing respondents to proceed with the survey. Respondents not meeting the required criteria were disqualified from the survey. Qualifying respondents were further profiled for classification purposes. Please refer to the methodology section of the Executive Summary of this report for further information regarding the qualification criteria and questions on respondents' profiles. The results of the respondent profiling process are illustrated below. Chart 2.1 shows the country classification of the broad category of respondents.

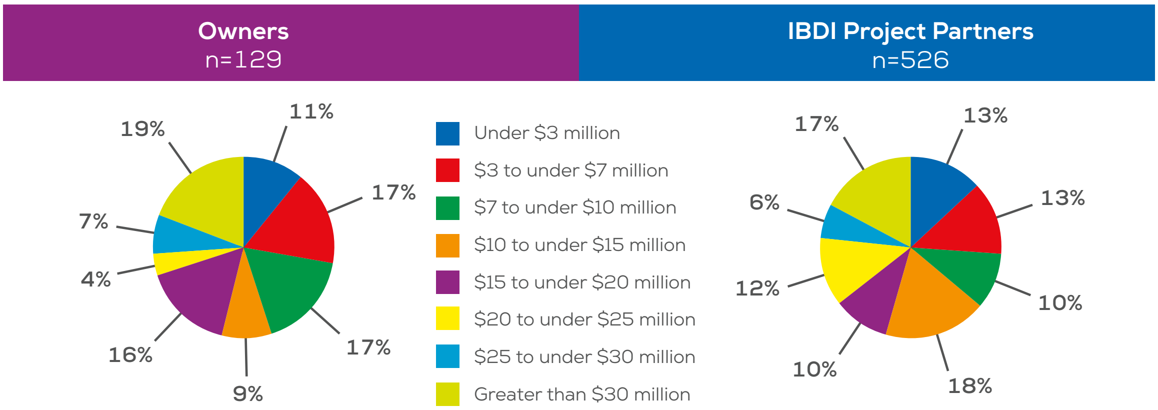
Chart 2.1: Country Classification within the Category of Respondents



Q: Country of organization

Qualified respondents were geographically categorized for United States (US) and Canada. The US respondents comprised 85 percent of the sample, while the remaining 15 percent were from Canada. Of the total sample, companies with revenues greater than USD $30 million comprised of 19 percent of owner-operated companies and 17 percent of project partner companies.

Chart 2.2: Annual Revenues of the Organization

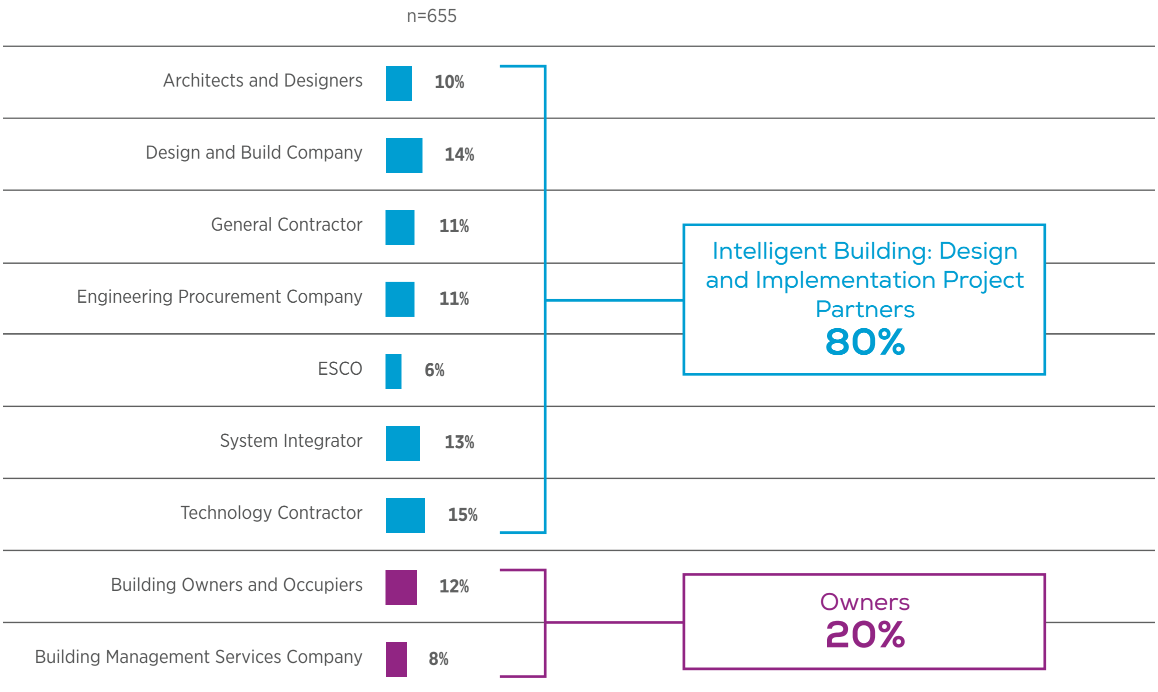


Q: What was your company's total revenue for the last full fiscal year?

Building owners work with select partners to define the project design and develop plans that meet project goals, budget, and other requirements. They were further categorized into "building owners and occupants" and "building management services companies." For the purpose of this report, the term "project partner" encompasses the following entities of the IB industry value chain: architects and designers, design and build companies, general contractors, engineering procurement companies (EPCs), system integrators (SIs), technology contractors, and energy service companies (ESCOs).

Approximately 20 percent of respondents were building owners and 80 percent were project partners, as seen from Chart 2.3. Further categorization of respondents was based on their job profile within the organization, thus allowing the research team to obtain feedback and insights from decision makers and ensuring results with a higher degree of accuracy.

Chart 2.3: Organizational Classification of Respondents



Q: What type of organization do you represent?

Chart 2.4: Profile of Respondents

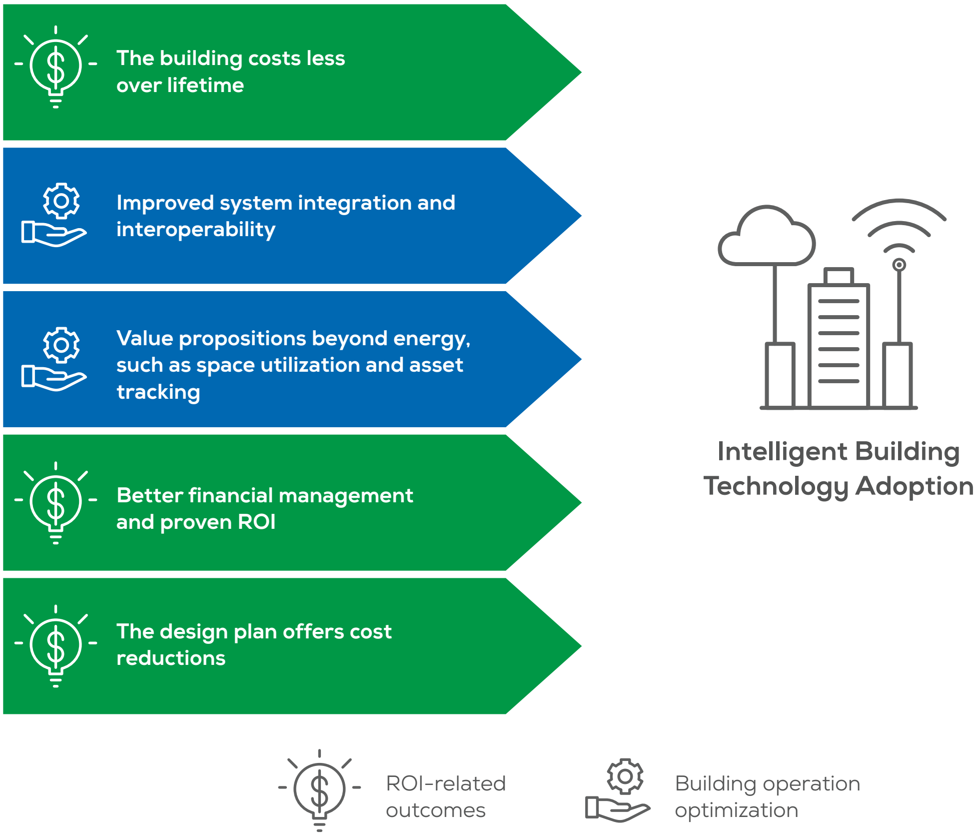
	Owners n=129	IBDI Project Partners n=526
Building Technology consultant / specialist	15%	23%
IT and IoT consultant	5%	17%
General contractor	8%	13%
Consulting Engineer	6%	12%
Owner or partner	28%	6%
Executive decision maker	14%	9%
Architect	1%	6%
Operations	9%	4%
Facility / Property Manager	12%	2%
Contractor	0%	4%
Dealer / distributor	0%	1%
Capital Planner / Financier	1%	0%
Other	0%	2%

Q: Which of the following best describes your job title?

2.3 PERCEPTION REVIEW OF TECHNOLOGY AND DESIGN PROCESS: IMPLEMENTATION DRIVERS AND CHALLENGES

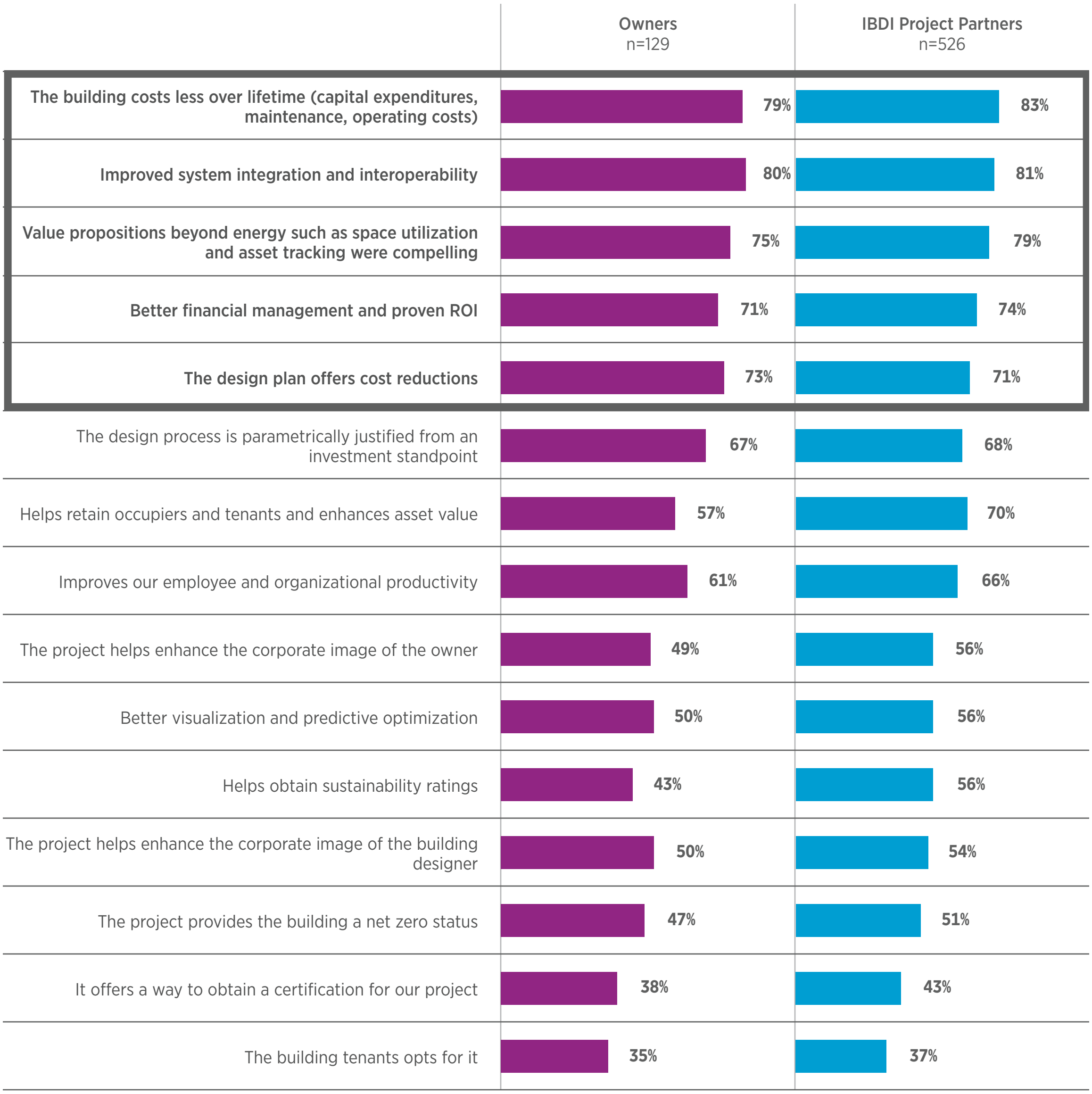
The industry research survey provided important insights into the overall intention for the adoption of IB technologies and the challenges faced. The questions in this category sought to understand the key objectives for adoption. The adoption of IB processes, including conceptual design, procurement, implementation, and further operation, is mostly driven by operational and financial considerations. Various respondents broadly agreed on both the benefits associated with the return on investment (ROI) and the gains in operational efficiencies. The intentions for the adoption are more focused on the overall benefits that the owner, occupant and operator expect to gain from the use of IB technologies within the environment that they inhabit or operate from. Chart 2.5 represents the top five drivers and benefits of IB technology per this research.

Chart 2.5: Drivers of Intelligent Building Technology



A significant 79 percent of building owners and 83 percent of project partners feel that the adoption of IB technology is associated with substantial reductions in operating costs, which is one of the primary drivers for embracing smart and interoperable technologies within a building.

Chart 2.6: Drivers of Intelligent Building Technology by Owners and Project Partners



Q: What are the drivers for adoption of intelligent building technologies?

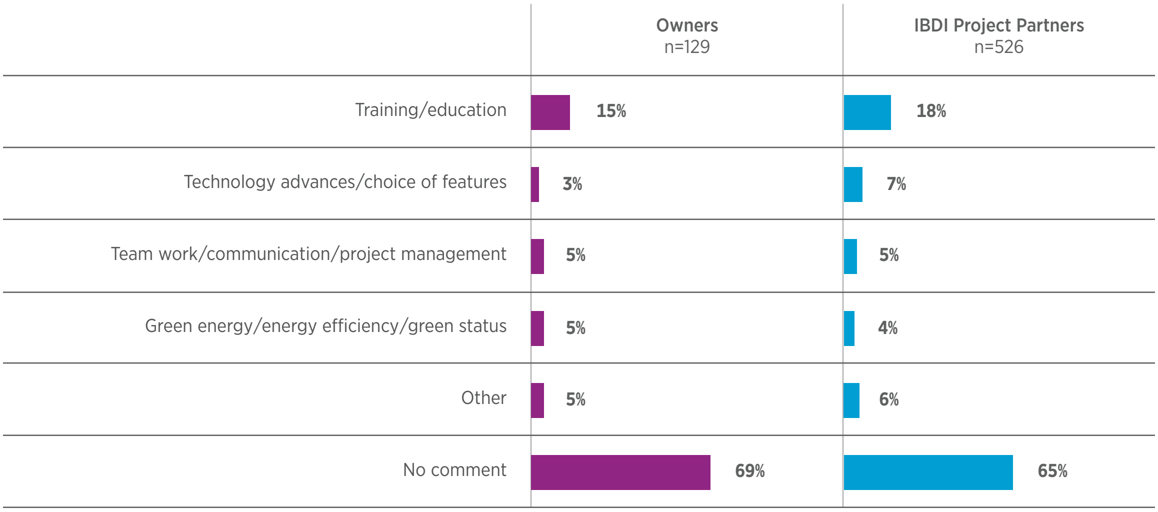
Frost & Sullivan's research also identified some challenges faced by building owners and project partners for the adoption of IB technology. The critical challenges are the lack of awareness of the benefits associated with an IB and lack of awareness of the latest technologies. The building owners perceive some of the IB technologies as highly expensive. Because they have budget constraints, there is more focus on the upfront cost of the building. Thus, due to the high investment associated with IB technologies, some building owners hesitate to incorporate all IB technologies. Compatibility of new technologies with existing equipment is another challenge faced by building owners and project partners, especially during retrofits and renovation projects.

To overcome some of the challenges associated with the adoption of IB technology, as well as those in the design and implementation process, building owners and project partners have taken several initiatives. A few owners and project partners have implemented informative sessions as an important tool to educate end-clients. Additionally, project partners were involved in motivational efforts by managing an educational course on benefits associated with proper implementation of energy management systems, such as lighting and heating, ventilation, and air conditioning (HVAC), and more importantly latest innovations in IoT and cloud based solutions that can help enhance their experience of an IB. Initiatives creating awareness about IoT, cloud-based, HVAC, and lighting technologies are the most common strategies adopted by project partners. This awareness provides insight to end-customers about the latest best-in-class technologies that keep systems updated and about the appropriate methods to manage smart systems to avoid malfunctions.

Given that technology solutions related IoT is still relatively new, an effective way of finding out about the benefits of such solutions hinges upon IoT solution providers being able to offer the right technology advice to owners and occupants. In this regard prospecting sessions that offer a way for critical information exchange among technology vendors and building owners were found to be highly significant in helping facility operators, owners and occupants understand the right options available in IoT based solutions, and also adopt the most optimal way of procuring them.

As seen in Chart 2.7, 15 percent of owners and 18 percent of project partners are engaged in creating awareness and training end-customers on the use of IB technologies. Five percent of owners and project partners educate end-users about the importance of communication and teamwork during the implementation of an IB.

Chart 2.7: Major Initiatives to Educate End-Customers on Intelligent Building Design and Implementation



Q: Please describe major initiatives you have organized or have been a part of regarding the education of your occupants / end-users on intelligent building design/implementation.

As illustrated in Chart 2.8 and Chart 2.9, SIs, technology contractors, and building management services companies undertake the most initiatives to participate in informative sessions and educate and train end-customers. This research indicates 28 percent of SIs participated in training provided by value chain partners and in-turn half of them took initiatives to educate end-customers by providing technology briefings after the systems were integrated. Specialists such as technology contractors and original equipment manufacturers (OEMs) also participate to brief value chain partners about the technology and their solutions before or after the installation process.

Chart 2.8: Major Initiatives by Project Partners to Educate End-Customers on Intelligent Building Design and Implementation

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Training/education	13%	12%	18%	18%	8%	28%	15%
Technology advances/choice of features	2%	6%	6%	5%	8%	14%	7%
Team work/communication/project management		5%	6%	6%	3%	5%	6%
Green energy/energy efficiency/green status	5%	5%	5%		8%	1%	4%
Other	2%	5%	9%	3%	3%	4%	11%
Nothing	81%	73%	58%	70%	72%	53%	62%
Don't know				2%			

Q: Please describe major initiatives you have organized or have been a part of regarding the education of end-customers on intelligent building design/implementation

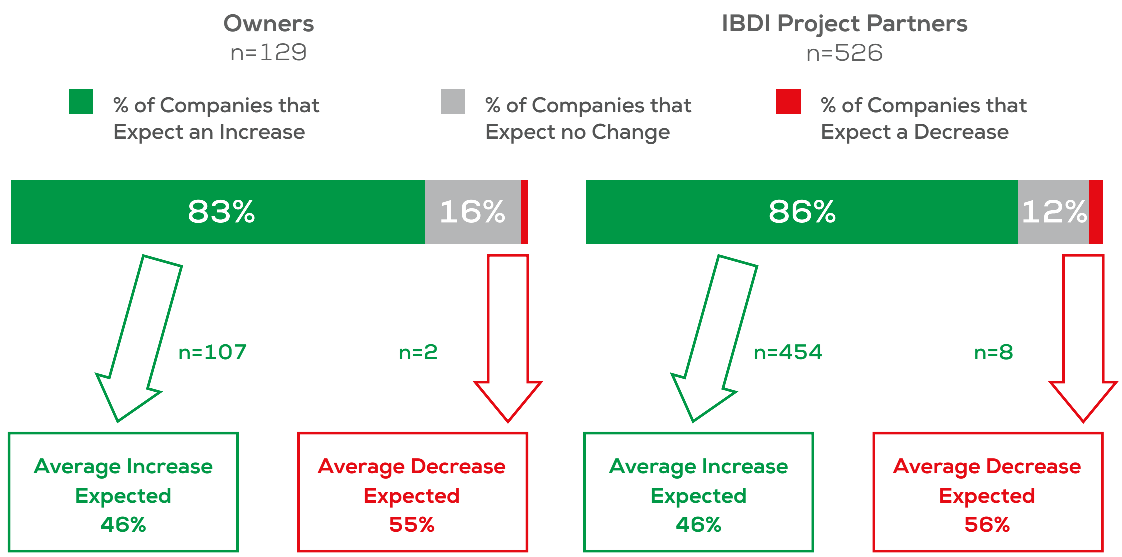
Chart 2.9: Major Initiatives by Building Owners to Educate End-Customers on Intelligent Building Design and Implementation

	Building Owners & Occupants n=78	Building Management Services Company n=51
Training/education	10%	22%
Technology advances/choice of features	3%	4%
Team work/communication/project management	3%	8%
Green energy/energy efficiency/green status	3%	8%
Other	4%	8%
Nothing	78%	55%
Don't know		

Q: Please describe major initiatives you have organized or have been a part of regarding the education of end-customers on intelligent building design/implementation.

As indicated by the research, an improved adoption practice is directly linked to an increase in perceived benefits. Individually, 83 percent of the building owners and 86 percent of project partners are anticipating a positive trend in adoption of IBs. They expect the adoption rate of IB to surge by an average of 46 percent over the next two to three years.

