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Case report

A sustainable future: Leveraging IPD and BIM for green construction success

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Abstract: In response to growing environmental concerns in the construction industry, we investigated how Integrated Project Delivery (IPD) and Building Information Modeling (BIM) jointly support the implementation of sustainable construction practices. Using a comparative case study approach, we examined two high-performance projects: Kendeda Building (Living Building Challenge-certified) and Science Square (LEED-certified) to assess how general contractors integrate IPD and BIM in decision-making related to energy use, material optimization, life-cycle assessment, and project coordination. Qualitative data were collected through site visits, observations, and interviews with contractors, while quantitative performance metrics, including cost, schedule, and energy efficiency, were analyzed using a cross-case matrix. Our results showed that IPD–BIM workflows consistently outperformed traditional delivery models, with the studied projects using 55–75% less operational energy, completing 12% faster, and finishing approximately 6% under budget while reducing punch-list items by 25%. These outcomes stem from early-stage collaboration, model-based coordination, and shared accountability embedded in the IPD–BIM process. Here, we present a novel decision-making framework and performance matrix that highlights the tangible benefits and remaining barriers to broader IPD adoption, particularly the need for early trust-building and multiparty contract structures. The findings offer actionable insights for industry professionals seeking to advance sustainable construction through integrated, technology-driven methods.

Keywords: Green construction; Integrated Project Delivery; Building Information Modeling; Living Building Challenge

1. Introduction

The intersection of Integrated Project Delivery (IPD) has become increasingly significant in the context of sustainable construction practices [1]. The construction industry, as a major contributor to environmental challenges, is adopting more sustainable methods to reduce energy consumption, minimize waste, and optimize material use throughout the building life cycle. The use of Building Information Modeling (BIM) has gained traction in the design and construction phases due to its ability to enhance decision-making and streamline project delivery while supporting green building initiatives. Recent studies indicate that successful BIM deployment is best achieved within an IPD framework, which assembles a dedicated, multidisciplinary team to facilitate seamless information exchange and manage high-performance goals [2].

Numerous researchers have examined the benefits of BIM adoption in enhancing decision-making and sustainability analyses during the early design and preconstruction stages to achieve sustainability goals [3–5]. Additionally, Hardin (2009) [6] and Bernstern *et al.,* (2015) [7] highlighted industry's best practices in leveraging BIM not just in the planning/preconstruction stage but also in the construction phases of green building to meet the stringent performance criteria and regulatory requirements. However, their research outlooks on BIM development for sustainable construction seem predominantly technology-focused, emphasizing tool and functionality enhancements to streamline certification processes using BIM models [6,7]. More recently, Liang *et al.* (2024) developed a Green BIM prototype with well-defined business processes and execution plans, extending the framework beyond LEED to encompass several international sustainability rating systems [8].

Consequently, BIM's technological advancements, particularly its parametric modeling capabilities, provide valuable insights into the impact of building design and construction decisions on energy use and overall performance. However, its integration with IPD as a framework for enhancing collaboration across project teams remains underexplored [9]. Also, limited research has also been conducted on understanding the business processes involved in BIM and IPD implementation or how BIM execution planning in green building projects impacts overall project outcomes. This epistemological gap in knowledge is further highlighted by the limited research on integrating IPD and BIM for sustainable building projects with different certification standards, i.e., LEED and Living Building Challenge (LBC).

We aim to investigate the synergy between IPD and BIM and their combined impact on sustainable construction practices. Through on-site case studies and interactions with general contractors (GCs), we evaluate how these methods optimize energy, material use, reduce waste, and enhance collaboration. This helps us understand how contemporary construction with different levels of certification can evolve to meet sustainability targets and promote sustainability. This also helps identify the advantages and gaps in green building methodologies, such as the absence of clear sustainability objectives in the early project stages and the insufficient integration of material, labor, and waste management throughout the building's life cycle. The research underscores the importance of integrating data and processes to achieve sustainability goals, proposing a framework that documents these targets in an integrated responsibility matrix. This framework advocates a unified strategy that links decision-making to ongoing checks and improvements, offering valuable insights into how the construction industry can better incorporate sustainable practices for improved environmental and economic outcomes.

2. Literature review

2.1. IPD impact

Recent research highlights the increasing alignment of Integrated Project Delivery (IPD) and Building Information Modeling (BIM), showing how their combined use drives more sustainable construction outcomes [10]. When compared to the traditional Design-Bid-Build (DBB) and other project delivery approaches, IPD method has demonstrated a substantial improvement in project outcomes. As shown in Figure 1, research indicates that IPD projects not only achieve higher quality with fewer deficiencies and improved system performance but also accelerate project delivery through reduced design and construction timelines and more efficient change order processing [11]. Complementing these process centered perspectives, Liang *et al.,* (2024) reviewed more than 300 projects and found that BIM based energy analysis, 4/5D planning, and LCA tools routinely cut energy use and construction waste by double digit margins compared with traditional approaches [8].

