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Integrated design process of green building projects: A review towards assessment metrics and conceptual framework

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ABSTRACT

Integrated design process (IDP) as an innovative and collaborative design approach for green building (GB) delivery has gained recognition in practice over the past decade. Yet, a significant knowledge gap exists theoretically and practically on how the process can be assessed for possible improvement. The purpose of this paper is to develop evaluation metrics and a conceptual framework for assessing IDP of green building projects. Through a critical review and content analysis of extant industry guidelines, models, and peer-reviewed articles, four sets of IDP metrics were identified. The first metric focuses on the project's attributes, including cost, complexity, scope, as well as intended sustainability features. The second set pertained to process attributes, including goal-setting process, delivery system, timing of activities, as well as communication-related issues. The third metric concerned team attributes, ranging from team members' resourcefulness, competency, and skilled recourse. The client attributes within the organizational and managerial context represent the fourth metric. A framework was proposed which established the relationship between IDP indicators and green building delivery performance. The proposed framework would be beneficial for research into IDP effectiveness as well as aiding practice, policy decisions, and development of new IDP guidelines. The possibility of decision support models through innovative algorithm and digitalized platform was brought to the fore.

1. Introduction

The construction industry is expected to deliver projects that reduce greenhouse gas (GHG) emissions. The sector has been consistently criticized over the past decade for contributing largely to GHG, hence the need to embrace sustainability practices. Green buildings are primarily driven by sustainability goals, using subsidiary goals and targets as a means to achieve them. Green building (GB) is expected to meet a variety of energy and environmental requirements, such as improved indoor air quality, excellent daylighting, water efficiency, and renewable and non-polluting materials [1,2]. Owing to these requirements, an efficient delivery process is required for implementing GB projects, otherwise the developmental process might be loaded with frequent design revisions, specification changes, waste, schedule delays, and higher project costs [1,3,4]. GB projects require a larger multidisciplinary team to

Abbreviations: BIM, Building Information Modelling; BREEAM, Building Research Establishment Environmental Assessment Method; EDGE, Excellence in Design for Greater Efficiencies; GB, Green Building; IDP, Integrated Design Process; IED, Integrated Energy Design; LEED, Leadership in Energy and Environmental Design.

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function together in a systematic manner to achieve the desired goal.

Since the advent of the GB movement, there have been fundamental changes in building design and construction practices [3,5]. It has been realized that high performance green building cannot be achieved through the conventional design process (CDP) [6]. The linearity, fragmentation, and work division among multidisciplinary teams in the traditional design method present a momentous limitation on CDP usage in achieving innovative green building design [1,7,8]. Hence, an alternative design approach, integrated design process (IDP), gained recognition [2].

IDP is a holistic process that involves harmonizing contributions from several stakeholders through an intensive multidisciplinary design process [8]. It is an innovative concept engaged to overcome the ills of the CDP. Different from the conventional process, IDP allows stakeholders to contribute to decision making right from the early phase of the project, enabling collective decisions while integrating outputs [1]. Since GB design demands building optimization towards creating sustainable buildings [7,9], IDP brings interdisciplinary experts and stakeholders together for an inclusive collaboration towards achieving the project's sustainability goals [7,10,11]. IDP is a critical aspect of GB delivery that potentially enhances design quality and higher sustainability performance [1].

Increasing evidence indicates that GBs can be cost-effective, with lower or no additional cost when integrated design and resource-efficient approaches are applied [1,9,12,13]. Intuitively, IDP can also be a net time saver, but the initial phase may take longer, while the later stages will take less time. Overall, a fast delivery schedule can be achieved. Recognizing these benefits, several leading engineering firms in the United States, Canada, and Europe have deployed IDP strategies on high-performing projects [14]. Governments and green building certification systems consider IDP as a holistic approach to achieve sustainable building designs [1,12,14].

In the last three decades, there have been several guidelines and documents prepared across countries to aid IDP implementation on projects. For instance, the "Integrated Project Delivery Guide" and "Architect's Guide to Integrating Energy Modeling in the Design Process" were developed in the US by the American Institute of Architects (AIA) [9,15]. An EU-funded project investigated integrated design (ID) projects in the United Kingdom, Sweden, Italy, Norway, Greece, Poland, Austria, Slovakia, and Slovenia. This led to the production of IDP guides such as TASK 23-IDP, Integrated Energy Design (IED), INTEND and MATRID [16,17]. The Danish building industry has developed a series of IDP guidelines such as IDP-AAU, IDP-DTU and Integrated Design Build Method (IDBM MT) [16].

Additionally, green building certification systems such as the US LEED (Leadership in Energy and Environmental Design) and the German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen) DGNB have specified IDP as partial criteria for certification. IDP is perhaps the most acknowledged cost-effective strategy for GB projects. Several architectural firms in the United States, Europe, and Australia use an IDP approach. Few conduct projects explicitly using IDP benchmarks [1,6,12,14]. These show that the IDP concept has been widely embraced in sustainable building design globally.

Despite the well-reported efficacy of IDP on GB projects, it appears that the concept has gained greater interest in practice than in research. A substantial proportion of publications on IDP such as [8,9,15,18–21] emanated from the industry, professional institutions, and GB experts using case-based studies and field evidence. Although seminal works [3,22] and more recent works [10,11,16,23–27] contributed immensely to the subject, it appears that much focus has been on the technical and design optimization components (such as design simulation as well as energy and lighting modelling). The multidisciplinary interaction of actors within the process (which invariably makes the process integrated) is often neglected. Only a few studies have explored IDP implementation in GB projects. This is perhaps due to methodological issues and a dearth of theoretical frameworks to guide such studies. Thus, IDP is still lagging from a theoretical standpoint.