Chart 2.10: Expected Upward Trend in the Number of Intelligent Building Projects in the next Two to Three Years



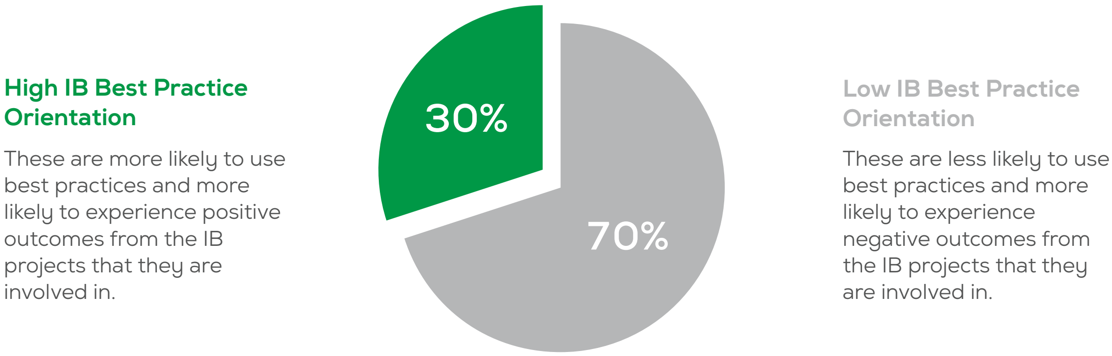
Q: Do you expect the number of your intelligent building projects in a typical year to increase, decrease, or remain the same over the next two to three years? What percentage change are you expecting over the next two to three years?

2.4 DEPENDENCY ANALYSIS: DESIGN, IMPLEMENTATION AND OUTCOME REVIEW

It is important to have the right project plan and processes factored in when developing or executing an IB design build process to promote synergies between all the project partners, building owners, and occupants for proper execution and implementation of a project. Appropriate design, process planning, and consulting from the onset of the project is essential for a positive outcome and successful completion of the project.

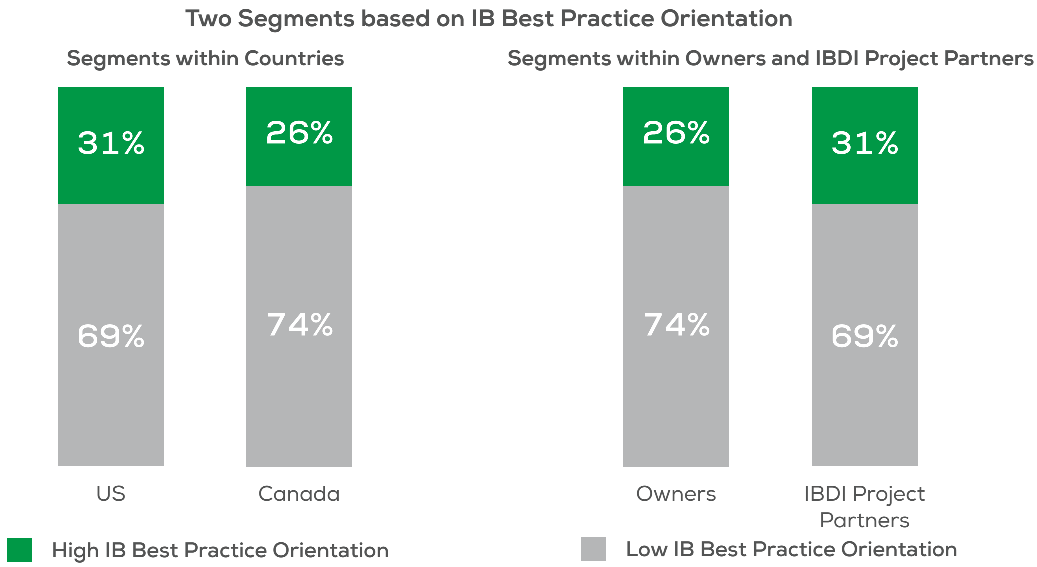
Of the total sample, 30 percent of companies adopted high best practices for design and implementation of IBs, resulting in a positive outcome. On the other hand, the companies that adopted fewer best practices experienced hitches and delays, resulting in a negative outcome.

Chart 2.11: Two Segments based on IB Best Practice Orientation



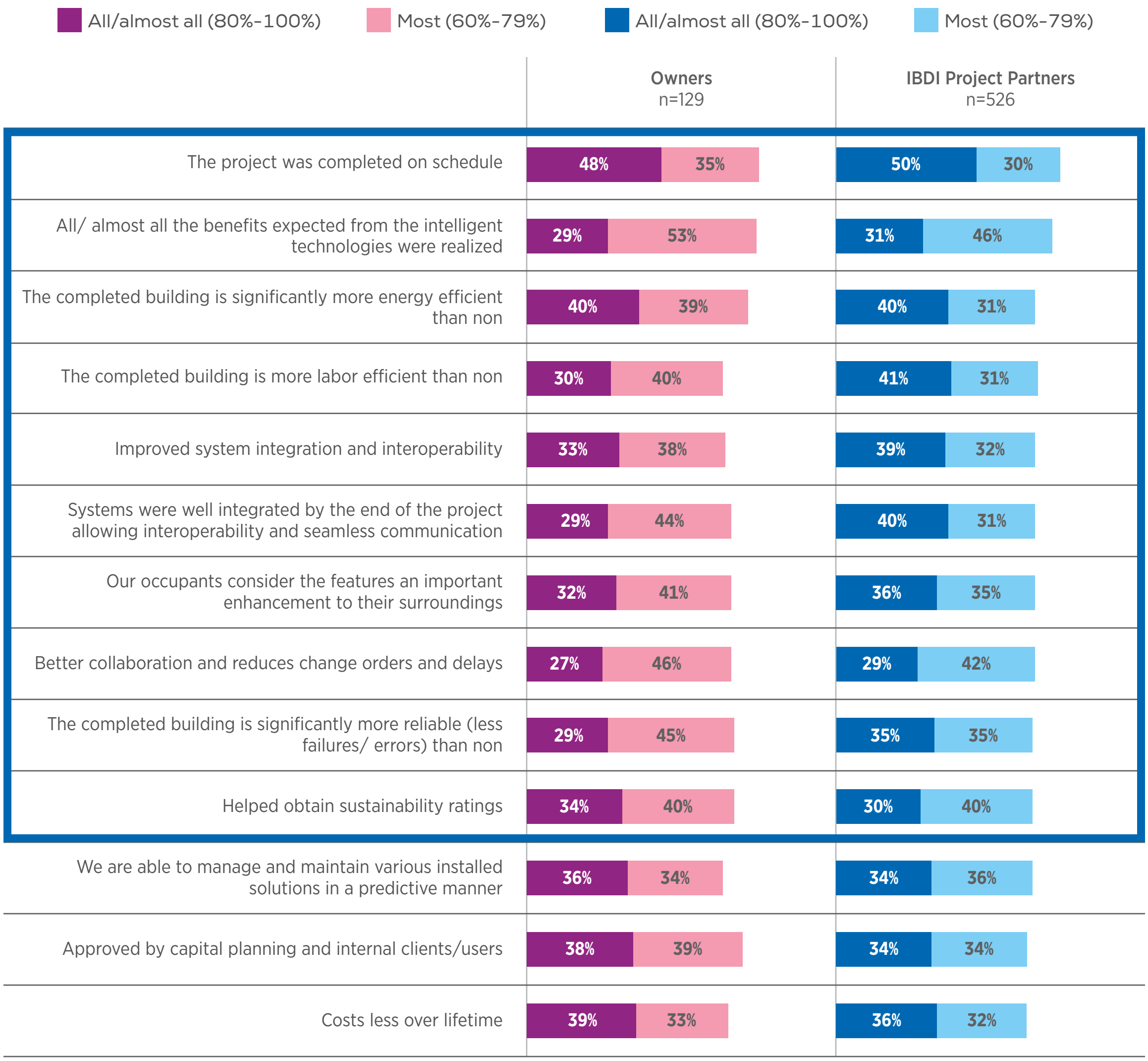
The application of best practices is more likely to be put in place by the US companies than by Canadian companies. Chart 2.12 shows that during the design and implementation of an IB, 31 percent of companies in the US follow high best practices when compared to 26 percent in Canada. Relatively higher adoption of the best practices was noticed among the project partners.

Chart 2.12: Two Segments Based on IB Best Practice Orientation by Country and Value Chain Partners



A significant 48 percent of building owners and 50 percent of project partners who implemented best practices in almost all their past projects completed the project on schedule. Better collaboration between the project team during the execution stage was adopted by 27 percent of building owners and 29 percent of project partners, which was vital for achieving a successful project outcome.

Chart 2.13: Positive Practices and Outcomes of Intelligent Building



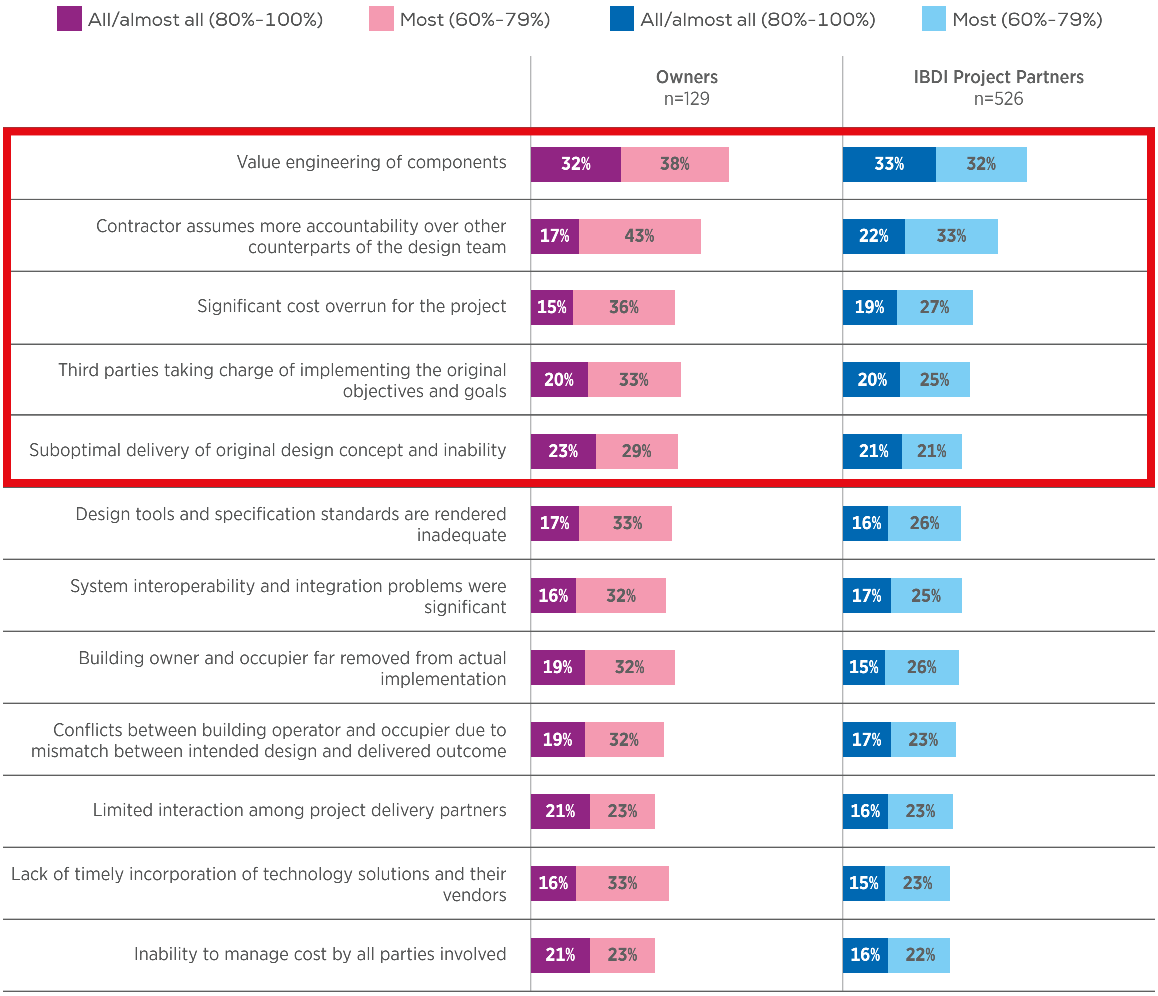
Q: How closely do each of the following statements describe the intelligent building projects (exclude non-intelligent building projects) that your company was involved in these past two years?

The industry perception research found that the benefits from using high best practices and having a successful project implementation offered distinct tenant satisfaction and led to optimizing ROI from the building's operation over time. Chart 2.14 provides a snapshot of the various positive outcomes cited by 30 percent of respondents who adopted for good project execution practices and experienced successful design and implementation of an IB project.

Chart 2.14: Positive Outcomes of Intelligent Building Projects

A significant 70 percent of companies that were not able to successfully manage the project were found to have low adoption of best practices. Out of which 23 percent of building owners and 21 percent of project partners who failed to implement best practices in almost all their projects had sub-standard project delivery. A lack of good design and a lack of communication between the key stakeholders were major challenges encountered by these companies during the design and implementation of an IB, as confirmed by this research.

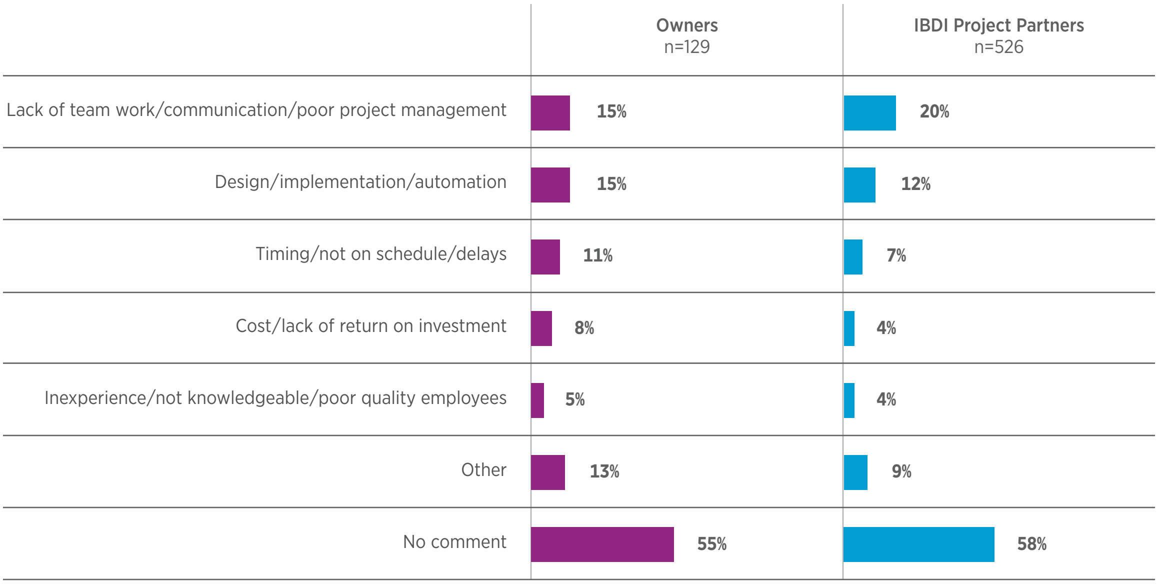
Chart 2.15: Negative Practices and Outcomes of Intelligent Building



Q: How closely do each of the following statements describe the intelligent building projects (exclude non-intelligent building projects) that your company was involved in these past two years?

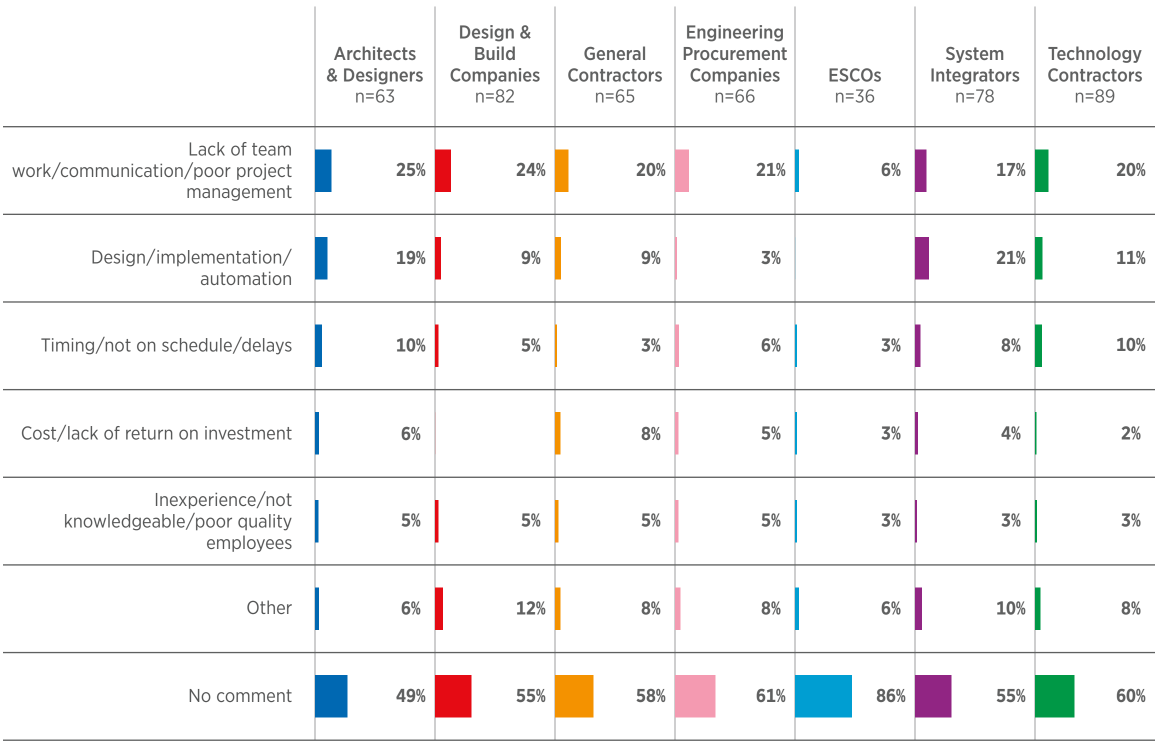
Charts 2.16 and 2.17 provide an overview of the top reasons for poor project execution. A significant 15 percent of building owners and 20 percent of project partners considered lack of teamwork and poor communication between the project team and vendors to be the primary reason for the project hindrances. Due to these challenges, approvals and work order managements get delayed within an organization, with considerable time wasted in reconfiguring plans and design. In turn, this affects deadlines and financial outlay.

Chart 2.16: Top Reasons for Sub-Optimal Intelligent Building



Q: Recall an intelligent building project that you consider to be a failure or was poorly designed or planned. What would you consider to be the top reason it was a failure or why was it poorly designed or planned? What did the project team fail to do?

Chart 2.17: Top Reasons for Sub-Optimal Intelligent Building by Project Partners

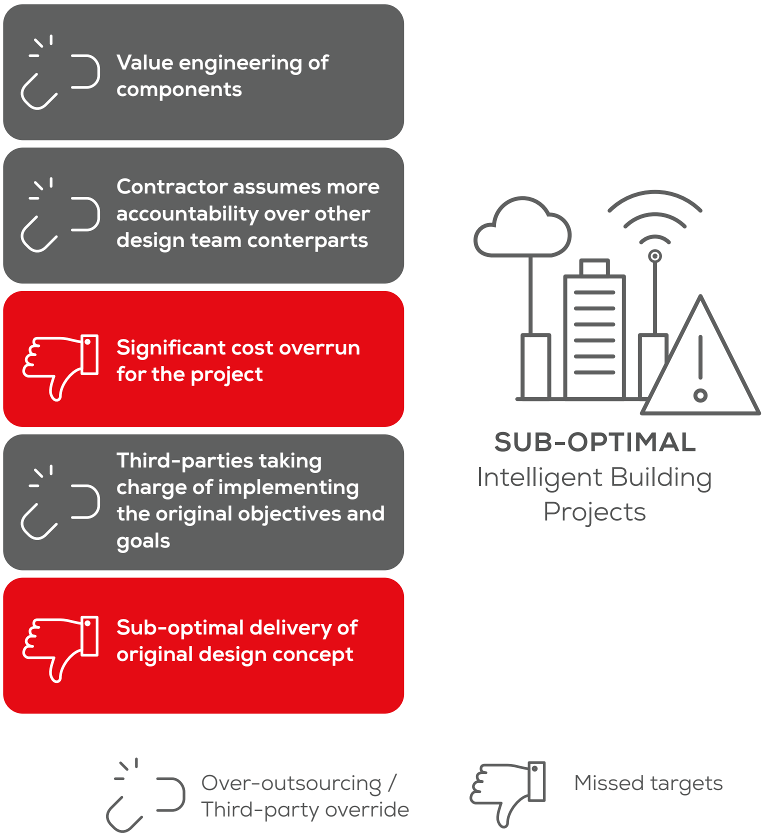


Q: Recall an intelligent building project that you consider to be a failure or was poorly designed or planned. What would you consider to be the top reason it was a failure or why was it poorly designed or planned? What did the project team fail to do?

Furthermore, what proportionally correlated to such negative outcomes was the inability of the project team to incorporate new project entities and specialists that had to be included to enhance the schematic design and intended outcome. Some building owners did not coordinate and refused to accept new specifications or expert advice on the technologies involved in an IB. This created an obstacle for project partners. A lack of teamwork, improper planning, and a lack of long-term visibility of stakeholders leads to the negative outcome of design and implementation of IB projects.