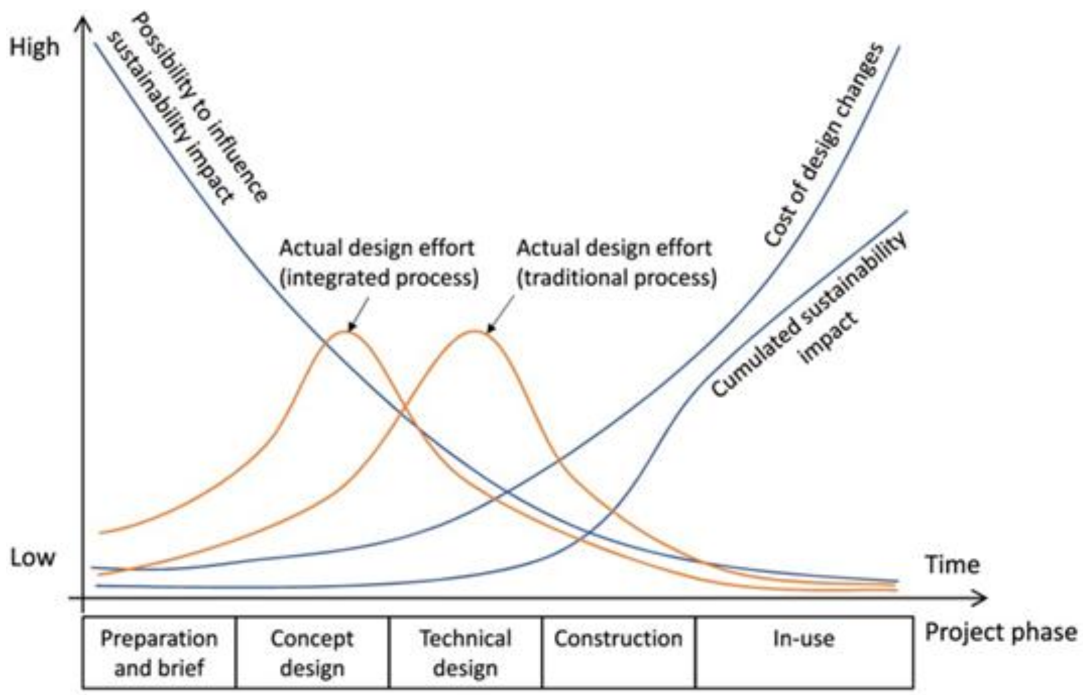

Figure 1. The IPD integrated process versus the traditional delivery method over the project phases with their influence on design and construction timelines, cost of design, and cumulated sustainability impact [11].

As one example of sustainable building practice [12], the PAE Living Building in Portland, a 58,000 ft² commercial office, utilized an IPD contract and BIM-enabled decision making to attain net positive energy performance and achieve both Living Building Challenge and LEED Platinum certification. Early IPD workshops cut the construction schedule by nearly one fifth and aligned trades around shared cost targets, while detailed energy modelling guided an 870 Kw solar array and biophilic design features that boost occupant wellbeing. These contemporary studies replaced earlier technology centric accounts and reinforce the argument that IPD enabled BIM workflows are now critical, evidence-based pathways to cost effective, time efficient, and low emission construction.

Adel et al. also investigated the role of IPD in achieving sustainability in construction projects using case study analysis [1]. It was found that the adoption of IPD effectively achieved sustainability objectives, resulting in optimized economic, social, and environmental outcomes by reducing project costs and construction time, while contributing positively to community impact. Notably, it was concluded that IPD is more impacted by the owner's commitment and the timing of participant involvement than by the project delivery strategy selected [1]. The establishment of mutual respect and trust among involved parties plays a pivotal role in accomplishing project goals, facilitating the free exchange of ideas and controlling costs. These collaborative dynamics manifest in the project's economic dimension, stimulating the generation of innovative concepts for energy conservation and pollution reduction to preserve the environment. The collaborative environment fostered by the IPD methodology promotes mutual benefits and rewards, encouraging a sense of collective ownership among all parties. This shared responsibility drives a focus on time optimization, cost reduction, and enhanced quality [1,13]. This commitment extends to maximizing the project's overall value by considering its environmental impact throughout the construction process.