Chart 2.18 depicts a snapshot of the overall outcome of enacting improper design and implementation practices with an IB. Due to negligence and undesirable practices involved within the design and implementation process, the outcome of an IB project can deviate from its original plan and purpose.

Chart 2.18: Negative Outcomes of Intelligent Building Projects



Based on design and implementation methods, the outcomes were further classified into two broad categories as discussed below.

Outcome by Design Practice

The technical design stage is when the most important decisions are made to obtain the desired outcome for an IB project. The research revealed some interesting findings and correlations between outcomes that had a good design and those with sub-standard design practices from the onset of the project.

Chart 2.19: Impact of Design on IB Process and Outcome

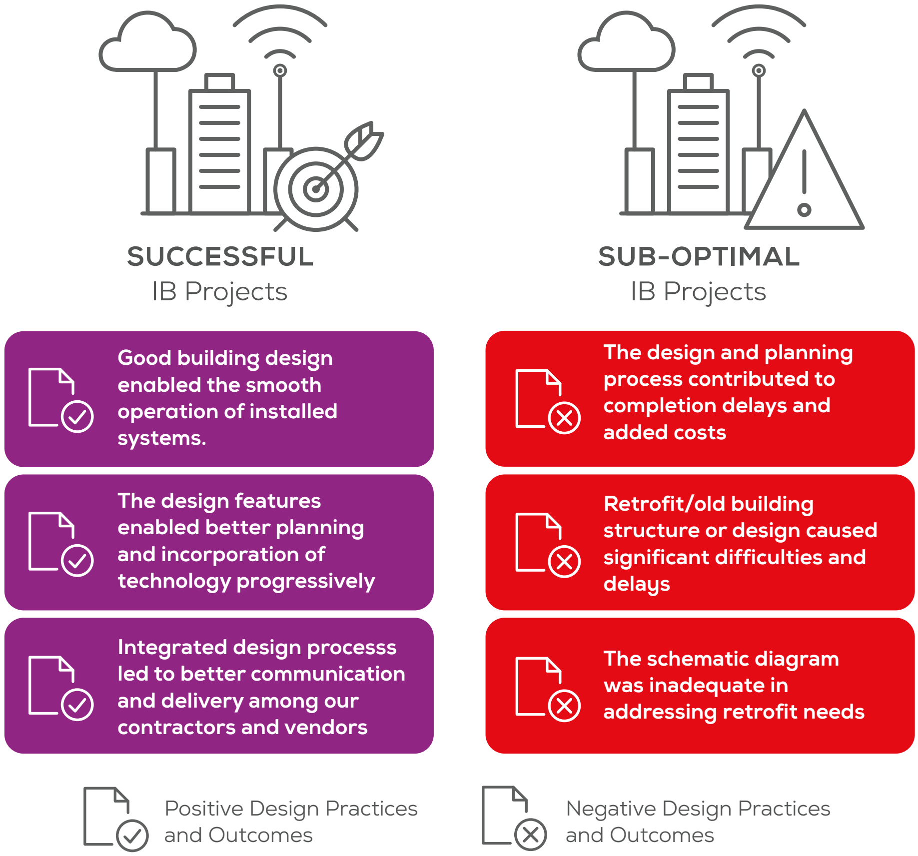
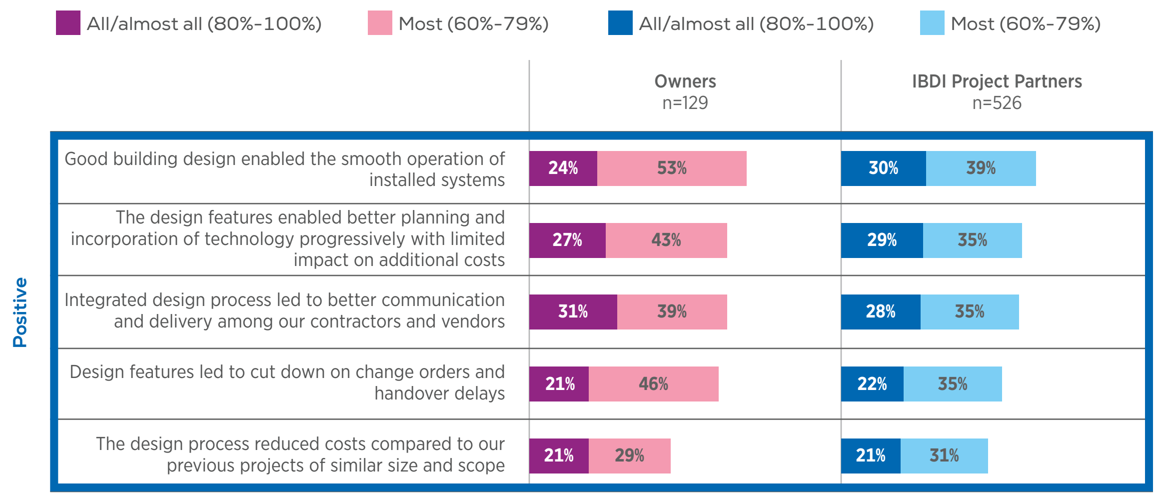


Chart 2.20 illustrates outcomes that result from the adoption of positive design practices by building owners and project partners from the very beginning. A significant 24 percent of building owners and 30 percent of project partners who implemented good design practices in almost all of their IB projects had seamless execution of various integrated systems. The adoption of good design practices was a forerunner to better planning and incorporation of technologies and smooth operation of installed systems, leading to a positive project outcome.

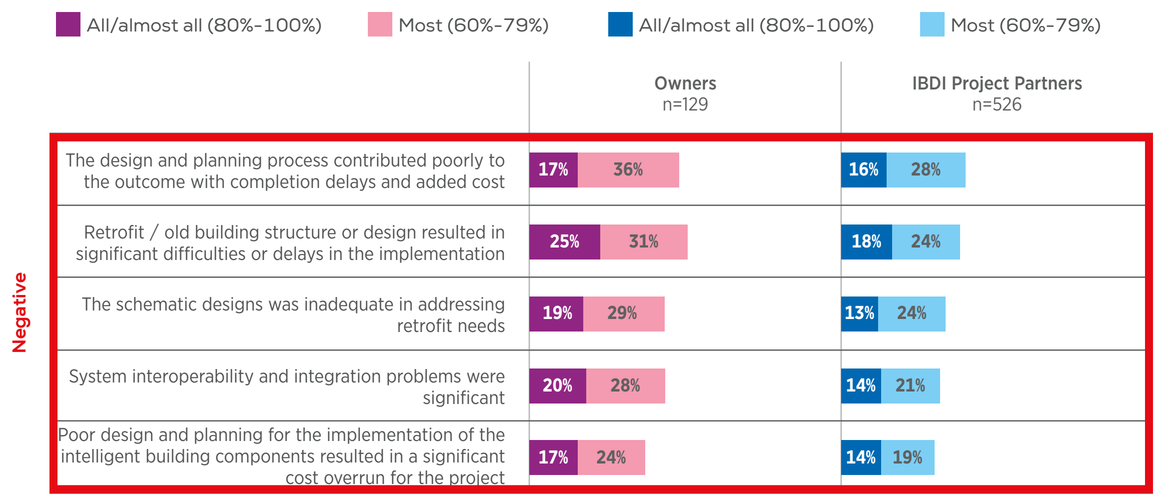
Chart 2.20: Impact of Good Design on IB Process and Outcome



Q. How closely do each of the following statements describe the intelligent building projects (exclude non-intelligent building projects) that your company was involved in these past 2 years?

Similarly, Chart 2.21 provides a snapshot of negative outcomes that were a result of the adoption of poor design practices. A significant 17 percent of building owners and 16 percent of project partners who lacked a proper design process and plan during the execution of almost all IB projects ended up having a delay in construction and sub-standard design, leading to cost overruns and negative outcomes.

Chart 2.21: Impact of Sub-Standard Design on IB Process and Outcome



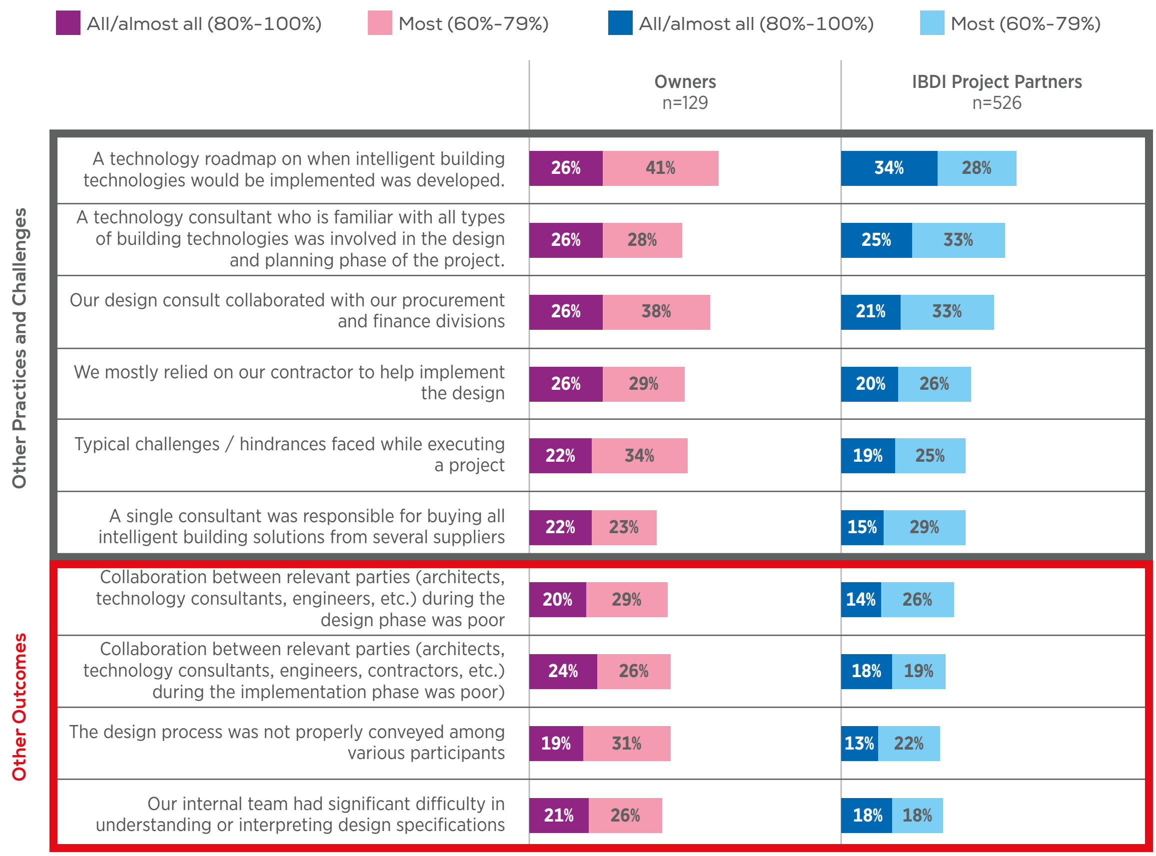
Q. How closely do each of the following statements describe the intelligent building projects (exclude non-intelligent building projects) that your company was involved in these past 2 years?

Outcome by Project Stages

Project stages such as planning, managing, and coordinating resources were evaluated to determine the unique aspects of IB design and implementation characteristics associated with these stages. The findings point to some crucial gaps that need bridging in this industry. First, a comprehensive roadmap is essential for a holistic view of what the IB is expected to achieve currently, and in the future. Chart 2.22

states that 26 percent of owners and occupants mandatorily adopted a technology roadmap in almost all their past IB projects and were able to achieve the desired positive outcomes. Similarly, if the practices during the execution stage were not well applied, the desired outcome was poor. The chart shows that 24 percent of owners were not able to collaborate with relevant parties during the implementation of almost all of their past projects and experienced poor outcomes that lead to delayed delivery and a sub-optimal IB.

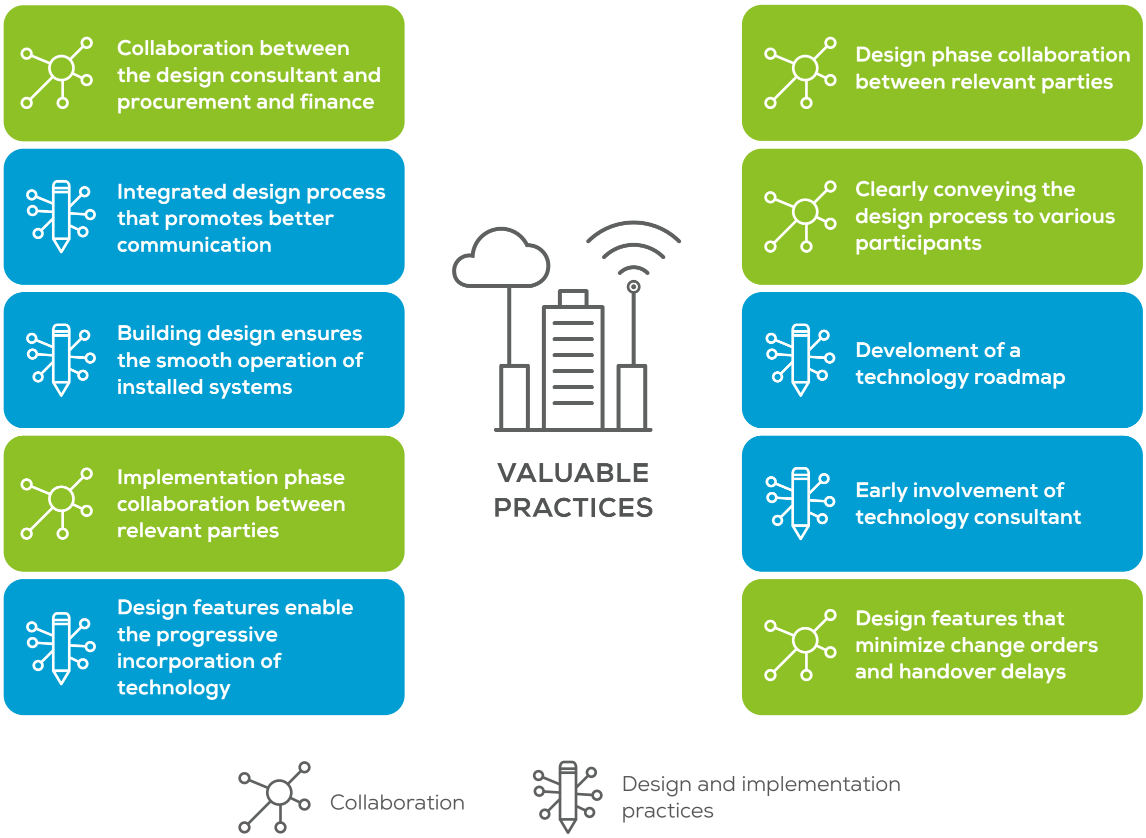
Chart 2.22: Impact of Other Project Practices on IB Process and Outcome



Q9. How closely do each of the following statements describe the intelligent building projects (exclude non-intelligent building projects) that your company was involved in these past two years?

The most valuable key practices to follow during design and implementation to ensure a positive outcome are stated below in Chart 2.23.

Chart 2.23: The Most Valuable Practices in Intelligent Building Process



2.5 APPROACHES ADOPTED BY DESIGNING, PLANNING, AND IMPLEMENTATION TEAMS: PERCEIVED VALUE ANALYSIS

The questions in this category were used to understand the most valuable and the least valuable practices related to successful implementation of an IB. Due to various reasons, such as time and budget pressure, design consultants generally do not coordinate with procurement and other members within the value chain. The perceived value of collaboration between the design consultants, procurement, and finance divisions is comparatively higher than other practices followed by owners and project partners of an IB. A significant 95 percent of building owners and project partners perceive collaboration as the most valuable practice, closely followed by having an integrated design process that promotes better communication among contractors and vendors in the IB. A significant 93 percent of respondents from design and build companies and 95 percent of respondents from general contractors also have the same opinion. Chart 2.24 shows the practices that respondents perceived as valuable for design and implementation of an IB.

Frost & Sullivan believes that the high perception of collaboration between the design consultants, procurement, and finance divisions reflects a desire of owners and project partners to have strong engagement and more transparency with other value chain participants. However, despite the inclination, this is only sporadically achieved.

	Owners n=129	IBDI Project Partners n=526
Collaboration between the design consultant and the procurement and finance divisions	95%	95%
Integrated design process that promotes better communication among contractors and vendors	95%	94%
Building design ensures the smooth operation of installed systems	93%	93%
Implementation phase collaboration between relevant parties (architects, technology consultants, engineers, contractors, etc.)	93%	93%
Design features enables the progressive incorporation of technology with limited impact on additional costs	90%	92%
Design phase collaboration between relevant parties (architects, technology consultants, engineers, etc.)	91%	92%
Clearly conveying the design process to the various participants	92%	92%
Development of a technology roadmap on when intelligent building technologies would be implemented	87%	91%
Early involvement of a technology consultant who is familiar with all types of building technologies	90%	90%
Design features that minimize the possibility of change orders and handover delays	90%	90%
An internal team that can clearly understand or interpret design specifications	92%	89%
Design ensures system integration and interoperability	91%	89%
Timely incorporation of technology solutions and their vendors	86%	90%
Excellent delivery of original design concept	92%	87%
Management of cost and quality by all parties involved	87%	89%

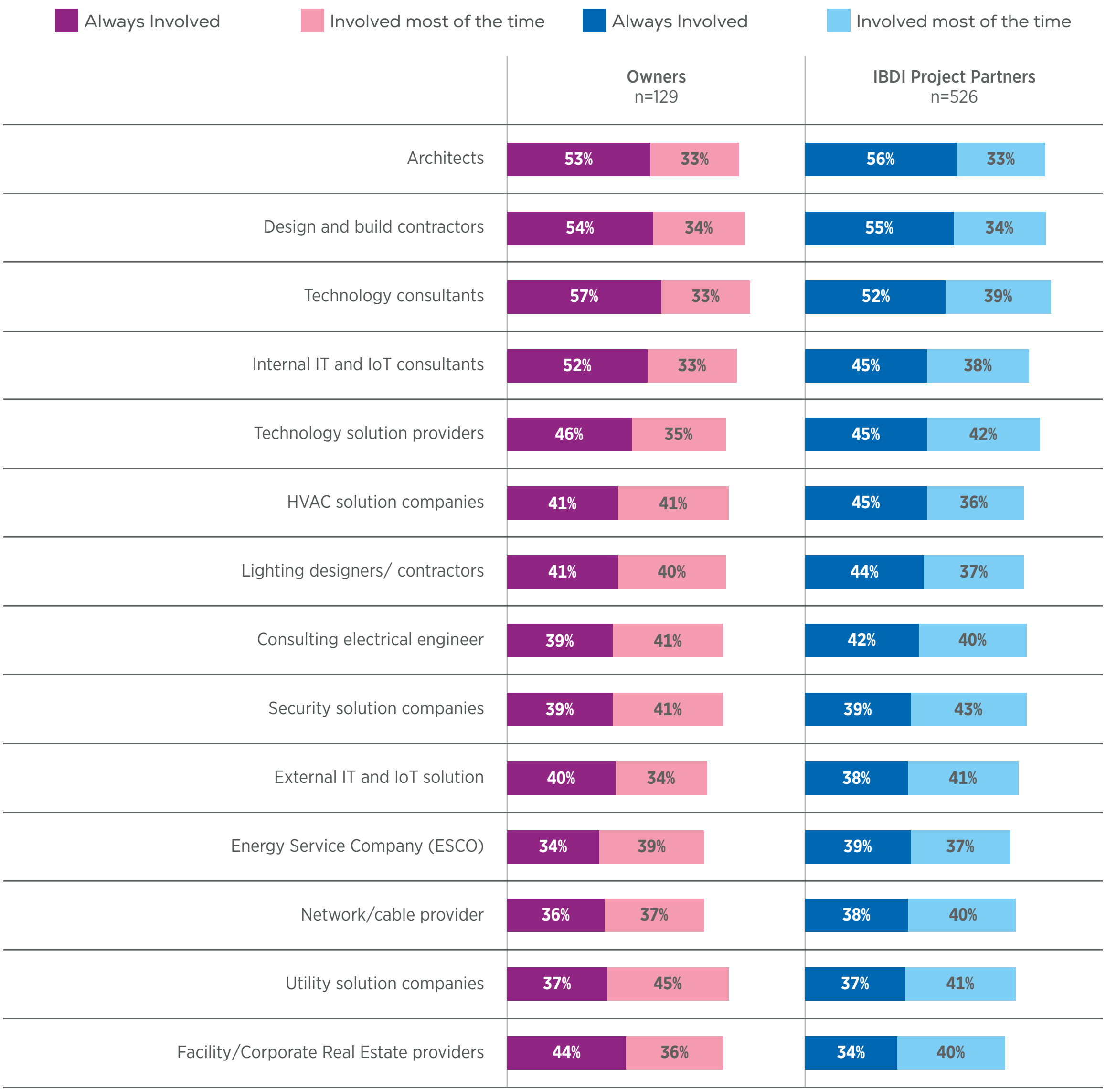
Chart 2.25: Perceived Value of Design and Implementation Practices by Project Partners

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Collaboration between the design consultant and the procurement and finance divisions	92%	93%	95%	94%	97%	95%	96%
Integrated design process that promotes better communication among contractors and vendors	94%	93%	95%	91%	94%	94%	94%
Building design ensures the smooth operation of installed systems	95%	89%	92%	91%	89%	92%	94%
Implementation phase collaboration between relevant parties (architects, technology consultants, engineers, contractors, etc.)	89%	90%	94%	89%	100%	91%	93%
Design features enables the progressive incorporation of technology with limited impact on additional costs	84%	90%	95%	88%	94%	92%	94%
Design phase collaboration between relevant parties (architects, technology consultants, engineers, etc.)	87%	89%	94%	88%	97%	90%	93%
Clearly conveying the design process to the various participants	86%	88%	94%	88%	94%	94%	93%
Development of a technology roadmap on when intelligent building technologies would be implemented	83%	89%	94%	89%	94%	90%	94%
Early involvement of a technology consultant who is familiar with all types of building technologies	83%	89%	92%	86%	89%	92%	90%
Design features that minimize the possibility of change orders and handover delays	86%	85%	91%	88%	92%	91%	92%
An internal team that can clearly understand or interpret design specifications	81%	91%	94%	86%	94%	82%	89%
Design ensures system integration and interoperability	84%	88%	92%	82%	92%	88%	91%
Timely incorporation of technology solutions and their vendors	86%	88%	92%	82%	94%	94%	92%
Excellent delivery of original design concept	86%	89%	89%	88%	89%	83%	88%
Management of cost and quality by all parties involved	83%	88%	89%	91%	100%	91%	90%

2.6 ROLE OF VENDORS, PROJECT PARTNERS AND SERVICE PROVIDERS

This segment of the research module was directed at understanding the role and involvement of key stakeholders and how they influence the decisions of various entities during the design and implementation of an IB. Charts 2.26 and 2.27 illustrate the involvement of various parties in the development of specifications for an IB. Building owners and project partners have rated architects, design and build contractors, and technology consultants as the top three parties involved in the development of specifications for a typical IB project. A significant 53 percent of building owners and 56 percent of project partners feel that an architect is always involved and plays a crucial role in the development of specific standards and specifications for design and implementation. SIs and architects feel that an architect plays the most important role and is always involved in influencing the specifications of an IB. However, design and build companies feel design and build contractors and technology consultants are always involved in the development of specifications.