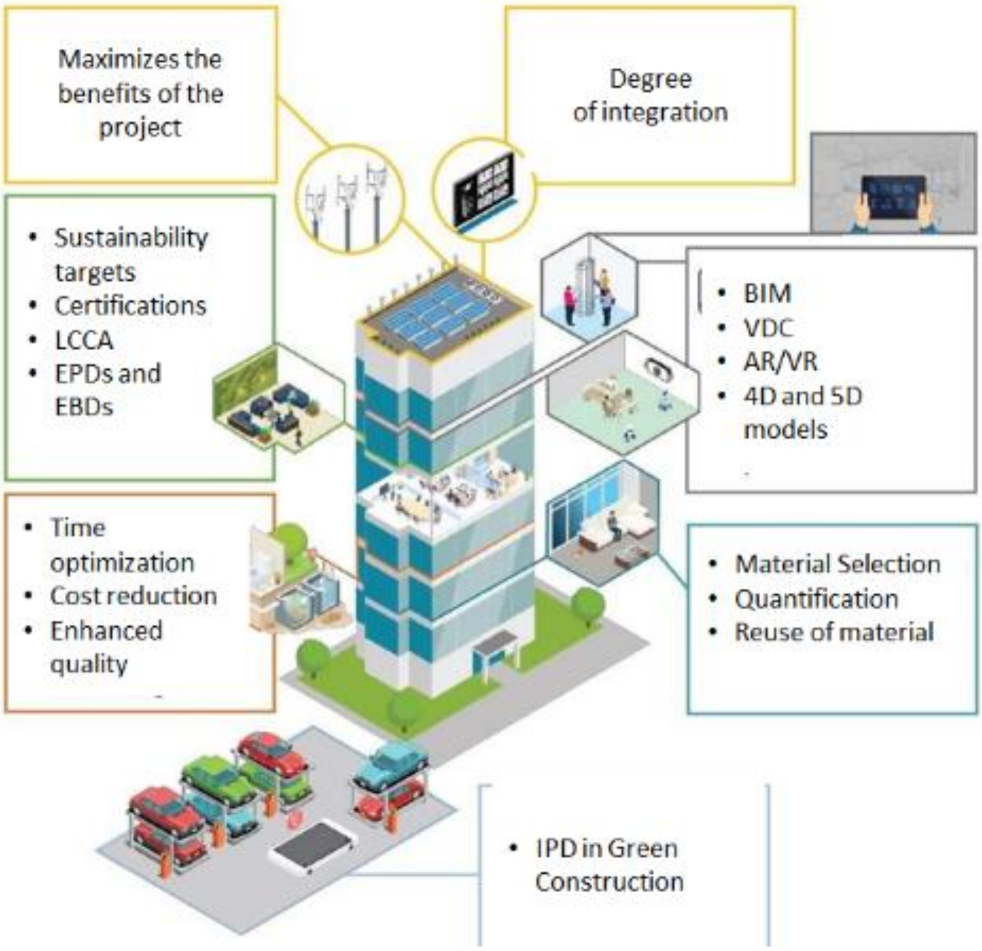

Figure 2. IPD in Green Construction across certifications and integrated solutions (adapted from arcadis.com).

Additionally, early involvement of the contractor and consultants right at the design phase is very important for the model-based sustainable framework for maintaining seamless information flow and enabling timely, sustainability-focused decisions throughout the project life cycle [14]. IPD can be further enhanced by integrating intelligent collaborative computer agents with a whole system thinking approach to refine designs prior to construction. Tools such as 4D scheduling, 5D cost estimation, and Virtual Design and Construction (VDC) using 3D BIM models support this integrated approach, creating a platform for centralized information flow and enabling real-time updates and analysis throughout the project. Furthermore, IPD can also be deployed for the selection and use of sustainable building materials, which has been identified as an important strategy in the design of a sustainable construction. Meng et al. [15] identified sixteen technical, managerial, and policy barriers that continue to slow BIM diffusion in green projects, arguing that economic externalities will persist without targeted incentives. They further highlight that high upfront costs, client hesitation, limited practitioner expertise, and shortages of skilled labor and green material suppliers are persistent obstacles to wider adoption of sustainable materials [15]. With IPD, a comprehensive decision-making approach becomes possible, taking into account the materials' life cycle and potential issues related to availability and cost. Additionally, as the project evolves, IPD's continuous improvement component enables flexibility in adjusting material selection (Figure 2).

2.2. Impact of BIM

BIM is a concept that is useful for managing information throughout the building lifespan and for smoothly integrating building data [16]. Architects, engineers, and contractors (AEC) teams, among other project stakeholders, may communicate and share information more easily when using BIM as a central platform of communication. As illustrated in Figure 3, as BIM adoption grows, firms are expanding its use beyond modeling to enhance design integration and coordination. Improved interdisciplinary collaboration within BIM is streamlining workflows and optimizing project outcomes. It also provides a three-dimensional representation of the project and accurate material quantities, enabling accurate cost and schedule calculations. According to Watfa, 2020, 70% of respondents to the NBS national BIM survey stated that BIM helped reduce project costs by 33% for both the project's initial construction and overall lifetime costs. A total of 60% of those surveyed thought that BIM might reduce the total project timeframe from start to finish by 50% [17].

The research by Liang et al. (2024) introduced the concept of “Green BIM,” defined as the deliberate fusion of BIM processes with sustainable design and construction strategies to minimize environmental impacts throughout the building life cycle [8]. It is characterized as a method for producing and coordinating information data to improve energy efficiency in construction and establish essential sustainability objectives by creating a 3D model. The clash detection function of BIM increases productivity and lowers waste, energy use, and greenhouse gas emissions by supporting sustainable decision-making. Energy Analysis models generated with the help of BIM help to project and monitor the energy consumption and functioning of systems throughout the project’s lifecycle. By incorporating BIM dimensions such 3D models with Time/Schedule, Budget/Cost, and sustainability with the Green Construction Rating Standard, Building Efficiency Analysis Software, and compatibility with BIM-based design models, there has been simplification in the development of environmentally sustainable designs (Figure 4). As BIM technology and LEED systems are making continuous improvement, it has become overwhelming for project teams to work out an optimal strategy to exploit their technology and management strength in LEED project delivery. For instance, Wu and Isaa (2012) proposed a new business paradigm so project teams can leverage cloud-BIM in achieving LEED automation [18]. They concluded that the new paradigm not only addresses the limitations of conventional desktop computing and stand-alone BIM but also enhances capacity and communication, wherein stakeholders can gather and examine project data to assess sustainability ratings. It was also reported to enable scalable, concurrent collaboration, which is essential for delivering high-performance sustainable projects, including LEED-certified developments.

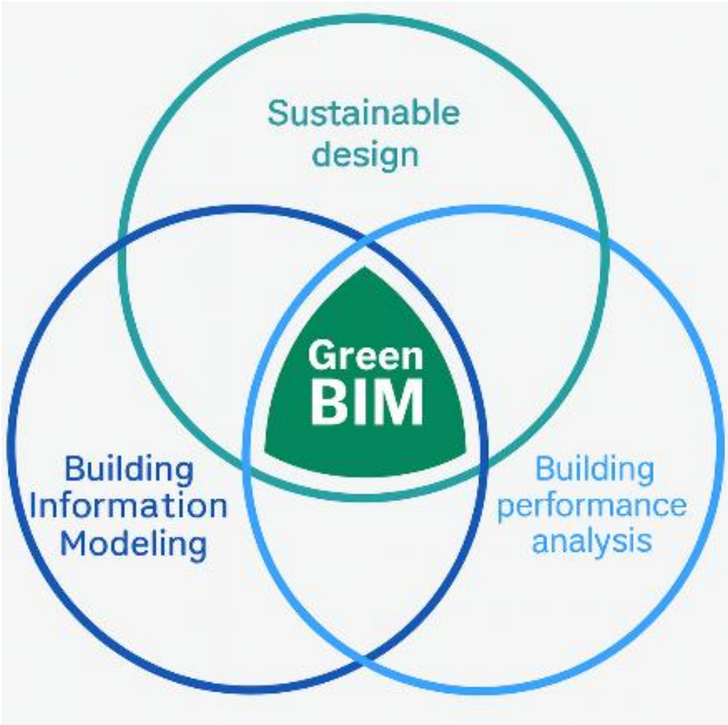

Figure 3. BIM as a central platform for collaboration [8].

Figure 4. Integrating BIM dimension: Time, cost, and sustainability into green construction (biblus.accasoftware.com).

BIM models facilitate the Life Cycle Assessment (LCA) of structures and materials, enabling informed material selection while supporting project scheduling, cost analysis, and financial control and ensuring alignment with sustainability goals [19]. Zhou et al. (2009) used the LCA method to classify sustainable materials by taking into account mechanical, financial, and environmental factors (Figure 5) [20]. The authors proposed a thorough examination of materials in three phases: Pre-building, building, and post-building. This was validated by an example that the system can select suitable materials to develop sustainable products while improving the overall efficiency assessment across the building's life cycle. A key contribution of BIM to IPD is its ability to establish a centralized and collaborative platform. This platform enables architects, engineers, contractors, and other professionals to work together in a synchronized manner, sharing real-time information and updates. Through a shared 3D model, stakeholders can visually assess and analyze the environmental impact of design decisions, promoting a holistic approach to sustainability. BIM enhances the iterative nature of the design process by enabling rapid prototyping and evaluation of alternates, adding to IPD's principle of continuous improvement.

Figure 5. BIM's application in Life Cycle Assessments and Project.

3. Methodology

In this research, we adopted a qualitative research methodology using a case study approach. A qualitative methodology was selected, as it was more suitable when trying to seek a deep understanding of views or perceptions of a given subject. Unlike quantitative methods, where the inquirer collects data through specific instruments, qualitative research uses a more open-ended approach to enable the participants to share their ideas and experiences and build general themes based on those shared ideas and experiences. Especially with the emerging sustainable practices, the case study approach is the most suitable practice to sufficiently examine and study the research problem through real-life experiences retrieved from subject matter experts.

We began with a literature review that aimed to answer questions on the current IPD and BIM impact, perceived benefits in sustainable practices, and formulated the interview questions. The second phase of the research study was the data collection, where structured interviews and site visits were conducted to understand their point of view of how IPD and BIM influence sustainable practices. The two projects were on the Georgia Tech campus in the Science Square and Kendeda Building. Both emphasized sustainable design and applied for different green building certifications of LEED and LBC, respectively. The in-person site touring enabled a comprehensive understanding of the implementation of construction methods in projects. These visits enabled direct observation of green building elements and features at the construction location, including material used, waste management strategies, and energy-efficient design elements. The structured interviews provided insights into the construction processes, project delivery strategies, challenges encountered, and the role of technology in achieving sustainability targets. The interview participants were purposefully selected to include General Contractor's Project Managers, lead architects and Facility management team members. A combination of in-person interviews, virtual meetings (via Zoom or Microsoft Teams), and email-based follow-ups were used to gather and clarify information. Interviews followed a semi-structured format and lasted approximately 30 to 60 minutes, focusing on sustainability strategies, project delivery approaches, technological integration, and implementation challenges. Key themes such as energy consumption, life cycle analysis, material procurement, and stakeholder collaboration were explored in depth. Data saturation was pursued by interviewing multiple stakeholders across both projects until recurring themes and patterns began to emerge consistently.