Chart 2.26: Involvement of Parties in the Development of Specifications for a Typical Intelligent Building Project



Q: What is the involvement of each of the following in developing the specifications for a typical intelligent building project that your firm is involved in?

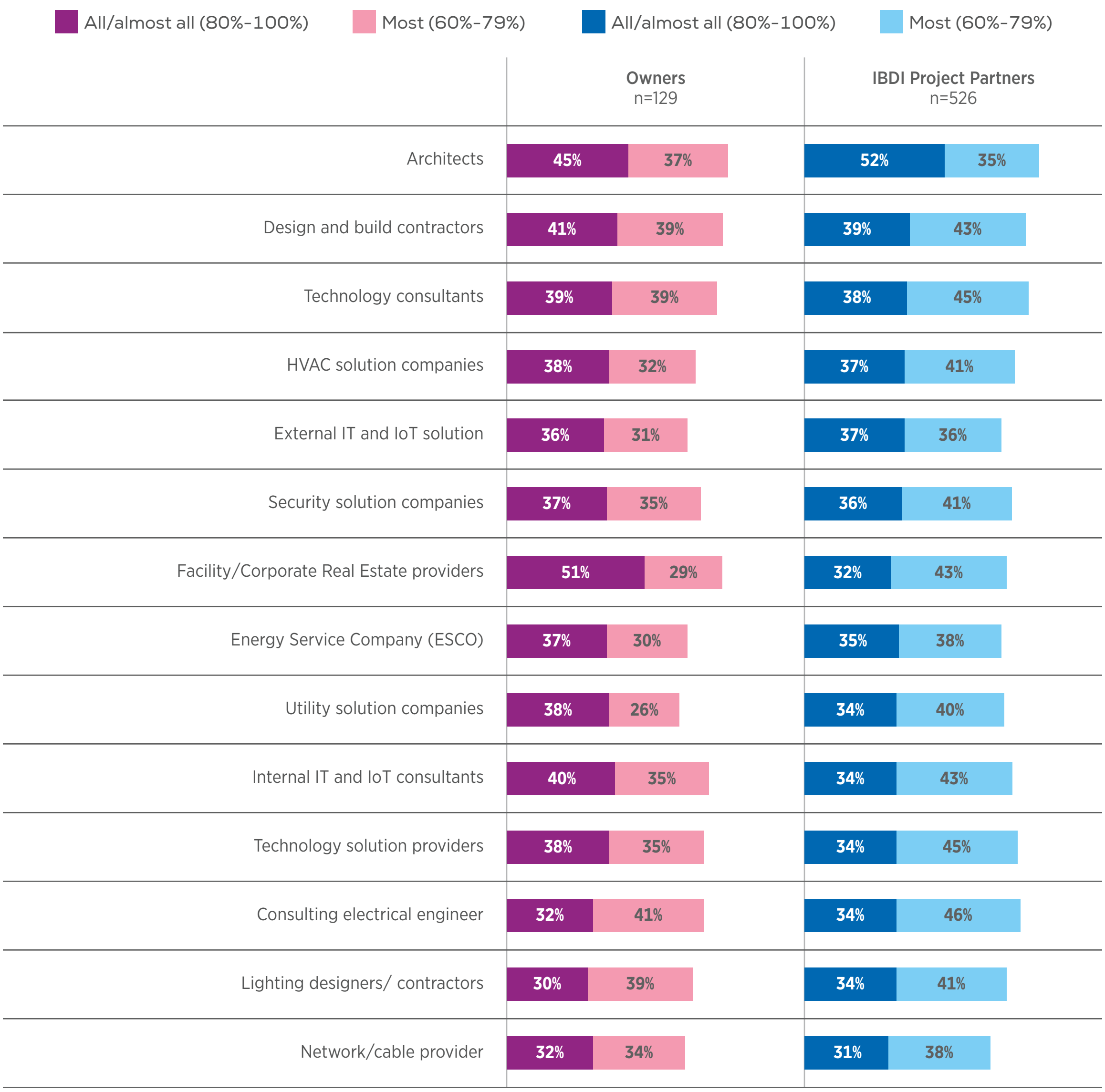
Chart 2.27: Involvement of Parties in the Development of Specifications for a Typical Intelligent Building Project

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Architects	68%	61%	43%	59%	58%	69%	48%
Design and build contractors	48%	67%	54%	45%	58%	67%	47%
Technology consultants	43%	62%	45%	42%	64%	58%	56%
Internal IT and IoT consultants	37%	51%	32%	41%	53%	55%	52%
Technology solution providers	35%	61%	40%	42%	50%	45%	51%
HVAC solution companies	35%	50%	45%	41%	64%	54%	37%
Lighting designers/ contractors	51%	45%	37%	41%	50%	55%	39%
Consulting electrical engineer	43%	48%	35%	67%	56%	44%	31%
Security solution companies	32%	41%	40%	45%	47%	44%	37%
External IT and IoT solution	27%	40%	31%	26%	36%	56%	46%
Energy Service Company (ESCO)	40%	39%	31%	36%	53%	55%	34%
Network/cable provider	27%	30%	32%	33%	50%	56%	38%
Utility solution companies	33%	49%	35%	39%	44%	45%	29%
Facility/Corporate Real Estate providers	37%	33%	37%	35%	44%	33%	34%

Q: What is the involvement of each of the following in developing the specifications for a typical intelligent building project that your firm is involved in?

Chart 2.28 provides a snapshot of how respondents perceive the role of various partners to influence specifications involved in an IB project. According to 51 and 45 percent of building owners, the corporate real estate provider and architect respectively have full authority to influence the development of a specification. However, in the case of project partners, the majority of respondents stated that the architect has full authority to influence the development of specific standards. According to respondents, design and build contractors are another value chain partner with major approval authority. Because architects and design and build contractors have comprehensive involvement in specifications development, and have significant approval authority, these groups are integral to the process. Therefore, their full involvement throughout design and implementation processes is essential to avoid substantial barriers during execution.

Chart 2.28: Authority in the Specification of IB Solutions for a Typical IB Project

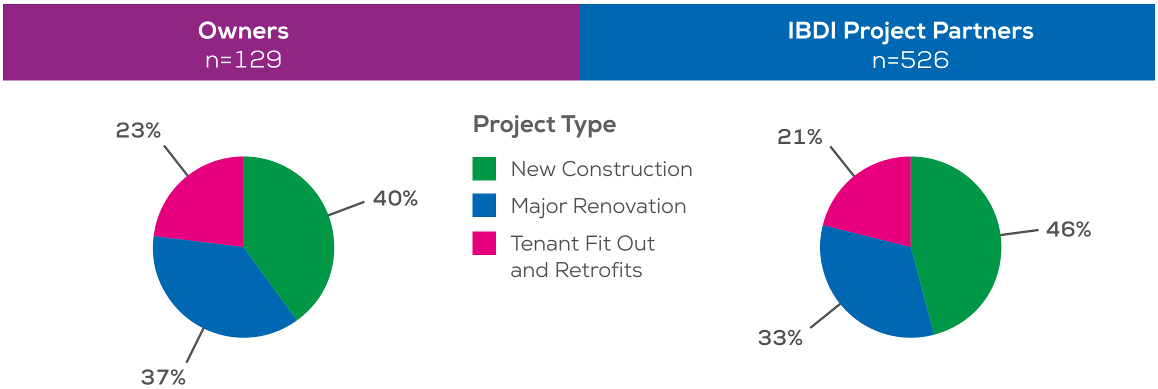


Q: For the specification of intelligent building solutions, what is the authority or influence of each of the following on a typical intelligent building project undertaken by your firm?

2.7 VALUE CHAIN INTERDEPENDENCY ANALYSIS: PERCEIVED ROLE AND INFLUENCE OF VARIOUS ENTITIES

This segment of the research module was directed at understanding the change in the perceived influence level of various individuals involved in the following three types of project option categories: new construction, major renovation, and tenant fit-out and retrofit. As Chart 2.29 depicts, 40 to 50 percent of the projects executed by the respondents during the past two years were new construction projects, followed by 30 to 40 percent of projects in the major renovation category.

Chart 2.29: Type of IB Project



Q: In the past two years, what proportion of the projects involving intelligent building design and implementation was for new construction, major renovation and retrofit such as tenant fit out, and / or converting existing or old buildings into intelligent buildings)?

Various parties reflected a significant variance in the amount of authority approval and influence when they were involved in the three construction categories. For new construction activities the level of influence of architects, design and build contractors and technology consultants is higher compared to renovation and retrofit projects. Their level of authority and influence decreases as we move from new construction projects towards retrofit projects. These entities were responsible for influencing project processes approximately 55 to 60 percent of the time for owners, occupants, and other project partners involved in the execution process, as seen in Chart 2.30.

Chart 2.30: Influence Level of Parties for New Construction

Q. How does the influence of each of the following change for new construction? - New

Chart 2.31 illustrates the influence levels of various parties when they are involved in a major renovation project. The influence level of architects, design and build contractors, and technology consultants is more or less similar to that for new construction activities. The building owners and other project partners stated that for 50 to 60 percent of time, these entities were responsible for influencing project processes involved during the renovation project of an IB.

Chart 2.31: Influence Level for Major Renovation

Q. How does the influence of each of the following change for major renovation?

Chart 2.32 illustrates the influence levels of various parties when they are involved in fit-outs and retrofit projects. Generally, the owner takes the lead in defining the scope of work required in tenant fit-outs and retrofit projects. Therefore, building owners and project partners were of the opinion that the influence level of architects, design and build contractors, and technology consultants for changes in design specifications in retrofit projects is moderate compared to the other two categories.

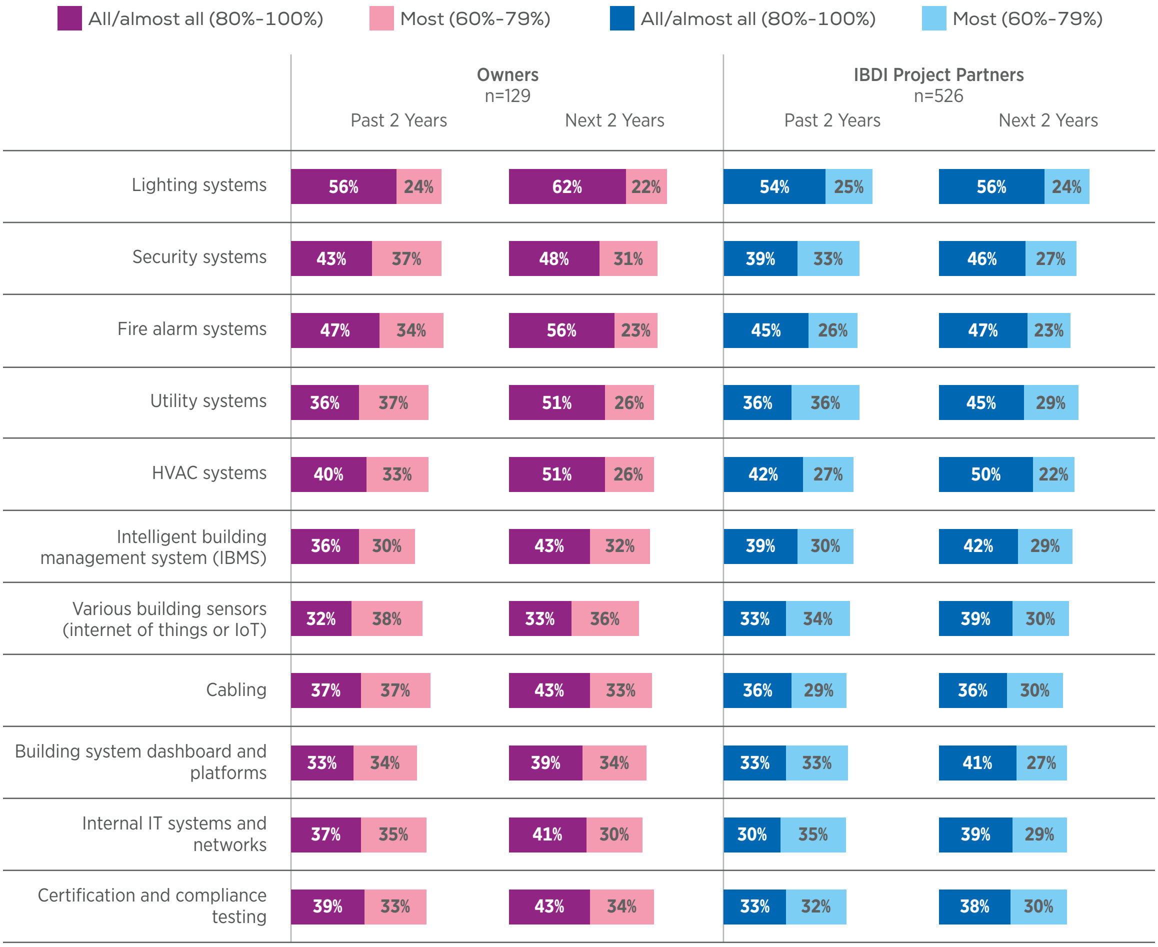
Chart 2.32: Influence Level for Fit-Outs and Retrofit Projects

Q. How does the influence of each of the following change for fit outs and retrofit projects?

2.8 FEEDBACK ON SPECIFIC TECHNOLOGIES, PROCESSES AND PROJECT PARTNERS

The gamut of products and technologies that go into an IB is fairly exhaustive. Generally, the more commonly used technologies by owners and project partners are lighting systems, security systems, fire alarm systems, and HVAC systems. Chart 2.33 shows the technologies included in the past two years and others that could be potentially adopted in the next two years by respondents. The adoption of all technologies is expected to increase in almost all IB projects. In the past two years, 56 percent of owners included lighting systems in almost all projects. However, 62 percent of owners are likely to include lighting systems in their design plans in the next two years. Thus, a surge in demand for lighting systems is expected from building owners and occupiers. A significant 56 percent of project partners expect that lighting system will be included in the design for almost all their projects in the next two years, compared to 54 percent in the past two years.

Chart 2.33: Type of Technologies Included in the Design or Plan



Q: In what percentage of the intelligent building projects that your company was involved in these past two years were the following types of technologies included in the design or plan?

Chart 2.34 provides an overview of technologies used by various project partners during the design and implementation of an IB project. A strong 87 percent of SIs and 82 percent of design and build companies included lighting systems in their design or plan.

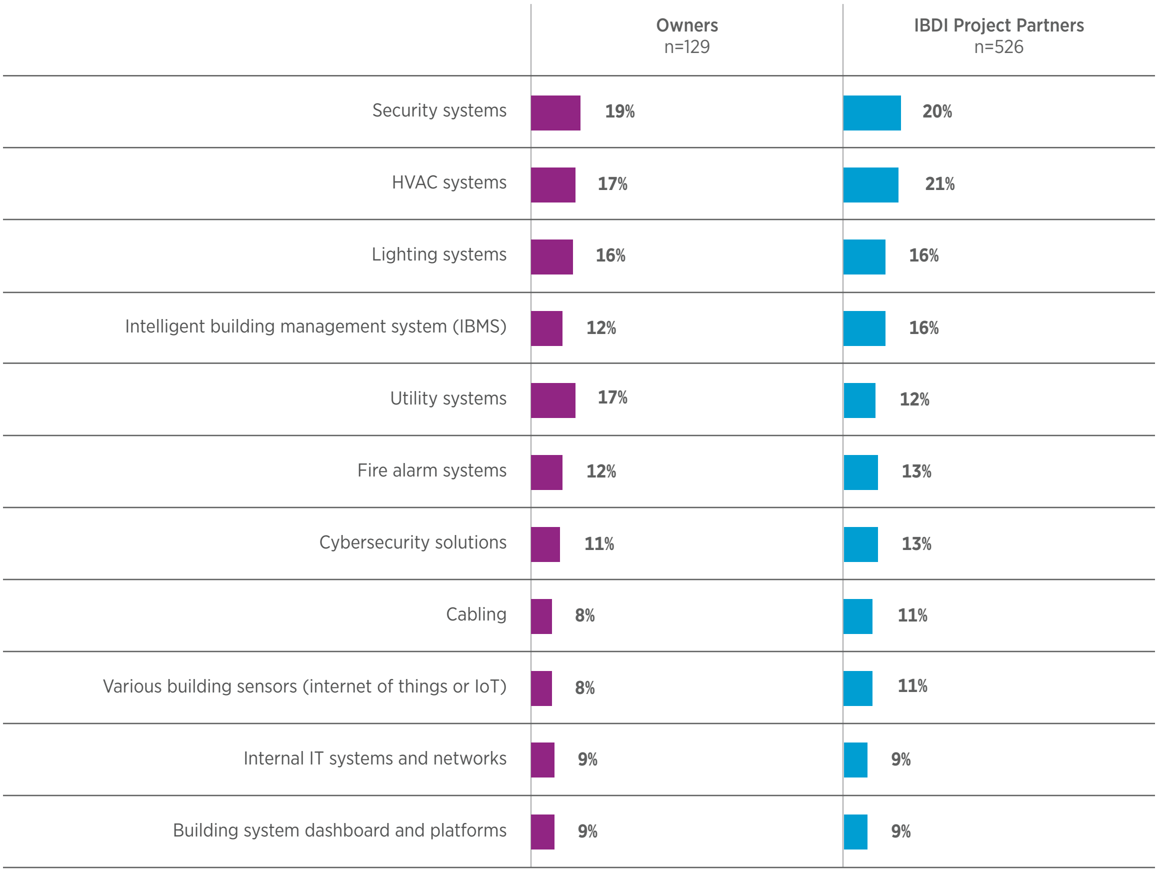
Chart 2.34: Type of Technologies Included in the Design or Plan by various Project Partners

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Lighting systems	78%	82%	74%	77%	78%	87%	74%
Security systems	70%	74%	69%	65%	83%	85%	67%
Fire alarm systems	71%	76%	62%	73%	75%	78%	66%
Utility systems	67%	76%	58%	68%	83%	83%	67%
HVAC systems	70%	72%	65%	67%	72%	77%	61%
Intelligent building management system (IBMS)	62%	71%	60%	71%	78%	82%	65%
Various building sensors (internet of things or IoT)	59%	70%	60%	71%	75%	76%	61%
Cabling	63%	68%	57%	61%	75%	77%	57%
Building system dashboard and platforms	52%	70%	58%	73%	81%	79%	66%
Internal IT systems and networks	63%	68%	57%	56%	78%	81%	60%
Certification and compliance testing	56%	63%	60%	61%	83%	78%	60%

Q: In what percentage of the intelligent building projects that your company was involved in these past two years were the following types of technologies included in the design or plan?

Several technologies were considered challenging by respondents due to the complexities associated with installation processes. Due to the involvement of numerous components and constant technology upgrades, 19 percent of owners and 22 percent of project partners found the integration of security systems to be the most problematic in an IB. HVAC was considered another challenging technology due to frequent changes in technology and the complex integration associated with auto cooling and heating technology. These technologies were considered challenging to implement depending on the project partner in question. For instance, security systems were considered challenging by technology contractors, engineering procurement companies (EPCs), and general contractors. For architects, designers, and ESCOs, HVAC systems were challenging. Due to the significant intricate wiring involved in lighting systems, general contractors also considered it a challenging technology.

Chart 2.35: Challenging Technologies by Owners and Project Partners



Q: Based on your experience, which of the following technologies tend to be most problematic or most challenging to implement?