After conducting the interviews, analysis of the collected data using a content analysis approach for both types of interviews were carried out. A comparative analysis was developed to evaluate the effectiveness of the role that IPD and BIM could play in both projects. By examining similarities and differences in their application, the study identified best practices, limitations, and opportunities for improvement. This structured methodology ensured a holistic assessment of how collaborative project delivery and digital modeling contribute to sustainability in contemporary construction practices.

4. Case study results

4.1. The Kendeda Building, Georgia Tech

The Kendeda Building exemplifies sustainable architecture by integrating visionary design with environmentally conscious construction practices. As a model of the LBC, it strengthens Georgia Tech's reputation while setting a benchmark for green construction. Utilizing Construction Management at Risk (CMAR), the project fostered collaboration among architects, engineers, contractors, and stakeholders, ensuring a strong commitment to sustainability. Design charrettes, involving students and end users, helped shape the final plan and budget. BIM played a pivotal role in optimizing design, enhancing resource efficiency, and incorporating passive strategies to minimize energy consumption and carbon footprint.

The Kendeda Building has achieved LEED Platinum designation and LBC certification by meeting the highest green building criteria. Smart lighting, high-performance insulation, and effective HVAC systems were used to prioritize energy saving (Figure 6). Reliance on traditional power was reduced through the integration of renewable energy sources, including wind turbines and solar panels. Rainwater collection, low-flow fixtures, and intelligent irrigation improved water conservation. The Red List criteria were met by sustainable materials that prioritized recyclability and minimal environmental effects. Recycling and material reuse were the main goals of waste management. Ecological design and native landscaping promoted biodiversity, biophilia and natural lighting and non-toxic materials enhanced indoor air quality. Long-term sustainability was guaranteed by ongoing life cycle assessments (see Table 1).

Table 1. Kendeda Building. Sustainability Integration: Performance Metrix and Construction Methodology [21–23].

Feature	Details	Operation and Management Savings	GC's Challenges
Construction Waste Diversion	Achieved exceptional 99% waste diversion. Incorporated reclaimed 140-year-old heart pine joists, NLT panels from 25,000 linear feet of salvaged two-by-fours, diverting more waste than produced.	NLT ceiling panels from salvaged wood cost "less than a third of a million-dollar bid" compared to new materials, indicating upfront savings. Broader salvaged material use saved communities millions in disposal fees.	More complex sourcing/logistics (proactive finding, non-profit coordination, dedicated warehouse). Intensive quality control/preparation (kiln-drying) of irregular materials. Integration of workforce development program.
Fluid-Applied Air Barrier	Uses Red List-free modified Prosoco fluid-applied air barrier, creating a tight building envelope.	Higher material cost than traditional barriers. Saving potentially up to 40% in energy costs by preventing air leaks, and reduced maintenance on mechanical systems.	Specialized applications require skilled applicators. Precision needed for a high-performance seal, despite moisture-cured nature reducing weather delays.
Photovoltaic (PV) Array	330 kW (DC) solar canopy (917 panels) produces ~400,000 kWh annually. Generated 225% of energy needed in performance period, making it a net-positive energy building.	Initial cost estimated at \$2.50/watt (excluding storage), considered a "slight premium." Effectively eliminating electricity utility expenses	Complex structural integration for a massive "solar canopy" (not merely roof panels), supporting 917 panels while providing shading/rainwater collection.
DOAS HVAC System	Employs decoupled Dedicated Outdoor Air System (DOAS) and water-based radiant systems in concrete floors. Consumes 75% less	DOAS has "significant premium initial installation cost." Radiant systems also have higher upfront costs (\$6–\$20/sq ft for hydronic). Offset by	Managing the inherent complexity of decoupled DOAS and seamlessly integrating it with radiant flooring, campus chilled water loop, and heat pumps. Required extensive

	energy than the national average. Achieves net-positive energy and water by effectively conditioning occupants and utilizing thermal mass, condensate capture, and campus chilled water loop/heat pumps.	substantial long-term savings: DOAS alone can reduce energy consumption by 15-30% in commercial buildings. Overall system drastically lowers utility expenses.	coordination among mechanical, plumbing, and electrical trades.
Lighting Power Density (LPD) & Occupancy Sensor Effectiveness	Achieved LPD of ~0.4 W/sf (approx. 50% better than code) via daylight harvesting, automatic external shades, and highly effective occupancy sensors with short off-delays.	High-efficiency LED lighting and advanced controls have higher upfront installation costs ($3.20–$4.00/sq ft). LED uses 75% less energy than traditional; monthly energy costs can drop by 30–50%, with 2–3 year payback.	Managing complex design/installation of interconnected lighting controls integrated with daylight harvesting, automated shades, and occupancy sensors.
Stormwater Storage Cistern & Water Management	Designed for net-positive water, collecting/treating ~460,000 gallons of rainwater annually. A 50,000-gallon cistern captures stormwater. Greywater diverted to constructed wetlands. Composting toilets/waterless urinals eliminate blackwater.	The 50,000-gallon cistern was a significant component of the overall $25M project cost (overall project 13% higher than conventional). eliminated municipal water utility expenses due to net-positive water. Collected 15x water needed during performance period.	Significant excavation/structural integration for basement cistern. Material delivery/equipment access in constrained environment.

The interview with the PMs and GCs from Skanska highlighted the integrated approach taken in managing a risk-intensive project using the CMAR delivery method with a Guaranteed Maximum Price (GMP). Skanska actively participated in design meetings, ensuring alignment with sustainability goals under the LBC (Figure 7). Early collaboration through a biophilic charrette enabled seamless contractor involvement, fostering adaptability in design modifications to meet sustainability targets while maintaining budget constraints.

The project was inherently risk-intensive, particularly concerning managing budget fluctuations from changing orders. A key difficulty arose in material selection, which required a dedicated committee to prioritize cost reduction and material reuse while strictly adhering to the rigorous Red List requirements. As illustrated in Table 1, a dedicated committee that prioritized cost reduction and material reuse while guaranteeing adherence to Red List requirements overcame the difficulty of material selection. Risk management was a priority, particularly in handling budget fluctuations from changing orders. The CM utilized a repeated budget check model and leveraged BIM to facilitate dynamic design revisions, keeping the project on track financially and structurally. Advanced tools like BIM 360, Assemble, and AR/VR enhanced coordination, optimizing design and project management.

Figure 6. 3D Model section of Kendeda explaining its green features (livingbuilding.gatech.edu).

Figure 7. Kendeda Building. Project Delivery Methodology to achieve LBC Certification.

The project faced high upfront costs for sustainable materials and technologies due to its stringent LBC requirements. Environmental Product Declarations (EPDs) and Life Cycle Cost Analysis (LCCA) were used to maintain environmental effect transparency while proving to stakeholders the long-term sustainability benefits. The project's dedication to efficiency was reaffirmed throughout a three-year performance monitoring phase after completion. Despite being classified as CMAR, the project adhered to the principles of IPD by incorporating end users, consultants, contractors, and owners at every stage of the process. As an example of a comprehensive, team-based approach to green building execution, the CM's proactive involvement from design to post-construction monitoring established a standard for future sustainable construction.

4.2. Science Square, Georgia Tech

Science Square is a pioneering development that blends science, sustainability, and innovation into a dynamic mixed-use space. Anchored by Science Square Labs, the project is designed to foster collaboration, research, and connectivity, linking seamlessly with Georgia Tech and the broader innovation ecosystem. Designed by Perkins & Will and built by Brasfield & Gorrie (B&G), the 18-acre development is constructed in five phases, with Phase 1, including a Lab/Office Tower and 280 residential units, set for completion in April 2024 [24]. The project prioritizes environmental responsibility and human-centered design, targeting LEED Gold Certification to ensure long-term sustainability. With its combination of advanced technology, thoughtful architecture, and flexible spaces, Science Square is set to redefine how science and sustainability intersect in an urban setting.

Sustainability is at the core of Science Square's design, with a strong focus on green building strategies across transportation, water, energy, materials, and indoor environmental quality. The development promotes alternative commuting methods with bike-friendly infrastructure, accessible public transport, and EV charging stations. Water conservation is a priority, with an advanced rainwater management system, water-efficient fixtures, and a high-investment water recycling system that offers long-term benefits. Energy efficiency is enhanced through smart glass, which regulates indoor temperatures and reduces glare, as well as photovoltaic (PV) panels that generate renewable energy. As demonstrated in Table 2, the project also emphasizes material sustainability by sourcing locally, using recyclable materials, and ensuring transparency through Environmental Product Declarations (EPDs). Additionally, indoor spaces are designed for occupant well-being, incorporating low-emission materials and air quality monitoring to create a healthier living and working environment (Table 2).

The project also follows a CMAR delivery method with a GMP, ensuring early contractor involvement to align sustainability goals with budget constraints (Figure 8). While architects and engineers led the green design efforts, B&G played a crucial role in ensuring feasibility and cost-effectiveness. One of the major challenges was balancing sustainability initiatives with financial constraints. To address this, B&G provided early cost estimates and continuous feedback throughout the design phase, helping identify budget-friendly solutions without compromising sustainability. The GMP structure enabled the owner to manage financial risks while giving the construction team the flexibility to find cost-effective alternatives for green materials and building methods. Technology played a crucial role in keeping the project on track, with BIM, streamlining coordination, reducing design errors, and improving efficiency. Tools like BIM 360 enabled real-time collaboration between teams, ensuring that sustainability goals were integrated seamlessly into the construction process. Despite the added costs of green materials, strategic budgeting, value engineering, and open communication among stakeholders ensured that sustainability targets were met within financial constraints. The success of Science Square lies in its collaborative approach, bringing together owners, designers, contractors, and consultants to create a forward-thinking, environmentally responsible urban space. This project sets a benchmark for sustainable development, proving that innovative planning, teamwork, and technology can drive meaningful progress toward a greener future.