Chart 2.36: Challenging Technologies by Various Project Partners

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Security systems	13%	20%	25%	27%	11%	15%	30%
HVAC systems	27%	24%	18%	23%	28%	17%	20%
Lighting systems	22%	13%	25%	14%	6%	10%	15%
Intelligent building management system (IBMS)	19%	16%	17%	21%	17%	28%	10%
Utility systems	16%	13%	12%	17%	14%	6%	12%
Fire alarm systems	14%	16%	14%	14%	14%	4%	18%
Cybersecurity solutions	14%	15%	12%	17%	6%	13%	10%
Cabling	16%	10%	14%	9%	14%	12%	8%
Various building sensors (internet of things or IoT)	14%	11%	5%	11%	14%	8%	11%
Internal IT systems and networks	11%	12%	6%	11%		10%	15%
Building system dashboard and platforms	8%	7%	9%	14%	6%	14%	7%

Q: Based on your experience, which of the following technologies tend to be most problematic or most challenging to implement?

Frost & Sullivan's research identified various types of challenges involved in the implementation of different technologies in an IB. Chart 2.37 shows that issues were encountered by project entities while installing lighting, security, and HVAC systems. The challenges encountered during installation are mostly propagated by complexities associated with technology installation and integration, compatibility of new technology, lack of technology awareness, quality of the product, and lack of proper coordination between building owners and project partners.

Chart 2.37: Challenges in Implementation of Different Technologies

	Owners	IBDI Projec Partners
Lighting systems	Installation issue (15%)	Installation issue (16%)
Utility systems	Complexity (18%)	Complexity (14%)
HVAC systems	Installation issue (36%)	Installation issue (25%)
Security systems	Installation issue, quality, complexity (13%)	Installation issue (14%)
Fire alarm systems	Complexity (20%)	Installation issue (19%)
Cabling	Installation issue, complexity (10%)	Installation issue (28%)
Intelligent building management system (IBMS)	Complexity (20%)	Installation issue (16%)
Various building sensors (IoT)	Installation issue (30%)	Installation issue (28%)
Building system dashboard and platforms	Installation issue (19%)	Installation issue (9%)
Web	Complexity (30%)	Installation issue, complexity (9%)
Access to cloud	Technological issue (20%)	Complexity (15%)

These challenges can be subdivided into the following categories:

Challenges Propagated by Lack of Technology Awareness

Owners did not anticipate any technology upgrades during the installation of new HVAC systems in old buildings because they were not completely aware of the latest options available. Because certain old HVAC systems are not compatible with new technology, they require upgraded HVAC components. This was one of the major challenges faced during IB implementation. This challenge was further aggravated by the integration of latest sensor-based and IoT technologies that augment HVAC installation.

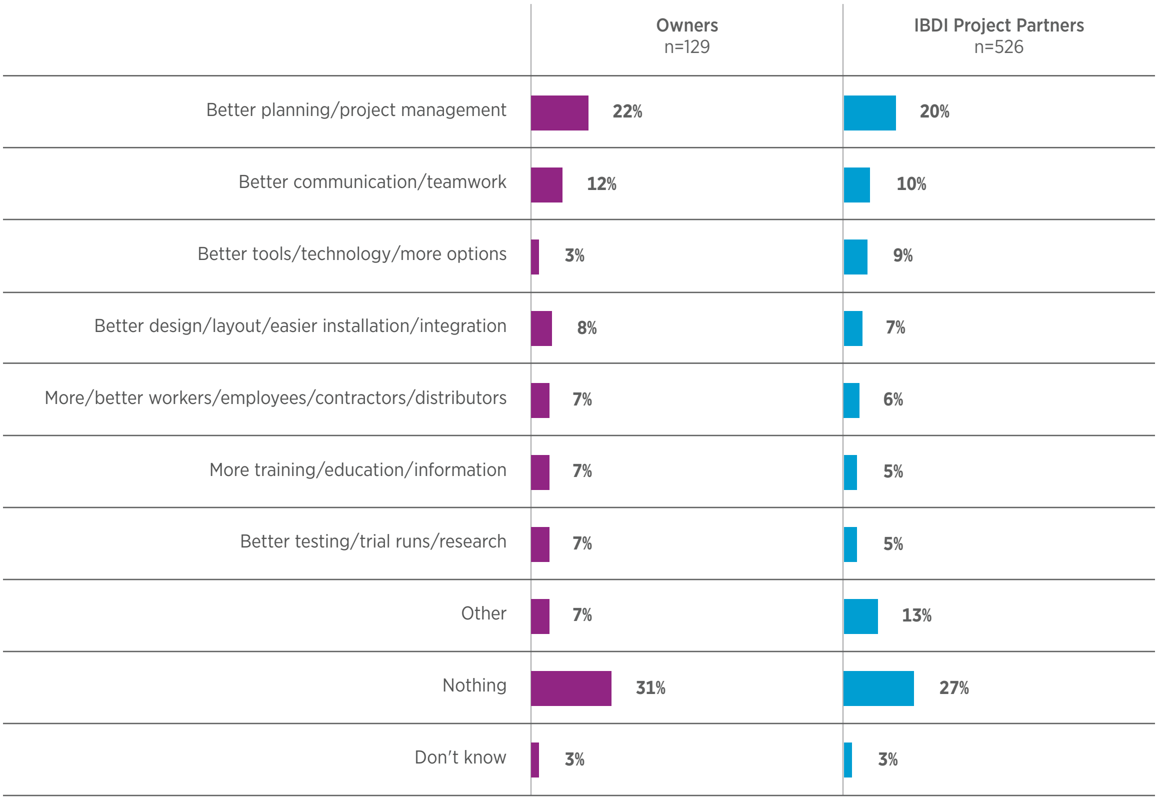
Challenges Propagated by Upfront Cost Considerations

Some owners identified that the lighting systems are the most expensive technology included in IBs. The desire to postpone budgets for future considerations, or completely forego the installation in favor of a lost cost alternative was cited as a common resort. This indicates a higher level of focus on the upfront cost of technologies involved in an IB when compared to long-term operational costs.

Challenges Propagated by Project Partners

The major challenge faced by various project partners is in the interoperability and incompatibility of numerous devices that affect the seamless integration of devices and technologies within an IB's physical and IT network. The risk management associated with information systems, considered fundamental to providing effective security solutions, is related to this challenge. Process planning is an essential step for avoiding the challenges and producing the desired IB outcome. For a continuous communication flow, a well-qualified and experienced team is needed to prevent miscommunication during implementation. Charts 2.38 and 2.39 provide a snapshot of measures taken to prevent implementation problems by owners and various project partners. A conservative fraction comprising 22 percent of building owners and 20 percent of project partners were of the opinion that better planning and proper project management are key to achieving desired and successful outcomes and avoiding difficulties.

Chart 2.38: Measures to Prevent IB Implementation Problems



Q: What could have been done in the design or planning phase to prevent those problems or challenges?

A significant 30 percent of project partners rely on better planning and better teamwork to successfully complete the IB project.

Chart 2.39: Measures to Prevent IB Implementation Problems by Partners

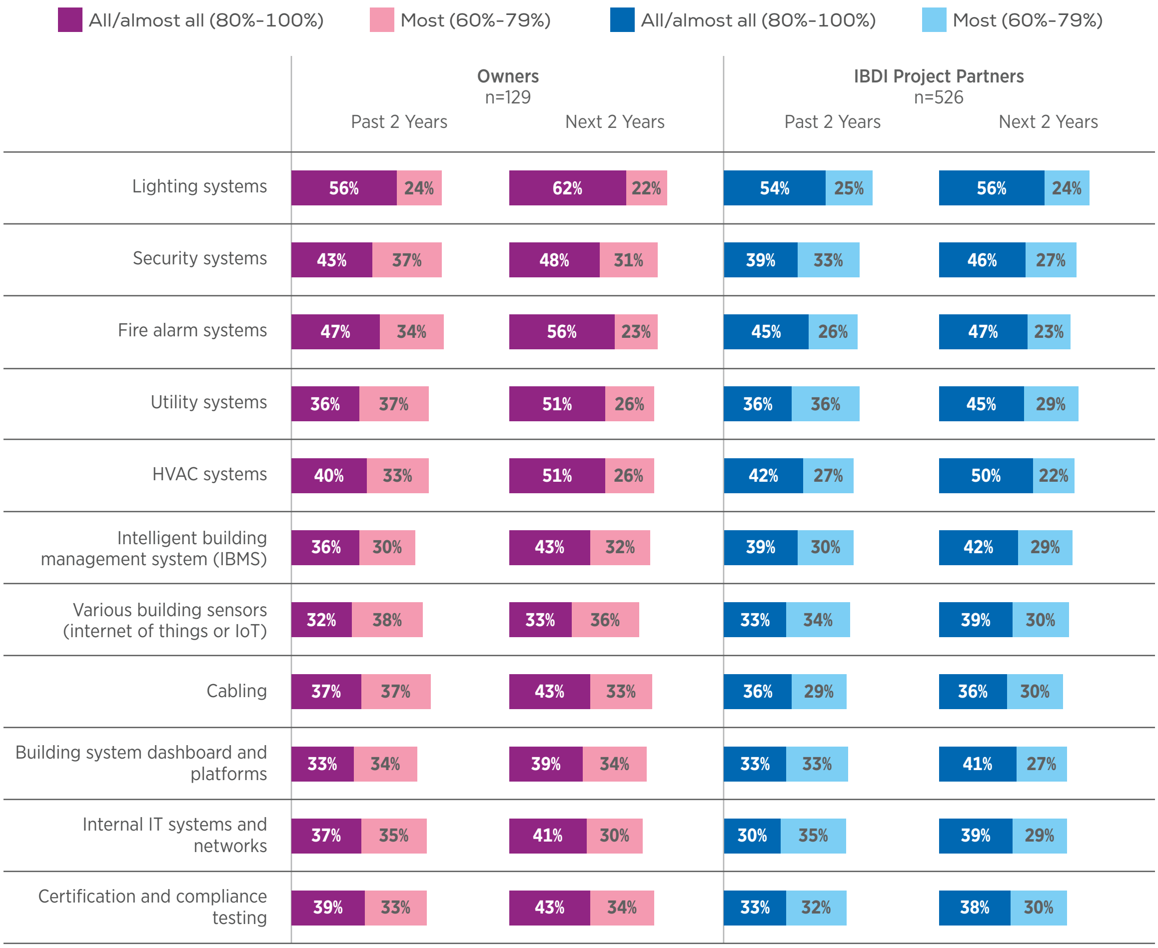
	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Better planning/project management	19%	18%	12%	23%	28%	24%	22%
Better communication/teamwork	13%	9%	11%	14%	3%	5%	15%
Better tools/technology/more options	8%	13%	6%	14%	8%	14%	7%
Better design/layout/easier installation/integration	5%	11%	3%	2%	3%	8%	6%
More/better workers/employees/contractors/ distributors	5%	10%	6%	3%	8%	6%	7%
More training/education/information	6%	9%	8%	6%	3%	4%	
Better testing/trial runs/research	10%	2%	6%	8%			3%
Other	6%	10%	12%	17%	11%	19%	11%
Nothing	29%	24%	37%	18%	36%	22%	30%
Don't know	8%	1%	3%	2%		1%	2%

Q: What could have been done in the design or planning phase to prevent those problems or challenges?

2.9 FUTURE ADOPTION POTENTIAL: TECHNOLOGY AND DESIGN PROCESS INFLUENCERS

The research probed about the future adoption potential of various technologies and project management processes included in the design and planning of an IB. As seen in previous sections, the adoption of IB technologies is expected to increase due to the increased awareness among value chain participants. Lighting is anticipated to be a lead technology for future renovation, tenant fit-outs and new installations, based on the interest shown by respondents. Building owners expect to see a penetration of six percent for lighting systems to be included in design and planning stages in the next two years. However, the increased rate of adoption for technologies such as fire alarms, utility-installed energy systems, and HVAC systems is expected to be between 10 and 15 percent in the next couple of years. A significant 51 percent of owners are likely to include HVAC technology in designing and planning of almost all projects in the next couple of years, compared to 40 percent during the past two years. A surge in demand for HVAC systems is also expected from building owners and occupants. Project partners are anticipating a significant surge in demand for security, energy, and HVAC systems. A strong 50 percent of project partners expect HVAC to be included right from the onset of IB designing and planning for almost all the projects they will be involved in over the next two years, as compared to 42 percent during the past two years. Charts 2.40 and 2.41 show the type of technologies expected to be included in most projects during the next two years by owners and various project partners.

Chart 2.40: Types of Technologies to be Included in the next Two Years



Q: In the next two years, in your opinion, in what percentage of your intelligent building projects will the following types of technologies be included in the design or plan?

Chart 2.41: Types of Technologies to be Included in the next Two Years by Project Partners

	Architects & Designers n=63	Design & Build Companies n=82	General Contractors n=65	Engineering Procurement Companies n=66	ESCOs n=36	System Integrators n=78	Technology Contractors n=89
Lighting systems	78%	84%	82%	80%	86%	81%	78%
Security systems	73%	73%	71%	71%	72%	75%	73%
Fire alarm systems	75%	71%	68%	68%	72%	71%	75%
Utility systems	68%	78%	69%	73%	81%	74%	68%
HVAC systems	71%	79%	68%	70%	67%	73%	71%
Intelligent building management system (IBMS)	62%	74%	69%	67%	81%	72%	62%
Various building sensors	60%	70%	65%	68%	81%	69%	60%
Cabling	62%	66%	63%	61%	72%	68%	62%
Building system dashboard and platforms	63%	70%	57%	73%	81%	69%	63%
Internal IT systems and networks	65%	67%	58%	62%	75%	69%	65%
Certification and compliance testing	67%	66%	60%	65%	83%	70%	67%

Q: In the next two years, in your opinion, in what percentage of your intelligent building projects will the following types of technologies be included in the design or plan?

Creating awareness and educating the team on the use of good design and implementation practices is likely the key to adopting good project management processes. As indicated above, various project partners and building owners are interested in adopting better design and implementation processes by including critical technologies in their design plan from the early stages. This will help avoid glitches and cost overruns during the implementation of an IB. Significant influencing factors identified for the adoption of better execution processes are favorable cost-benefit ratio associated with project planning that resulted in better financial management, improved system integration and interoperability, and better visualization for predictive optimization and achieving best-in-class productivity.

2.10 KEY TAKEAWAYS

The key highlights and observations of the industry research are discussed below. These are also mentioned with further details in the Executive Summary chapter.

Growth Potential

Adoption rates for IBDI practices are expected to witness significant growth in the coming years. Integration and interoperability remain key requirements for ensuring project success in this market. Some of the key drivers in the immediate term include safety and security, energy efficiency, reduction in operational expenses and better ROI management.

Practices and Outcomes

The successful execution of an IB project demands positive practices in place, a unified approach to technology procurement and incorporation, having a universal view of the design and implementation plan and active collaboration between project partners. Absence of any of these factors could contribute to project failures.

Adherence to Best Practices

Presently, 30 percent of respondents were observed to have been actively following best practices such as using a collaborative approach to partner and design integration, having a qualified internal team for overseeing implementation, a proactive plan for cost management, among others. On the other hand, respondents that were overtly reliant on contractors to carry out the IBDI processes on their behalf demonstrated low adoption of best practices, contributing to cost overruns and significant project delays.

Role of Value Chain Participants

Value chain participants have varying roles to fulfill in ensuring the successful implementation of an IB project. The architect, design build contractor, and technology consultant are the top partners in determining the standards and specifications of an IB project. The roles and influence levels of various participants are also dependent on the type of construction. Overall, this research confirms that the practices currently followed during the design and implementation of an IB, are not well-integrated by all value chain partners.

3 ADDRESSING KEY IBDI ADOPTION CHALLENGES

3.1 IBDI ADOPTION: CORE ISSUES AND CHALLENGES EVALUATION

Some of the key issues and challenges in IBDI processes include the improper balance of priorities between upfront costs of the project and operational costs of the building. Another key issue is poor co-ordination between participants on account of reasons such as ineffective communication, improper conflict resolution mechanisms and resources who are not properly trained to work on IB projects. These can lead to multiple challenges during the project's execution and subsequent operation, if not mitigated.

Addressing these concerns involves navigating a myriad of critical issues and challenges for all stakeholders involved. On one end of the spectrum are owners and occupants, whose propensity for a seamlessly functional and personalized IB experience warrants complete adherence to IBDI processes. The process of minimizing adoption challenges for project partners and service providers entails efforts by the entire ecosystem of players responsible for enhancing the adoption levels of IBDI processes and practices. While it is simpler for owners and occupants to lay down their intent and wish list from an IBDI process, the method of going about commissioning them is far more complex, and, at times, flawed. On the other hand, the ecosystem of service providers needs to step up their level of adherence to practices and coordination among peers to deliver to that intent. In this regard, some key issues and challenges for the industry stakeholders are shown in Figure 3.1.

Figure 3.1: IBDI Domain Issues and Challenges

Issues[1]	Challenge and Impact	Propagated By
Value Engineering of Components	• Driving project decisions on cost • Declining vendor interest for innovation	• Contractors, SIs, EPCs, Owners
Absolute Control of Contractors	• Lack of product incorporating knowledge • Driven by cost and schedule to complete and move on • Hindrance to the installation of other requisite systems as the project progresses	• General and mechanical contractions; sub trades
Inadequacy of Tools and Standards	• Lack of specific IB design tools • Generic elements and broad framework of design specification Master Formats • Inadequately defined specifications for rating quality and functionality of IB technologies	• Design Tool Developers; Specification Standard Developers; Professional Bodies

Issues[1]	Challenge and Impact	Propagated By
System Interoperability and Integration Issues	• Static design and inability to incorporate future innovative solutions • Limited control over processes and outcomes • Cost implications	• Vendors and SIs
Exclusion of Owners and Occupants	• Faulty structure of task allocation and communication flow • Lack of feedback loop • Vision and strategy mismatch with final outcome	• Design build firms; CEs; Vendors
Training and Certifications	• No institutionalized options • Training costs can be a deterrent • Consensus on qualifications to certify • Keeping pace with technology advancements • Maintaining a qualified resource pool	• Academic Institutions; Professional Certification Bodies; Vendors
Credits and Incentives	• Takes years to develop • Compliance cannot be enforced • Biased towards passive components • Lack of comprehensive treatment of IB technologies and practices	• Associations and Accreditation Agencies; Utilities

Value Engineering of Components

One of the most widely accepted challenges is the tendency across stakeholders to value engineer components for cost control. In the IB scenario, given the level of interoperability required, value engineering might result in the system continuing to work in isolation, but it can have a negative impact on the interoperability capabilities of the system. For example, occupancy sensors that are a part of the lighting system may not be required for lighting purposes in some cases. However, if the smart thermostat installed in the IB requires that information for temperature control and the sensors are removed from the design due to cost saving tactics, without consultation with other stakeholders, it can possibly result in project delays.

Absolute Control of Contractors

Often during construction and installation there are instances of faulty design or interim design changes flagged for addressing by concerned parties. In these cases, one of the common issues identified is that the project contractor assumes responsibility for design changes or project schedule changes in an attempt to prevent delays in execution. However, due to lack of design skills or tools at their disposal, the contractor might clear changes that can be detrimental to the outcome and impact future building operation, including hindrance to the installation of other systems as the project progresses.

Inadequacy of Tools and Standards

The current design tools available to architects and designers might not be sufficient to incorporate all aspects of IB design. These, in addition to inadequately defined specifications for rating quality and functionality of IB technologies, can result in project designs that require rework during the construction phase and cause issues in project delivery.

System Interoperability and Integration Issues

System interoperability and integration issues are the most significant challenges unique to IB implementation. Due to proprietary technologies and sporadic adoption of open protocols, brand-agnostic SIs face an increasingly complex task in ensuring interoperability and communication for various systems in the IB. These issues can arise at the execution phase or can also stem from the design and planning phase of the project during which requirements for various vendors are established. The appointment of vendors possessing systems that face increased challenges in integration with each other can prove detrimental in terms of project time and cost. For owners and occupants, the consequences of dwelling in an environment with static systems offering limited scope for incorporating future technology advances, defeats the objective of trying to create an IB in the first place.

Exclusion of Owners and Occupants

Due to the structure of task allocation and communication flow created during project execution, inputs from the building owners or occupants might not always get translated to changes during the construction or installation phases. Urgent feedback from suppliers and sub-contractors on various issues can face multiple roadblocks due to the communication structure. As the findings of the industry professionals' survey revealed in the previous chapter, inaccessibility to vital information throughout the entire span of IBDI process is a common occurrence that building owners and occupants encountered. A clear escalation matrix is an imperative requirement to ensure critical issues are identified and resolved before they have an adverse effect on project costs, timelines and impact to the pursued design.

Training and Certifications

Delivering a truly cohesive IB through IBDI processes calls for critical involvement of the right SIs and technology contractors. For traditional SIs, there is a lack of trade certifications that support the role and service profile of various value chain partners in the intelligent buildings industry. Due to the proprietary and unique nature of technology, each OEM often has to have the SI trained and certified on their respective technology. These training and certification costs are not borne by the OEM. SIs need to budget for these expenses to be able to take on projects that involve technology of that particular OEM. As a result, it is cost prohibitive for SIs to spend multiple times to get certified under each OEMs banner. Without specific OEM certification, they take the risk of foregoing projects that calls for a specific OEMs technology.

At present, as no mechanical, electrical, or similar trade courses and certifications in the industry can serve as a close alternative, it is critical that industry associations give due attention to creating a trade certification course that can harmoniously represent the various technologies, standards, and installation requirements to complement the IBDI process. To standardize industry certifications and make them effective, this would require OEMs to take a stand on open and interoperable technologies, and ensure that they move away from proprietary locked-in solutions. Though this is a hard proposition for the industry, installers and integrators would be able to work with, and represent, a wider spectrum of OEMs, without having to acquire multiple certifications that do not provide them much incentive.