Table 2. Science Square. Sustainability Integration: Performance Metrix and Construction Methodology [24–26].

Sustainable Feature	**Details**	**Operation and Management Savings**	**GC's Challenges**
38,000 sq ft Solar Panel Array	Produces ~920,840 kWh annually of clean energy atop the parking garage, contributing to overall building energy efficiency. Energy & Atmosphere: Optimize energy performance (11/10) Regional Priority Credits: Renewable energy production (1/1)	Significant long-term savings by reducing grid reliance and offsetting utility expenses.	Complex structural integration, electrical system coordination, logistics for installation at height, and ensuring roof waterproofing and drainage.
Smart Glazing & Daylight Control	Electrochromic glass automatically tints to manage UV light and solar heat gain, reducing cooling/heating needs without blinds. Indoor Environmental Quality: Daylight (3/3), Quality views (1/1) Regional Priority Credits: Daylight (1/1)	Reduced HVAC energy consumption, lower blind maintenance, and enhanced occupant comfort.	Specialized installation, requiring proper electrical wiring and control system integration for automatic tinting. Meticulous quality control needed for seamless operation and effective sealing.
Konvekta Energy-Recovery System	Captures waste air to return energy to the HVAC system, reducing CO_2 emissions and heating/cooling costs. Energy & Atmosphere: Optimize energy performance (11/10)	Reduces heating/cooling loads, lowering utility expenses and carbon footprint.	Requires extensive coordination among mechanical, electrical, and plumbing trades for optimal performance.
Occupant Wellness & Amenity Design	"The Commons" and "SkyDeck" offer collaborative spaces, outdoor lounge with fire pits, greenery, and views, promoting occupant well-being. Sustainable Sites: Open space (1/1) Indoor Environmental Quality: Quality views (1/1)	Enhanced occupant satisfaction, leading to improved performance and reduced absenteeism.	Complex structural considerations for a high-floor outdoor lounge, intricate landscaping/ irrigation, fire pit installation, and ensuring accessibility/safety.

The comparison between these two case studies with respect to construction processes used to achieve the green building goals is described in Table 3.

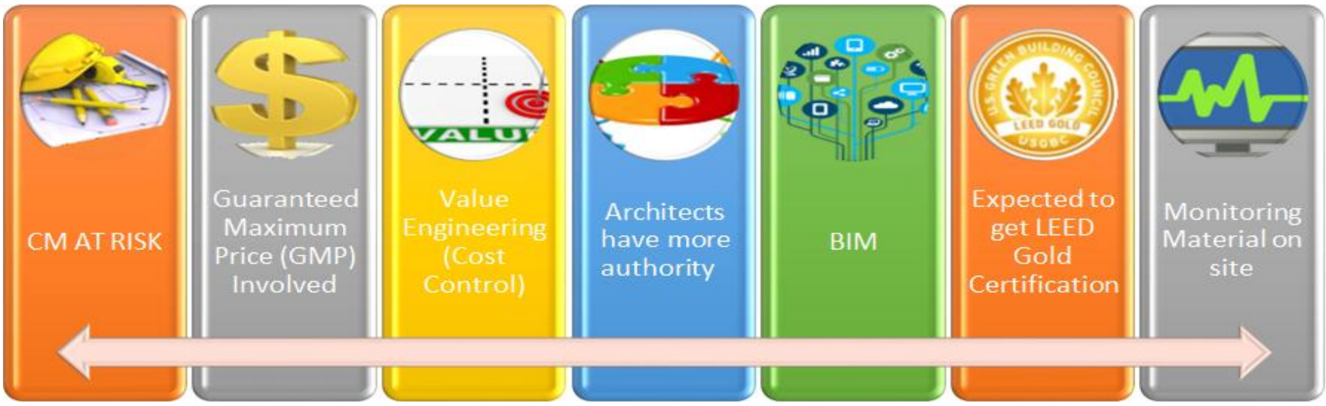

Figure 8. Science Square. Project Delivery Methodology to achieve LEED Gold Certification.

Table 3. Comparative analysis between Kendeda Building and Science Square based on Project Delivery Methods used to achieve respective Green Building Certifications and recommendations for improving sustainability through IPD.

Criteria	Kendeda Building	Science Square
Sustainability Certification	LBC Certified	Targeting LEED Gold Certification
Green Building Goals	Net positive energy and water, regenerative design, locally sourced materials, zero waste.	Renewable energy integration, water recycling, sustainable material sourcing, and smart building technology (e.g., smart lighting system).
Project Delivery Method Used	CCMAR with GMP	CMAR with GMP
Challenges Identified	High upfront costs for sustainable materials and technologies, rigorous LBC requirements, need for extensive collaboration.	Balancing costs while meeting green goals, managing value engineering without compromising sustainability, stakeholder coordination.
Recommendations	IPD could foster early collaboration among architects, engineers, and sustainability experts, enabling more effective integration of LBC goals. By aligning financial incentives, it supports cost-sharing for green technologies and minimizes last-minute compromises on sustainability objectives.	IPD could enhance cost predictability and facilitate the integration of sustainability features into construction planning. Its collaborative contract structure promotes proactive problem-solving, optimized material sourcing, and equitable risk-sharing, leading to more efficient execution of green building projects.

The case studies of the Kendeda Building and Science Square highlight the importance of a collaborative approach in achieving green building goals. Both projects faced challenges such as high upfront costs, material selection complexities, and the need for strong coordination among stakeholders. While they followed the CMAR with GMP delivery method, adopting an IPD model could enhance efficiency by involving all key players, including designers, engineers, contractors, and owners, from the start (Table 3). This early collaboration would yield better decision-making, reduced waste, and a more seamless integration of sustainability goals throughout the construction process. BIM within an IPD framework would further strengthen these efforts by providing a shared digital platform for real-time collaboration, sustainability tracking, and material optimization. This approach would help minimize delays, improve cost control, and ensure that green building strategies are effectively implemented. Additionally, forming a dedicated material selection team to assess options based on life-cycle analysis and environmental impact would help balance sustainability with cost-effectiveness. By integrating IPD, BIM, and strategic material selection, future projects can achieve higher efficiency, lower costs, and stronger sustainability outcomes.

5. Conclusion

The integration of IPD and BIM offers a powerful pathway for the construction industry to embrace sustainability. In this study, we employed a case study approach to examine how IPD and BIM influence the implementation of sustainable practices in construction projects. Two construction activities, Kendeda Building and Science Square with different green assessment certifications, were investigated. This green building is an inspiring example of how collaboration and technology can push the boundaries of green buildings. Qualitative data were collated via site visits, user observations, and retrospective interviews with the GCs and then analyzed to determine commonalities and thematic thinking on the roles IPD and BIM have on sustainable construction.

Comparing Kendeda and Science Square with comparable design-bid-build laboratories on the same campus showed the practical benefits of combining IPD and BIM. The two projects used 55–75 % less operational energy, finished about 12 % faster, and came in roughly 6 % under budget while cutting punch-list items by a quarter. These results stem from early, model-based coordination that refines quantity take-offs, clash detection, and life-cycle decisions. Together, they establish new reference points for cost, schedule, and carbon performance in sustainable construction. The findings highlight that integrating IPD with BIM can significantly advance sustainability in construction by promoting early collaboration, shared accountability, and efficient resource use. This combined approach enables teams to reduce waste, optimize materials, and enhance communication, leading to more cost-effective and environmentally responsible outcomes. To fully realize these benefits, the industry must adopt integrated, data-driven practices that support continuous improvement. This research encourages a shift from traditional methods toward collaborative, technology-enabled solutions to meet evolving environmental demands.

6. Limitations and future research

The adoption of IPD in today's construction industry, especially for green building projects, faces several practical challenges. One of the major limitations is that IPD is not a mainstream or fully mature project delivery method. As seen in the case studies presented in this paper, many projects continue to rely on traditional delivery models. This reflects the difficulty in encouraging stakeholders, such as owners, architects, and contractors, to move from familiar contractual structures toward a more collaborative, risk- and reward-sharing approach. Transitioning to IPD requires not only a shift in mindset but also changes in workflow, trust-building, and contract negotiation, all of which take time and resources to develop. As a result, widespread implementation is likely to be gradual and incremental.

Although the case studies incorporate elements of IPD, they operate under variations of CMAR, highlighting that the full potential of IPD to optimize sustainability outcomes remains largely theoretical or limited to a few pioneering projects. Several practical challenges continue to hinder broader adoption. These include the increased upfront time and cost needed to establish trust and negotiate detailed agreements among stakeholders; the demand for a high level of transparency and continuous open communication, which can be difficult to sustain; and the risk of project delays or disputes if collaboration breaks down due to misaligned expectations. Despite these limitations, IPD offers substantial promise for green building initiatives by promoting deeper collaboration, aligning stakeholder incentives, and enabling more integrated and efficient decision-making throughout the project lifecycle.

Future research should entail four key areas: (1) Comparative analysis of hybrid models like CMAR with IPD principles versus fully integrated IPD to identify which elements most effectively support sustainability outcomes; (2) investigation of stakeholder readiness and adoption barriers to inform practical strategies that encourage broader use of IPD in green construction projects; (3) explore the integration of digital twin technologies and IoT data streams with IPD-BIM workflows to enable real-time performance optimization and continuous commissioning throughout the project lifecycle; and (4) develop standardized IPD-BIM implementation guidelines, including contract templates, cost-sharing frameworks, and training modules, to support consistent and practical adoption by owners, contractors, and design teams on real-world projects.

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Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

The authors declare no conflict of interest.

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