Credits and Incentives

Given that rating tools in the industry are heavily focused on operational performance of buildings, it is necessary to highlight the inherently strong competencies of such tools and enhance their framework to support the adoption of IB solutions and services. There is a need for a more organized approach to measuring the investment benefits in IBs as well as for adopting IBDI methods to execute projects. Currently, the various rating tools and other credits and incentives available to the industry are more geared towards passive performance-based evaluations, as opposed to measuring the quantifiable benefits yielded by active intelligence. Furthermore, the initiatives that can help in earning a credit or an incentive are merely encouraged, not mandated.

Credits and incentives will continue to function as key inducers to investment in IB projects. Therefore, the credit systems need to adequately endorse the contribution of intelligent technologies. Given the fact that most credit and incentive programs are consensus based, and take a fairly long time to enact amendments and complete public review processes, it may be more prudent to form alliances with other programs in the industry.

3.2 INDUSTRY CONSENSUS DEVELOPMENT ON CORE ISSUES

Ineffective communication between stakeholders was a primary cause identified in terms of IB failures due to poor design and project planning as a part of the research findings highlighted in Chapter 2. This can be due to no communication, mis-communication, or delayed responses during design and implementation. The success of the design and implementation process for IB projects depends on its key supplier and fulfillment stakeholders working together. As IB technologies and projects continue to evolve, a diverse set of suppliers is expected to emerge with rapidly evolving technologies and standards.

Given the proliferation of new participants in the market providing possibilities for innovations in interoperability and communications, it is imperative that IB processes keep pace with these dynamic changes in the market. Chart 3.1 provides an overview of the key contributing factors for IBDI breakdowns and failures.

Chart 3.1: IBDI Breakdowns and Failures: Key Contributors

IBDI projects fail to deliver on their strategic goals in four key primary areas. While secondary contributing factors propagate these failures further, these primary factors are often the triggers that perpetuate a cycle of process breakdowns, typically with little scope for course correction in place.

Lack of Partner Alignment	Unclear Vision & Strategy	Disjointed Planning & Processes	Inability to Monitor, Test & Adapt
49%	**51%**	**56%**	**58%**
of participants experienced the impact of this factor in negative project outcomes	of project participants agree to this as a key contributor to IBDI failure	of the overall respondents attribute IBDI breakdowns to this factor	agreed to the inability to rectify problems or change course during the execution phase

The challenges start, primarily, with assembling project partners that are not necessarily well aligned with delivering the end results. Ranging from cost-driven bid evaluation processes, to overt reliance on past relationships and single parties, several reasons contribute to the persistence of this challenge. Once a faulty partner selection is initiated, the domino effect is triggered, which ultimately propagates each of the subsequent negative outcomes. Inadequate understanding of owner and occupant strategy, fragmented technology solicitation and planning, and finally, abject inability to course correct at the crucial juncture when such issues are identified, creates an ever-increasing rift between project goals and eventual outcome.

Effectively addressing these challenges requires consensus to be built among various participants in the value chain. Figure 3.2 lays down the key areas that require attention, and measures that will help mitigate the negative outcomes associated with IBDI projects and practices.

The best practices identified here for successful IB project implementation are achievable given the experience of multiple participants in implementing the same. Ensuring a wider adoption rate of these practices would contribute to increasing the number of successful IB projects.

Figure 3.2: IBDI Process Improvements: Key Areas and Activity Achieved

	IBDI Process Improvements	Identified Best Practices
Following an integrated communication approach	• The project vision should be deliberated and consulted upon by the owner, design build consultant, technology vendor, and contractors to ensure agreement and understanding of the project delivery strategy. • In case of a disagreement, conflicts should be escalated via appropriate channels for ensuring a resolution without impacting project timelines. • Automated reminders for responses, automated email escalations as per a pre-defined escalation matrix, and a structured repository of communication are some possible features of a project communications platform.	The Chandler Regional Medical Center project[2] in Arizona demonstrated a comprehensive communication approach in their demand flow central plant optimization. Best practices identified: • Project operator, Dignity Heath worked closely with Siemens Industry, Inc., Van Boerum & Frank Associates, and Nexant, Inc. • Utmost interoperability between systems achieved • Scope gap elimination achieved
Utilizing an engineering management platform	• Platforms for streamlining communication are currently present in the market but require wider adoption and effective use of their potential features. • If adopted by all stakeholders, this can be configured to have pre-defined rules for each aspect of the IBDI process. • Any issues with installation or construction can be red-flagged during the design/engineering phase ensuring better control with automated progress tracking.	The US Department of Defense (DoD)[1] mandates this for all projects. Best practices identified: • In-house engineering platform covers project delivery, asset performance and continual measurement and verification • Emphasis on shifting focus from initial costs to unintended consequences of adopting poor design • Managed to reverse O&M costs escalation by $200,000 for the next 10 years

	IBDI Process Improvements	Identified Best Practices
Creating scope for new vendors	• This measure will help the inclusion of technology contractors at the right juncture of the IBDI process. • Creating scope for the inclusion of new technology entrants, and IoT solution providers in particular, is necessary as it allows the building owner and occupant to take advantage of new innovative technology to enrich their IB experience. • Additionally, this will also allow inclusion of new technology from innovative small vendors at a price that may not be available from larger vendors.	TIAA-CREF headquarters[1] in New York City adopted a process to mandate innovative technology vendor inclusion in their IB Projects. Best practices identified: • Mandatory pre-qualification of new technology vendors for smart HVAC solutions and thermal ice storage systems • Evaluating of new technologies that could attract utility rebates, while ensuring a successful IB project • Outcome: realized over 20% in 10-year IRR, and project over $760,000 annual savings in OPEX by using innovative smart HVAC solutions from a new vendor
Avoiding decision making purely based on cost thresholds	• Cost thresholds are neither realistic nor achievable in actual projects, and prohibit qualifying solutions on the basis of expertise and value. • There should be no compelling reason for such cost thresholds to be adopted based on the outcome of the industry research in Chapter 2. • Removing this component could potentially help to optimize the process and allow for the inclusion of more vendors and suppliers into the selection process.	The project advisor, Northam Realty Trust, involved in retrofitting the headquarters of Bell Canada[2], Toronto, drove their decisions on long term value. Best practices identified: • Insistence on specifications that are performance based prior to tender of energy-related building improvements • Avoidance of traditional bid-and-spec method of tendering that could result in an uncertain outcome • By avoiding IBDI processes based on cost, the project realized annual energy savings of $170,000

	IBDI Process Improvements	Identified Best Practices
Mandating a feedback loop	• Ongoing performance monitoring and continuous improvement is important to a successfully delivered IBDI project. • The high degree of industry fragmentation complicates and significantly limits the prospect for technology incorporation and objective IBDI adoption. • Installers, architects, and even building operators often do not offer any vital feedback on the solutions they solicit, install, and operate, unless there is a problem. • Including this as a prescriptive requirement into the contractual process can offer valuable insights into technology performance, cost-benefit, and establish their importance in IB projects.	The NASA Sustainability Base project[3], California, led by architects, William McDonough + Partners is a prime example of how important a feedback loop is in achieving success with IBDI projects. Best practices identified: • Multi-pronged communication channels created, and ardently followed by all project participants, including designers, lighting experts, building owner, external project verifiers and energy service providers • Communication and feedback processes also included external watchdog organizations such as academic experts like Carnegie Mellon Silicon Valley and the University of California, Berkeley to offer critical evaluations of the IBDI processes followed

3.3 INCENTIVIZING IBDI USE

A key reason building owners adopt IB technologies is the possibility for credits and rebates that could offset some of the initial capital expenses. A number of these credits and incentives are more focused on energy-efficiency goals. With ever-increasing energy consumption requirements, utilities are relying on efficiency incentives to help customers implement suitable measures that would, in turn, drive down overall energy demand. IB technologies come with the added advantage of ensuring a reduction in energy consumption, thus these incentives are playing a role in incentivizing IB technology adoption, and thus creating a niche demand for IBDI practices.

Energy efficiency portfolios can consist of different programs to meet customer needs. Some such programs[4] are:

- Rebates for individual efficiency measures
- Custom incentives for large-scale retrofit projects
- Demand response and distributed generation programs

Rebates for Individual Efficiency Measures

The most common forms of energy efficiency programs are cash incentives for implementing certain defined measures in existing buildings. The incentives assist in paying the cost of upgrades for efficient equipment. By reducing a part of the initial investment in IB technologies, these incentives can contribute to cost control and shorten the project payback time.

Such programs have historically not included supporting technologies such as sensors, meters, and controllers. However, some programs have started including these as part of their incentivized technologies.

Some IB technologies incentivized through such programs include: advanced occupancy and vacancy sensors that work with lighting and heating, ventilation, and air conditioning (HVAC) controls; photo sensors for daylight harvesting; smart power strips; smart plugs; and building management systems (BMS). The commercial building programs of the US based utility, National Grid offer incentives for advanced lighting controls, high-efficiency air compressors, and building automation systems (BAS).

Some examples of incentives are listed below:

- Up to $40 for occupancy and daylighting controls
- $75 per sensor for hotel guest room occupancy sensors (used for temperature control)
- Between $100 and $200 for 15-75 horsepower (HP) air compressors having variable speed controls

Custom Incentives for Large-scale Retrofit Projects

Custom incentives for large-scale retrofits are programs based on overall system efficiency improvements. Building-wide, energy savings goals are determined for incentivizing specific energy saving technologies. Building owners and energy service companies are the key collaborators ensuring better savings through system improvements.

For example, the utility, Pacific Gas and Electric Company (PG&E), provides such incentives. For commissioning of retrofit systems, incentives can cover up to 50 percent of costs, for savings of $0.08/kilowatt-hour (kWh), $1.00/therm, and $100/kW peak demand.

A similar program by another US utility, National Grid, focuses on peak demand reduction and energy savings during the highest consumption periods annually for heating or cooling. National Grid can cover up to 50 percent of total installed costs of the new equipment or an amount buying down the project's cost to a one year payback.

Demand Response and Distributed Generation Programs

Smart meters are key components for driving utility demand-side management programs. The load data gives customers or customer energy management systems real-time information regarding electricity use of the building. This enables reduced electrical consumption during peak demand periods after identifying demand response opportunities.

National Grid offers a similar system for customers based in Massachusetts that involves net metering and distributed generation interconnection with the grid. Demand response, also taking into account generation by the buildings, can be effectively enforced and incentivized.

Additional Incentives

Additional incentives include building certifications, such as Leadership in Energy and Environmental Design (LEED), Energy Star, and Building Research Establishment Environmental Assessment Method (BREEAM), that serve as branding opportunities for participants and can assist in identification for rebates. Certifications such as these will be described in further detail in the coming sections.

Ensuring that it is not just the owners and occupants, but also other stakeholders in the design and implementation process, such as contractors, project fulfillment partners, and SIs, is imperative to ensure that a smoother implementation process followed in IBs. Levels of rating for such project partners based on the number of successful IB projects they have contributed to would ensure a higher level of ownership and better execution of IB projects.

Overall Assessment of Credits and Incentives for IBDI

Given that rating tools in the industry are heavily focused on operational performance of buildings, it is necessary to highlight the inherently strong competencies of such tools and enhance their framework to support the adoption of IB solutions and IBDI processes. There is a need for a more organized approach to measuring the investment benefits in IBs on a wider scale. As noted earlier, currently the various rating tools and other credits and incentives available to the industry are more geared towards passive performance-based evaluations, as opposed to measuring the quantifiable benefits yielded by active intelligence. Furthermore, the initiatives that can help in earning a credit or an incentive are merely encouraged, not mandated.

The research undertaken for this project indicates that credits and incentives will continue to function as key inducers to investment in IB projects. Therefore, it would be in the interest of this industry that the credit systems adequately endorse the contribution of intelligent technologies and the design and implementation processes that help enhance their adoption.

3.4 OPTIMIZATION OF THE TECHNOLOGY AND DESIGN INTEGRATION MODEL

A fully integrated technology design for IBs is required during the design and execution phases of a project to ensure effective coordination, validation, and an understanding of IB systems involved by all concerned stakeholders. This would also cater to the requirement for joint commissioning of integrated systems to ensure a seamless handover to the IB operations team. The evolution of building designs that cater to the new possibilities enabled by technology development requires further education of architects and other design professionals. This will help them understand the different aspects of IB technologies and the beneficial effect they can have on building design. The ecosystem[5] of IB technology design in terms of functional areas and stakeholders has been illustrated in Chart 3.2.

Chart 3.2: Integrated Building Technology Design Ecosystem

In addition to the education of designers and architects, the education of other stakeholders involved with IB technology system development and integration is essential to ensure better coordination with design teams and contractors. During the detailed design or engineering phase of the project, the process, consisting of schematic design, final design development, and construction documents, will have different areas of interaction with participants regarding different IB technologies.

For example, inputs from architects would be around spaces for equipment rooms, end-user devices, and related cabling that may need to be coordinated with finishes, millwork, and furniture. Mechanical design engineers are required to consider the HVAC system and the automation surrounding the same, with its effect on potential changes in HVAC design due to efficiencies that can be realized with IB technologies. Cabling, cable trays, and conduits need to be appropriately configured to account for control systems and interconnectivity.

The above systems should also consider aspects of scalability and make allowances for the future requirements of cabling and equipment storage in the case of building systems achieving a higher level of automation. One key aspect of ensuring scalability is utilizing modular components in building systems. This enables easy upgrades without the need for extensive rework, avoiding possible operational downtime.

3.5 STANDARDIZATION INITIATIVES NEEDED

Various standardization initiatives in the industry are a requirement to ensure that IB projects have successful implementation and a resultant higher adoption rate. These initiatives are required for standardization of features, connectivity of systems, tools employed for design and implementation, trade certifications, and standard methods of rating building 'intelligence'.

Standardization of Tools for Design and Implementation

Ensuring that the practice of using certain tools for enabling design and implementation is widely adopted is important in guaranteeing a high success rate for IB projects, especially given the added complexity of such projects, due to the increased interdependencies between building systems.

Ensuring project design, planning, and the engineering cycle are controlled and monitored on enabling platforms is required for guaranteeing minimal conflicts during the construction stage. Pre-defined permissions for individual drawings and packages in the project would ensure key stakeholders are kept informed about project progress and requirements.

Using tools such as building information modeling and energy modeling is also a requirement to ensure efficient IBs and minimal rework during the construction and operation stages. Including such requirements in building codes and recommended design practices would be a possible method to ensure adoption.

Recognition of Building Intelligence in Rating Tools

Rating tools for various aspects of operational performance of buildings need to be highlighted in terms of their respective competencies and require enhancement to include provisions for the intelligence of the building as opposed to energy efficiency and connectivity.

Popular rating tools such as LEED, Energy Star, and BREEAM focus on passive performance of building systems as opposed to features such as self-learning and autonomous control. Including incentives for the same, even from the point-of-view of energy savings, would be desired to ensure growth of truly intelligent buildings.

Trade Certifications

Certifications for the benefit of participants apart from owners and occupants in the value chain are required to ensure a higher level of involvement in the IB technologies implementation aspect of building projects. Presently, there is a lack of such certifications in the market. An increased level of training specific to IB technology implementation and mitigation measures for common project issues could help to distinguish participants who are 'IB-ready' as opposed to others. These could initially be a differentiating factor for participants such as architects and planners. A certification in this area for an architect would indicate their ability to design keeping IB considerations in mind and the ability to mitigate commonly encountered IB project issues during execution.

The number of successful IB-related implementations by a participant would also be desirable in motivating and identifying 'IB-expert' stakeholders.

3.6 PROSPECTS FOR COLLABORATIVE PARTNERSHIPS

With the rapid evolution of the IB industry and the changing landscape of stakeholder interactions, it is necessary for participants to collaborate during the design and implementation phases to ensure a differentiated offering and improved performance.

Partnerships among SIs and Energy Solution Providers

Issues during systems integration and a high level of downtime during operations due to improper integration are the common primary pain points of IB projects. The partnership among SIs, ESCOs and energy management platform providers could ensure a single point of responsibility, if issues arise during commissioning or operations.

A thorough understanding of each other's operational methods and requirements would ensure a reduced rate of issues during the installation and operation of a building's integrated control and monitoring system.

Partnerships among Allied System Suppliers

A partnership among suppliers providing IB technologies and solutions would ensure minimal involvement of system integrators and faster integration due to detailed in-house knowledge of the structure of each system. Such a partnership would require a high level of integration in terms of individually installing their systems and jointly setting up interconnectivity supporting infrastructure for the networked systems.

Other Collaborative Partnerships

Poor communication among stakeholders is one of the primary reasons for IB project failure. This makes it important to ensure that all stakeholders are involved in the design process and to ensure that unresolved issues follow the required escalation matrix. In this type of scenario, it is useful to utilize an automated project management platform for communication and control of the engineering cycle.

Ensuring partnerships over multiple projects between overall project fulfillment participants and project management platform providers would ensure faster platform configuration thanks to a shared experience of multiple IB project implementations. This will also act as a value proposition while bidding for a prospective contract for project management.

4 EVALUATION OF PROCESS OPTIMIZATION REQUIREMENTS

4.1 ELEMENTS OF AN OPTIMAL IBDI VALUE PROPOSITION

For every IBDI participant involved in project execution, it is imperative to ensure efficient management of day-to-day activities. These participating organizations should incorporate operational processes that will support predictive analysis of the project activities. Additionally, they will need to develop best practices in delivering products and service solutions that address the growing need for resourceful operations in the construction of an intelligent building (IB). The design and planning process needs to be well integrated and should involve joint efforts between various value chain partners, such as building owners, architects, and technology consultants. Preferably, the understanding of all stakeholders along the value chain should be fully exploited early in the design and planning process, but that is seldom observed under current arrangements[1]. A number of challenges are involved in arriving at an integrated design process, some of which include lack of communication, lack of teamwork, and lack of information and technology awareness. The industry is in the early phase of re-envisioning the currently used design and implementation processes.

The following elements must be considered when evaluating the strength of an IBDI value proposition: process optimization, interdependency of value chain partners during implementation, and best practices that stakeholders should adopt. These elements are analyzed in the following sections.

4.2 PROCESS OPTIMIZATION

Optimization aims at finding the most fitting solutions with respect to predefined objectives in any type of construction or customer segment of an IB project. This research finds that a majority of the organizations surveyed have not established well-structured practices in the design and construction management of an IB. In fact, fundamental issues underpin the process traditionally adopted during project execution, which leads to substantial cost overruns, time delays, and sub-optimal delivery of IBs. Process-related shortcomings are evident in each stage of project management. Due to the frequent shortcomings, optimization is identified as a major need to create a seamless flow of operational activities that are traditionally followed in a construction project. For deeper evaluation, shortcomings and areas of focus should be identified within different categories of each project stage, such as design and planning, execution, and control.

Figure 4.1 provides an overview of inadequacies found in traditional processes and the focus areas identified to achieve optimization and cutting-edge practices.

Figure 4.1: Challenges in Traditional Processes and Area of Focus

Stage	Challenges in Traditional Processes	Areas of Focus
Design and Planning	• Disconnect among value chain partners • Cost-driven approach by owners • Inadequate efforts to understand stringent project specifications leading to poor design • Lack of awareness about IBDI benefits • Lack of understanding of technology advancements • Team inexperience • Over-reliance on contractor	• Collaborate with project partners. Even earlier involvement of contractors, technology partners and operation and maintenance team is needed to provide feedback during the initial phase. • Building owners should focus more on long-term and operational costs. • Insist on establishing a complete and detailed understanding of the desired goal(s) and project specifications to ensure a strong design plan. • Stay updated on the latest technological advancements and associated benefits. • Have an experienced and multi-disciplinary team to generate the perfect design plan. • Understand the functionality of various technologies.
Execution	• Identification and allocation of resources • Slow to comprehend interoperability and integration of technology • Lack of communication and collaboration among project team, vendors, and owners • Lack of in-depth knowledge of technology	• Precise material and manpower should be allocated for specific activities. • Establish an experienced team for execution. The resources should be able to quickly grasp the integration and interoperability of the devices. • Maintain open communication with all project partners, including building owners. • Education and training is needed on the application of particular technologies to ensure contractors and system integrators provide solutions as per the project standards and specifications.
Control	• Weak project monitoring and control	• Building owners, consultants, and contractors should regularly monitor and use tools to control the progress and cost performance of the project.

Building owners and project partners should focus on incorporating diverse best practices within the design and implementation process of an IB to optimize the methods and obtain better outcomes. The following methods should be adopted to overcome the challenges currently restraining the traditional approach.

Determining and communicating the objective: An IB project should achieve specific goals and objectives. Building owners need to determine their specific goals and objectives and then coordinate with all project partners to ensure the desired objectives and project processes are clearly communicated and understood.

Focus on total cost of ownership: Building owners should focus on creating sustainable building technologies by focusing on total cost of ownership and ensuring best-in-class technologies are procured.

Common shared goals: All value chain partners and building owners should have a high visibility into the project. Building owners might prioritize value for money, whereas designers and architects might concentrate on aesthetics and conceiving the ideal building design. Aligning interests and establishing a single shared goal is essential to support the design and construction success of an IB.

Role of project manager in each organization: A project manager's responsibility is to plan, coordinate, and control the complex and diverse activities of IB design and construction management. Although each IB project will have its own unique characteristics, the activities of design and implementation are repeated from project to project. It is important for a project manager and team to transfer knowledge from one project to the next. They should understand the complexities and develop the critical path analysis needed to overcome all implementation challenges. Ultimately, any past experience can and should be used to support the successful implementation of an IB.

Mandate monitoring and control: Building owners and project partners should continuously track all project operations. The significant amount of project-related data should be collected and documented to analyze progress. In this way, if something varies from the set standards, it can be detected quickly and the root cause identified to implement effective remedies immediately.

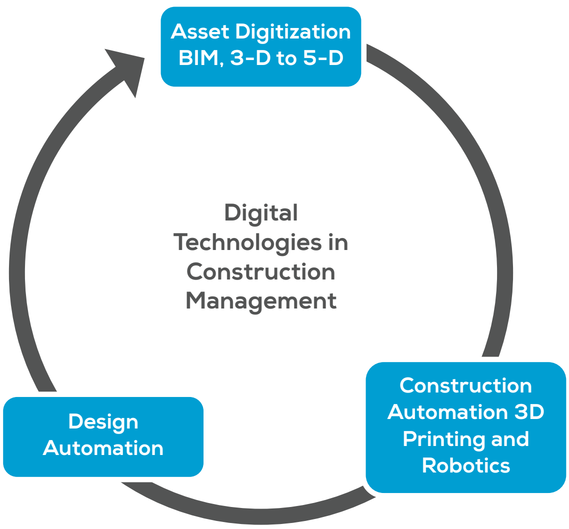
Teamwork: Teamwork helps building owners and project partners collaborate and gain a greater sense of visibility and accountability in offering the most optimal solution. It also supports proper allocation of material and resources.

Project completion and handover: A final inspection test should be carried out to verify compliance with standards and accurate interoperability of various devices. The final acceptance certificate should be issued to document the correct functioning of the entire integrated system within the IB.

The traditional processes can be optimized further with increased use of cloud-based collaboration software, which centralizes all content where stakeholders can meet, share, and develop ideas. Additionally, asset digitization software such as building information modeling (BIM) and virtual reality (VR) assists architects, designers, and building owners by simulating a building for identifying potential issues, even before initiating project activities. Adoption of these software platforms has begun and is gaining momentum within various IB construction projects. Chart 4.1 provides an overview of digital technologies used in the construction management.

Chart 4.1: Digital Technologies in Construction Management

Digital tools will continue to transform the construction industry by making processes more collaborative, efficient and cost effective, albeit their modest rate of adoption witnessed at present.



Asset Digitization

In a typical construction project, massive information streams are produced. Time and money spent on handling unstructure information could result in extra 20-25% cost additions. Solutions such as Cloud based BIM are helping to eliminate such issues.

Construction Automation

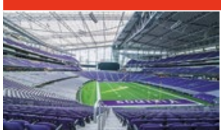
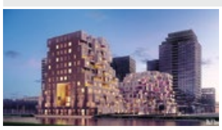
The adoption of 3D printing, robotics, and drones is increasing in the construction industry and has potential to change the nature of a construction process at the site.

Design Automation

The nascent field of building engineering using complex computer algorithms to automatically generate various design combinations.

Digital tools and technologies are adopted by various companies during design, detailed engineering, planning, onsite construction, and supply chain. A select list of projects demonstrating successful implementation of digital technologies in construction management is provided in Figure 4.2.

Figure 4.2: Implementation of Digital Technologies in Construction Management

Project Description		Highlights of Success
	Project : The 70,000-seat U.S. Bank Stadium, Minneapolis, MN Firm: Mortenson Construction	The company digitized the project work by using VR to spot the problems at an initial stage and later used BIM to efficiently deliver higher quality project saving cost and time.
	Project : Walt Disney Concert Hall, California Firm: S.L.Leonard & Associates	The design and construction of the Walt Disney Concert Hall in California was aided by the use of 4-D models and virtual reality right from the planning stage. This greatly helped to manage risk and improve the communication between the project partners to deliver the project successfully.
	Project : Summertime Housing Complex, Amsterdam, Holland Firm: HFB	HFB used digital technologies to create digital replicas and 3D model to have a real world feel. Cloud-based BIM was used to access and manage the data which helped company to effectively manage end to end project solutions.

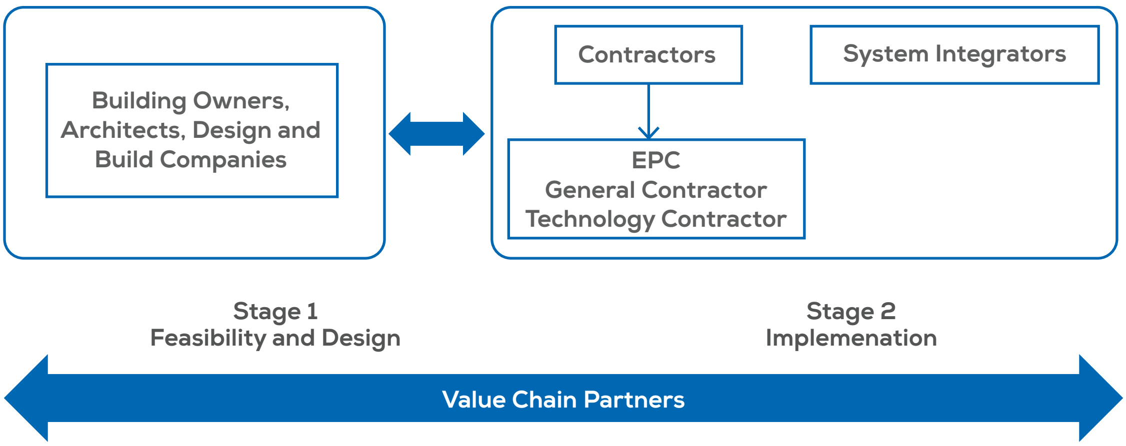
Thus, significant effort is required from all stakeholders to ensure proper collaboration, technology awareness, and that the latest innovations are used to adequately integrate smart technologies. The immediate industry need is establishing best practices and initiatives that support team collaboration in developing an IBDI framework. While some of the methods discussed are being incorporated on a project-to-project basis by building owners and project partners, more concerted effort is required at the industry level to firmly embed them into the traditional value chain practices of IB design and implementation.

4.3 VALUE CHAIN INTERDEPENDENCY IN IMPLEMENTATION

The heterogeneous nature of IB design and construction comprises a diverse mix of vendors and service providers that collectively offers smart technologies and connected services to end-users. In the absence of end-to-end delivery provision from a single value chain partner, collective efforts, coordination, and alliances between the participants are key requirements for delivering IB offerings.

To optimize processes and successfully implement an IB project, value chain partners need to understand the project objectives in detail and address the issues of coordination, communication, and project control across the entire value chain. This value chain interdependency during IB implementation is evident in the typical and collaborative models, which are analyzed in Chart 4.2 and 4.3 respectively.

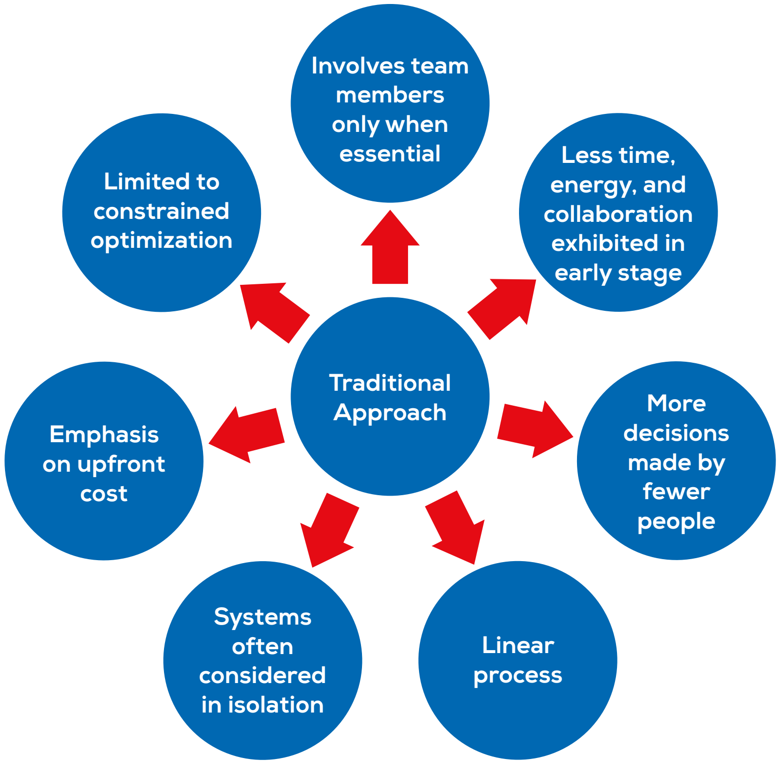
Chart 4.2: Typical Interdependency between Value Chain Partners



In general, architecture and design firms, along with building owners, develop specifications and actively participate in the conceptual stage of a project. However, some stakeholders, such as contractors and system integrators (SIs), are not acknowledged during the initial stage and are not always part of the primary planning phase, which negatively impacts project implementation. Although the design team develops an initial concept with the client, the lack of execution experience and a universal view of construction often results in design changes and an extended project time frame. For example, one of the most important and critical decisions for an IB is the selection of a heat, ventilation, and air conditioning (HVAC) unit. Architects and designers can fail to consider the particular type of air conditioning system, load requirements of different rooms, and materials needed to construct the system. Yet, all of these factors are vital to the proper sizing of a duct. Traditionally, dehumidification and air conditioning were considered an isolated system; however, with the latest energy-saving technologies, an integrated building system is available in the market. The space occupied by an integrated HVAC system is different from what is needed for isolated systems. Similarly, if an energy-recovery wheel is integrated into the HVAC system, it might reduce the cooling capacity required and save space by having a smaller compressor or other components in the system. Thus, if the HVAC equipment and ductwork design are not optimized during the design and planning phase, they may end up requiring design rework and cause project delays.

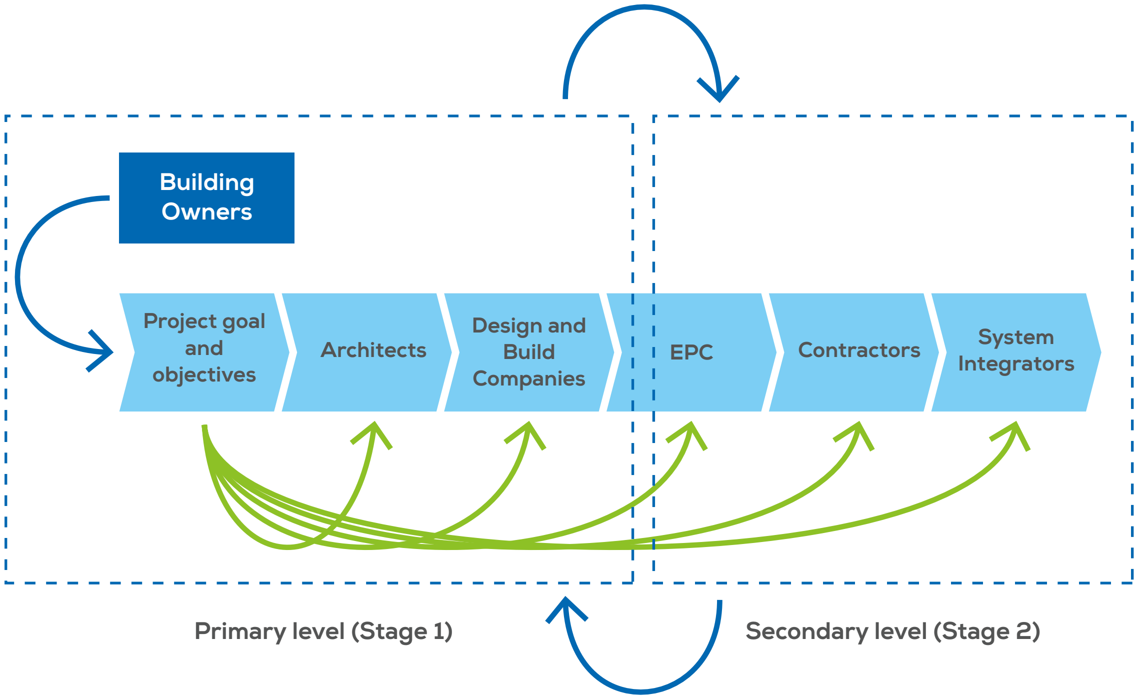
Some of the elements of the traditional approach adopted within the value chain are outlined in below Chart 4.3.

Chart 4.3: Elements of the Traditional Approach Adopted by Value-Chain Partners



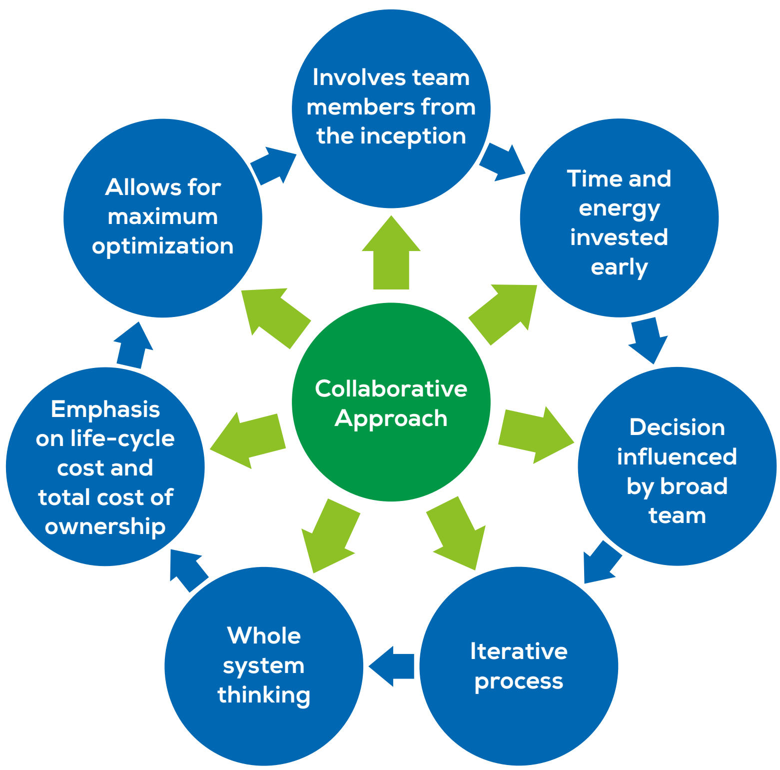
Ultimately, design development remains the expert domain of architecture and design companies, but to maximize a project's value as a whole, a more integrated approach is necessary[2]. An integrated approach will help dissolve the traditional barriers that isolate the design and implementation stages by bringing together all participants and their various knowledge and skills. The need is clear for a cohesive design and implementation approach to replace the typical transactional approach followed in IB projects. A collaborative approach permits early involvement of various participants, including different contractors and SIs, which positions them to understand the project goals, objectives, and design specifications, while empowering them with extra room to devise creative solutions and engage in the intensive exchange of ideas that is missing, yet needed, to help them better approach the project design and implementation of an IB[3]. Chart 4.4 illustrates the collaborative approach.

Chart 4.4: Collaborative Approach of Value-Chain Partners



The elements of an integrated approach adopted within the value chain are outlined in Chart 4.5.

Chart 4.5: Elements of an Integrated Approach



With adoption of a collaborative approach to the value chain, specific needs for early involvement of various project partners have been identified. Figure 4.3 outlines the needs of various value chain partners involved during the preliminary phase of a project.

Figure 4.3: Early Involvement Needs of Value Chain Partners

Value Chain Partners	Early Involvement Needs
Building Owners and Occupants	• Development of building codes and specifications • The objectives and goals such as degree to which systems integration is required should be understood, managed, and communicated to project partners from the beginning of new construction, renovation, or retrofit of an IB project
Architect and Design and Build Companies	• Finding the most economical and sustainable solution that can be reviewed with building owners and project partners at the early stage of an IB project
General Contractors, System Integrators, and Maintenance Team	• Use of knowledge gained from positive and negative experiences in previous execution of projects to optimize the design framework in support of a smooth operational process
Technology Contractors/Suppliers	• Expertise in state-of-the-art smart technologies used in an IB can provide product knowledge and updates on the latest technological developments

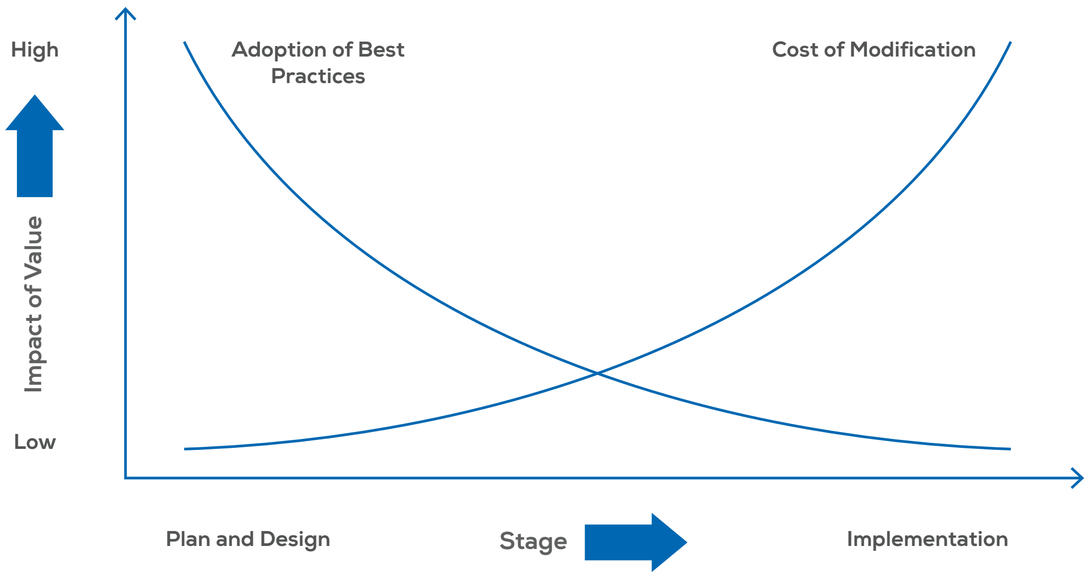
The positive implications of early involvement among value chain partners consist of improved cost estimation and planning, proper risk management, and fewer errors and changes during execution phases2. To achieve an optimal and sustainable performance level of an IB, the building owners, operation and maintenance team, vendors, and all other project partners must get actively involved during the design and planning phase. The purpose is to utilize every participant's knowledge and experience through all project phases to develop a better, more unified understanding of the project. Ultimately, the collaborative approach is needed throughout the design and implementation process to enable holistic evaluation of the project and to identify tradeoffs that will lead to the optimal IBDI value proposition.

4.4 BEST PRACTICES FOR STAKEHOLDERS

A wide range of technology is integrated into an IB to enable various functions that offer additional value for end-users. One of the key challenges for IBDI participants is ensuring best practices are adopted across the entire value chain. Yet, all project partners may not implement the same best practices or comply with all the required standards. For example, SIs may adopt best practices in their processes, whereas architects and technology contractors may adopt some, but not comply with the stringent design and implementation standards at the same level. Therefore, it is necessary for every organization and project partner to strongly emphasize team education and create awareness about the significant benefits associated with adopting and adhering to best practices.

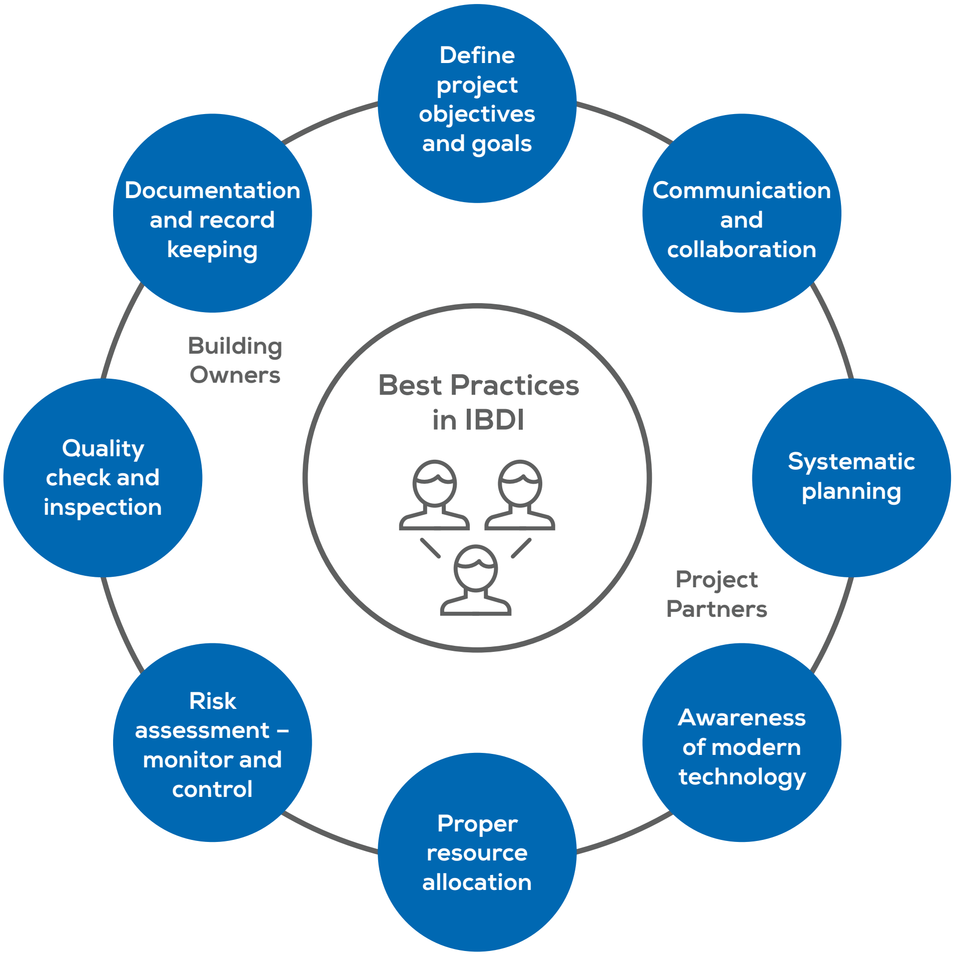
For instance, the reduced cost of a project is the major driver for implementation of best practices in design and construction of an IB. Once the project begins, there are numerous factors that increase the cost of the IB project. A design change is one of the factor causing subsequent delays and invariably increases budget costs. To achieve substantial improvements in costs associated with IB design and construction productivity, building owners and project partners must keep the implementation process in mind during the design, engineering, and execution stages. Chart 4.6 illustrates high adoption of best practices during the initial design and planning stage, which is the best way to mitigate and overcome cost overruns during a project.

Chart 4.6: Adoption of Best Practices in Relation to Cost of Modification



The mitigation of challenges in the IBDI process requires all stakeholders to adopt best practices that can help in predictive analysis. However, value chain participants have been adopting several different methods with varying levels of applicability in attempt to mitigate the design and operational challenges of an IB. After close inspection, several best practices and commonalities in the techniques stand out in the approaches of various project partners and building owners, as illustrated in Chart 4.7.

Chart 4.7: Best Practices in Design and Implementation of Intelligent Buildings



Best Practices: Project Partners and Building Owners

For successful execution and positive outcomes of an IB design, it is important for a project team to insist on adhering to best practices in terms of the following:

- Systematic planning, preparing, and understanding the project objectives
- Involvement of important value chain members during the first stage of design and planning
- Experienced, multidisciplinary, and well-managed team members chosen for the design and installation process
- Proper allocation of all resources
- Clear and timely communication with shared common goals between all project members and building owners
- Working efficiently as a team
- Regularly developing and monitoring project progress to resolve issues
- Carefully inspecting all third-party products and solutions before integration
- Staying updated on the modern technological developments that are generally used and integrated into an IB
- Educating end-users and training internal teams and partners to ensure secured deployment of products and solutions of an IB

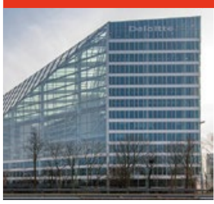
Best Practices: Design and Technology

Some of the key best practices in design and technology include the following:

- Good design to predict and proactively rectify all concerns
- Good design with integrity of proper placement of systems that are installed in an IB
- Most sustainable design and construction plan possible that will facilitate intercommunication with all desired systems
- Successful integration of the technology and inspection of a complete system

Thus, effective IB management requires more than a well-conceived design and implementation plan. It requires continuous vigilance throughout each stage of the project's life cycle. The collective understanding of best practices in IB construction is to have a solid design and plan, which forms a foundation for seamless execution. Armed with strong project execution framework architects, design consultants, system integrators, technology contractors, vendors, and other project partners can evaluate various options to determine the best approach when integrating their solutions into intelligent building projects. A select list of projects demonstrating successful integration of IBDI processes is provided in Figure 4.4.

Figure 4.4: IBDI Projects: Demonstrated Best Practices Review

Project Description	Key Stakeholders	Projects Pursued with an IBDI Method	Highlights of Success
 The Edge[6,7,8,9] 430,500 sq.ft. office building, owned by Deloitte.1081 LA Amsterdam, Netherlands	**Client:** OVG Project Development **Architect:** PLP Architecture Ltd, London and Oever Zaaijer **Interior Architect:** Fokkema & Partners **Contractor:** G&S Bouw **Installation Advice:** Deerns Acoustic, Building Physics and Fire Safety **Advisors:** LBP Sight **Design and Structural Engineering:** Van Rossum	Intuitive adjustments to lighting, temperature, facilities as per detected schedule, Ethernet powered LED lighting, automated heat regulation, autonomous control	• Highest rating by BREEAM: 98.4 percent • A total of 28,000 sensors • Collaborative approach with multiple stakeholders during design • Collaboration with academia for energy efficiency optimization
 NASA Sustainability Base[4,5], 50,000 sq. ft., Moffett Field, California	**Client:** NASA Ames **Design Architect:** William McDonough + Partners **Materials Assessment:** McDonough Braungart Design Chemistry Architect / MEP / Structural / Civil: AECOM **Lighting / Energy Consultant:** Loisos + Ubbelohde **Contractor:** Swinerton **Design Landscape Architect:** Siteworks Studio **External Partnerships:** Lawrence Berkeley National Laboratories (LBNL) , Carnegie Mellon Silicon Valley , University of California, and Stanford's Center for Integrated Facilities Engineering	Digital lighting management systems, daylight solar shading, automated climate control	• Usage of building information modeling (BIM) • Seamless coordination among lighting contractor/consultant and other technology contractors involved in integrated design process • On-site research with Carnegie Mellon Silicon Valley and the University of California, Berkeley as well as engagement with Stanford's Center for Integrated Facilities Engineering for neutral advisory assistance

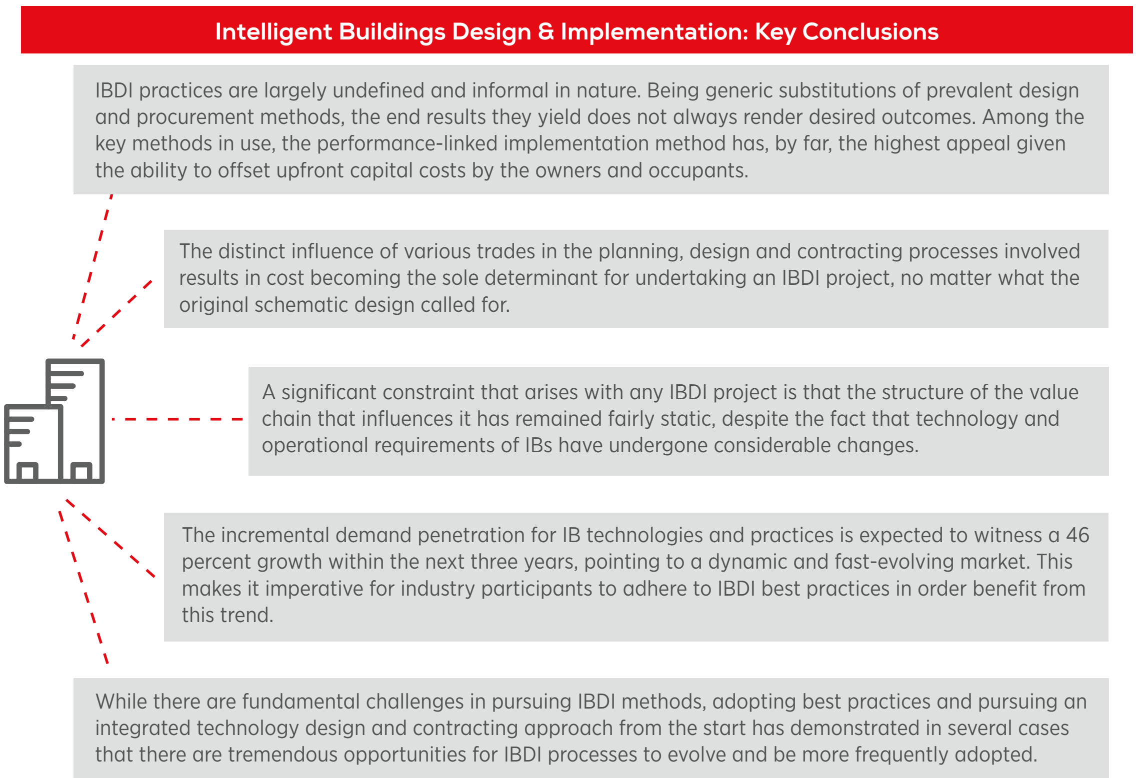
Project Description	Key Stakeholders	Projects Pursued with an IBDI Method	Highlights of Success
 San Diego Medical Center[10], 663,000 sq. ft., San Diego, California	**Client:** Kaiser Permanente **Architects:** CO **Design and Engineering:** ARUP **Construction:** Hensel-Phelps **Civil Engineer:** RBF Consulting **Structural Engineer:** KPFF Consulting Engineers **Other Partners:** Control Air Mechanical Pan Pacific Plumbing Electrical : Morrow-Meadows	On-site micro turbine based combined heat and power plant, integrated multi-system control for individual spaces, Circadian rhythm lighting	• Fourth and largest healthcare facility worldwide to earn a LEED-HC Platinum certification from the United States Green Building Council • Achieved 50 percent energy savings from projected baseline • Successfully implemented through an integrated design approach
 Hong Kong International Airport Expansion (Midfield Concourse)[11], 1,130,200 sq. ft., Hong Kong	**Client:** Airport Authority Hong Kong **Architect:** Aedas **Contractor:** Gammon Construction Ltd. **Lead Consultant and Engineers:** AECOM **Design Consultants:** Arup and Mott MacDonald **Other Partners:** Atkins, OTC, TDS, Bo Steiber Lighting Design, iGuzzini	Advanced lighting control, high-efficiency connected chillers, over 20,000 LED lights and 1,200 square meters of solar panels	• BIM technology used to design a virtual model before construction • Collaboration of entire project team via Revit and Navisworks
 TELUS Garden[12], Vancouver, Canada, is an office and residential complex; 1 million sq. ft.	**Client:** Westbank Projects Corp. **Architect:** Henriquez Partners **Lighting & Media Design:** Eos Lightmedia **Structural Engineering:** Glotman Simpson **LEED Consultant:** Icon/Light House Sustainable Building Centre **Contractor:** Icon Construction	Advanced lighting control, automated high-efficiency heat pumps and waste heat recovery, demand response ventilation	• First office building in Canada certified as LEED Platinum • Techniques of energy modeling used during design • Integrated design approach used • Residential tower targeting LEED Gold standard

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 KEY CONCLUSIONS

The top findings of this research validate some of the early hypotheses around the nature of complexities associated with the IBDI process, and the triggers that cause it to either fail, or perpetuate subpar project delivery. If not addressed appropriately, such faulty practices will continue to hinder market adoption rates of IB solutions and services, despite a desire of owners and occupants to experience and invest in IBs. Creating proper process flows, collaborative engagements and education will help drive focus to the right practices that owners, occupants and the industry can adopt to bolster the market acceptance of IB solutions and IBDI practices. The key conclusions of this research are summarized in Figure 5.1.

Figure 5.1: Intelligent Buildings Design & Implementation: Key Conclusions



The Role of IBDI Processes in Driving Intelligent Buildings

This research found that there are no clear cut IBDI methods or implementation processes that specifically exists for IB projects. However, various permutations of widely-used and traditional design and procurement methods, such as bid-and-spec and construction management, currently serve as the "go-to methods" for IB projects. Given the undefined and informal nature of this space it presents some key challenges, as well as offers unique opportunities for industry participants to pursue fundamental changes and create an organized approach to IBDI projects.

Encompassing all critical supply points within the design and delivery process, the value chain of the IB industry assumes a fairly robust sequential flow with value-added components moving from suppliers to the building owners and occupants However, given the relatively nascent development of a full-fledged IB implementation process, clear definitions for the scope of responsibilities of various participants can vary from project to project. Key imperfections inherent to IBDI methods include extreme fragmentation of the delivery process and polarization of goals among project partners, lack of technology integration prospects, lack of design flexibility and an overall static approach to delivering projects in a highly dynamic IB industry.

Frost & Sullivan's research indicates that no matter how imperfect by nature, IBDI processes have thrived due to demand for technology and service solutions prompted by unique end-user needs and the perception of the cost-efficiency it provides the building owners and operators. Specification guidelines have been endorsed by the building technology industry in an effort to establish proper construction and installation practices for various service providers to follow and to ensure that technology requirements are met in a cost-efficient and competitive manner for the building owner, occupant or operator.

IBDI Processes and Industry Perception Review

The industry professionals' research survey provided important insights into the overall state of the IB technology adoption potential and the perceptions of various players towards prevalent IBDI practices and methods. The imperfections in design process integration, technology deployment using such processes, and the expectations of owners and occupants from project partners was obtained from this research. The top findings drawn from the survey are highlighted below.

Growth Potential: Significant growth potential exists for the adoption of an IB design and implementation practice or method. The research indicates this trend could witness an average of 46 percent penetration within the next three years, pointing to a dynamic and fast-evolving market. Due to the application of different technologies in an IB, it is essential to have proper integration and interoperability for a successful outcome.

Adherence to Best Practices: A complete analysis of an IB project and having positive execution practices in place are the most important criteria for successfully designing and implementing an IB. The favorable cost-benefit ratio associated with adequate planning are motivating factors for the adoption of proper design and implementation practices. Having a universal view of the design and implementation plan and active collaboration between project partners, such as design companies, architects, technology consultants, and SIs from the onset of the project is instrumental in leading to the desired outcome. Currently, only 30 percent of respondents follow best practices; however most respondents have a strong desire to implement key best practices.

Role of Value Chain Participants: The architect, design build contractor, and technology consultant are the top partners in determining the standards and specifications of an IB project. However, the influence level of these partners changes with the type of construction. These partners have the highest level of influence in new construction and renovation projects. Nevertheless, due to significant involvement of building owners and occupants in retrofit projects, they have less power in determining the standards.

Overall, this research confirms that the practices currently followed during the design and implementation of an IB, are not well-integrated by all value chain partners. Only 30 percent of respondents adopted a structured and systematic method of utilizing best practices in their IB processes. Because of this, most organizations have fundamental issues and challenges that need to be addressed in order to mitigate project completion delays and meet customer expectations.

Issues and Challenges in IBDI Adoption

The research identified several key issues and challenges that negatively impact the IBDI process flow. These areas will need to be addressed as per order of priority by industry participants in order for IBDI practices and methods to become more easily integrated in the IB industry. These include value engineering of components, absolute control of contractors, inadequacy of tools and standards, system interoperability and integration issues, exclusion of owners and occupants, lack of training and certifications and the lack of accreditation of IBDI practices from currently available credits and incentives.

The core issues that challenge incorporating IBDI processes revolve around broad themes of communication, CAPEX versus OPEX, conflict resolution, improper expectation setting, and the inadequate training of resources. These affect both adoption rate and project execution processes for IBs. The resulting impacts include significant cost overruns and project delays. In certain cases, drastic deviations from the original vision and objectives are responsible for recurring maintenance challenges of these buildings and ongoing downtimes. Addressing these concerns involves navigating a myriad of critical issues and challenges for all stakeholders involved.

Process Optimization

Optimization aims at finding the most fitting solutions with respect to predefined objectives in any type of construction or customer segment of an IB project. This research finds that a majority of the organizations surveyed have not established well-structured practices in the design and construction management of an IB. In fact, fundamental issues underpin the process traditionally adopted during project execution, which leads to substantial cost overruns, time delays, and sub-optimal delivery of IBs. Process-related shortcomings are evident in each stage of project management. Due to the frequent shortcomings, optimization is identified as a major need to create a seamless flow of operational activities that are traditionally followed in a construction project. For deeper evaluation, shortcomings and areas of focus should be identified within different categories of each project stage, such as design and planning, execution, and control.

Significant effort is required from all stakeholders to ensure proper collaboration, technology awareness, and that the latest innovations are used to adequately integrate smart technologies. The immediate industry need is establishing best practices and initiatives that support team collaboration in developing an IBDI framework. While some of the methods discussed are being incorporated on a project-to-project basis by building owners and project partners, more concerted effort is required at the industry level to firmly embed them into the traditional value chain practices of IB design and implementation.

5.2 RECOMMENDATIONS

The key recommendations of this research are provided in Figure 5.2. Based on the findings of this research, Frost & Sullivan recommends the following:

Figure 5.2: Intelligent Buildings Design & Implementation: Key Recommendations

1	Standardize requirements for design inputs and technology specification parameters to conform to IB principles for streamlining processes
2	Engage with owners, occupants and operators to capture project vision, long term goals and IB technology orientation to preempt design elements that responds to these aspects cohesively
3	Develop partner strategies in working with the IBDI value chain, lay down stringent guidelines, and expect satisfactory compliance from peers across the implementation process
4	Promote better communication flow, including project records, feedback loop, and incorporation of neutral project advisors to ensure transparency at all times
5	Collaborate on industry initiatives around education, training, standards, and policy

As noted earlier, given the undefined and informal nature of currently prevalent IBDI methods and practices, it presents several challenges, as well as unique opportunities for industry participants to institutionalize best practices and adopt an organized approach to IBDI projects. Collaborative partnerships and alliances among value chain participants are inevitable given that there are distinct pockets of interested participants who wishes to make concerted efforts in that direction, as revealed by the industry professionals' research.

Building owner and occupant need evaluations are expected to be significant in determining the acceptability of various IB solutions offered and the need to undertake projects via IBDI methods. In addition, lobbying efforts to bring disjointed industry segments together and, more importantly, to have some collaboration at the level of industry associations is important for the IB industry to witness desired levels of IBDI adoption.

Achieving success in pursuing IBDI practices is a collective responsibility for the entire IB industry. Collaborative initiatives are vital to achieving industry-wide acceptance and bringing focus to implementing best practices with the right set of design metrics, process rigour, standards, and accreditation initiatives.

APPENDIX A: GLOSSARY OF TERMS

BAS	Building Automation System
BREEAM	Building Research Establishment Environmental Assessment Method
BMS	Building Management System
BIM	Building Information Model
CABA	Continental Automated Buildings Association
CAPEX	Capital Expenditure
CE	Consulting Engineer
ESCO	Energy Service Company
EPC	Engineering Procurement Company
GSA	General Services Administration
HVAC	Heating, Ventilation, and Air-Conditioning
HP	Horsepower
IB	Intelligent Building
IBC	Intelligent Buildings Council
IBDI	Intelligent Buildings: Design & Implementation
IBMS	Intelligent Buildings Management System
IoT	Internet of Things
IT	Information Technology
kW	Kilowatt
kWh	Kilowatt-hour

LBNL	Lawrence Berkeley National Laboratories
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
MEP	Mechanical, Electrical, and Plumbing
OEM	Original Equipment Manufacturer
O&M	Operation and Management
OPEX	Operational Expenditure
PG&E	Pacific Gas and Electric Company
R&D	Research & Development
ROI	Return on Investment
SI	System Integrators
US	United States
VR	Virtual Reality

APPENDIX B: REFERENCES

Chapter 1

1. Peluffo, M. (May 2015). *Defining Today's Intelligent Building*. Retrieved from: http://www.commscope.com/Blog/Defining-Todays-Intelligent-Building/
2. Palmer, T. (Jan 2016). *The Evolution of the Intelligent Building*. Retrieved from: http://www.distech-controls.com/~/media/files/news/new%20coverage/bacnet%20journal%20-%20ahr%202016%20edition.ashx
3. CABA Landmark Research Project (2012). *Intelligent Buildings and the Bid Specification Process*.
4. Khandavilli, S. (2017). *Intel Creates Smart Building Using IoT*. Retrieved from: https://www.intel.com/content/www/us/en/smart-buildings/smart-building-using-iot-case-study.html

Chapter 2

1. Frost & Sullivan. Primary research data gathered for this project *"Intelligent Buildings: Design & Implementation"*

Chapter 3

1. Frost & Sullivan's Consumer Research. (Sep 2017-Oct 2017). Based on primary research done for this project *"Intelligent Buildings: Design & Implementation"*
2. CABA Landmark Research Project (2012). *Intelligent Buildings and the Bid Specification Process*.
3. William McDonough + Partners. Retrieved from: http://www.mcdonoughpartners.com/projects/nasa-sustainability-base
4. Smart Buildings: *Using Smart Technology to Save Energy in Existing Buildings – ACEEE* (Feb 2017). Retrieved from: http://www.ourenergypolicy.org/wp-content/uploads/2017/02/a1701.pdf
5. Coordinating the Design of Integrated Building Technology Systems – Wall Street Journal (Dec 2006). Retrieved from: http://www.automatedbuildings.com/news/jan07/articles/sinopoli/061228120158sinopoli.htm

Chapter 4

1. Shaping the Future of Construction – World Economic Forum (May2016).Retrieved from http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf
2. Design Management- Early Contractor Involvement (2014). Retrieved from https://iglcstorage.blob.core.windows.net/papers/attachment-2f0d5f4b-abe3-458e-803f-03a542130000.pdf
3. Hindawi - Early Stakeholder Involvement in the Project Definition Phase (2013).Retrieved from https://www.hindawi.com/journals/isrn/2013/953915/
4. William McDonough + Partners. Retrieved from http://www.mcdonoughpartners.com/projects/nasa-sustainability-base
5. NASA Sustainability Base. Retrieved from: http://www.coolshadow.com/lighting%20design/nasa_lighting.html
6. Van Rossum. Retrieved from: http://www.vanrossumbv.nl/english/projects/the-edge-amsterdam

7. Deerns. Retrieved from: https://www.deerns.com/projects/real-estate/the-edge-head-office-deloitte-akd-amsterdam-the-netherlands
8. G&S Bouw. Retrieved from: http://www.gensbouw.nl/nl/projecten/detail/the-edge
9. PLP Architecture-The Edge . Retrieved from: http://www.plparchitecture.com/the-edge.html
10. Arup. Retrieved from: https://www.arup.com/projects/kaiser-permanente-san-diego?query=kaiser
11. Aedas. Retrieved from: https://www.aedas.com/en/what-we-do/featured-projects/hk-international-airport-midfield-concourse
12. Henriquez Partners Architects. Retrieved from: http://henriquezpartners.com/work/telus-garden/

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