To successfully implement IDP, it is essential to understand the key attributes of the process and stakeholders' connections. Indeed, industry professionals can benefit from IDP, but holistic efforts toward improving the process need to be theoretically and empirically driven. The objectives of this study are to (1) assess the status of the IDP concept in practice and research, (2) develop a set of metrics for IDP attributes, and (3) develop a conceptual framework for assessing IDP. Reed and Gordon [3] stated that research needs to provide answers to questions within the context of IDP such as "What are the benchmarks and metrics (indicators) that will help define success?" (p. 336). The metrics identified in this study will serve that purpose, such that IDP can be assessed and evaluated for future practice improvement. The next sections present the research methodology, an overview of the IDP concept, the IDP metrics, and conceptual framework development. The implications of the study as well as future directions are also presented.

2. Research method

This study is based on a critical review of the literature that covers the IDP and GB design processes. The primary aim is to identify a set of indicators that represent IDP elements and develop a conceptual framework for assessing the relationship between IDP and GB delivery performance. The need for a conceptual framework has become more apparent nowadays, owing to the manifold bodies of knowledge that are interconnected across various disciplines and the social phenomena that have become more complex. For better understanding of growing phenomena, a holistic, interdisciplinary, and multiplicity approach is required. Development of conceptual frameworks is a critical step towards knowledge creation [28]. It is a qualitative procedure of theorization and synthesizes knowledge. According to Miles and Huberman [29], a conceptual framework "lays out the key factors, constructs, or variables, and presumes relationships among them" (p. 440). It is a network, or interlinked perspective that together gives a comprehensive overview of a phenomenon [30].

Two types of research frameworks exist, namely, theoretical frameworks and conceptual frameworks. While the theoretical framework is exclusively rooted in existing theory, the conceptual framework operationalizes theory, empirical evidence, and industry best practices and aggregates them into variables and constructs [28]. Although the two frameworks are useful for research (especially for setting the pathway for inquiry and generalizability of findings), the choice of a research framework is driven by the goal of the study [28,30]. Due to the current state of knowledge of IDP and GB project delivery, developing a conceptual framework was considered worthwhile and necessary as a foundational platform upon which subsequent studies can be built.

Scholars [28–30] aptly described the developmental process of a conceptual framework in steps including; (1) establishing the statement of facts, and purpose of the study; (2) search for concepts, theories, and existing frameworks relevant for the proposed framework, (3) review of relevant frameworks/theories/literature; and discussing of the diverse components including positive (strengths) or negative (weaknesses) attributes, (4) aggregate components or variables (main and sub-components) of the proposed framework, and (5) development of schematic diagram showing the interconnection of main and sub-components.

In this study, the set objectives were achieved based on the developmental processes described in Fig. 1. First, to exemplify the present trends and efforts on IDP, industry guidelines and literature on IDP were reviewed. The extant IDP models and guidelines produced by the American Institute of Architects (AIA), the European Union (EU) commission, the Commission for Environmental Cooperation (CEC) Canada, and the Danish building industry, amongst others, were sourced from relevant online repositories and reviewed accordingly. The review was conducted based on a content analysis method. This approach allowed a clearer understanding of the state of practice on IDP across various national organizations, international institutions, and leading consulting firms.

In the second phase, peer-reviewed articles related to issues of IDP, GB design process and delivery performance were retrieved from reputable research databases such as Scopus, Web of Science and Google Scholar. These databases are the three most prominent databases used in construction management studies. Since the core objective of this study is to identify relevant indicators across existing studies rather than a bibliometric analysis, this approach was considered appropriate. The keywords used for the database search include green building, sustainable building, integrated design process, integrated design, design process, delivery performance, project performance and project success. For a concise search, Boolean search codes were used to combine the keywords in three formats as follows: (1) “green building” AND “integrated design process” (2) “green building” OR “sustainable building” AND “integrated design” OR “design process” and (3) “green building” OR “sustainable building” AND “project performance” OR “delivery performance” OR “project success”. These codes were applied during searches in the three databases.

Across the three sources, a total of 105 publications were initially downloaded. The subsequent content analysis of the articles showed many of the articles retrieved focused on design optimization such as day lighting, BIM, and energy modeling, while issues of team integration, communication, goal setting, design activities, and actor characteristics were not discussed. These sets of articles were excluded since the objective of this study is to identify indicators that define IDP activities. After the exclusion of such articles, a final set of 70 articles were selected and reviewed extensively. This approach allowed the identification of variables and measures that define the GB design process and delivery performance.

The third phase involves categorization of core IDP attributes based on knowledge harnessed from the extant models and literature. The thematic and content analysis serves as the basis upon which the metrics were categorized [28,29]. Thereafter, a conceptual framework was developed to guide and aid proper assessment of IDP and green delivery performance. The conceptual framework was illustrated by graphically depicting the interconnection of main and sub-components of IDP and delivery performance.

3. Results

Based on the objectives of this study, results are presented in three components as follows: an overview of the IDP concept, development of IDP metrics, and development of a conceptual framework for IDP.

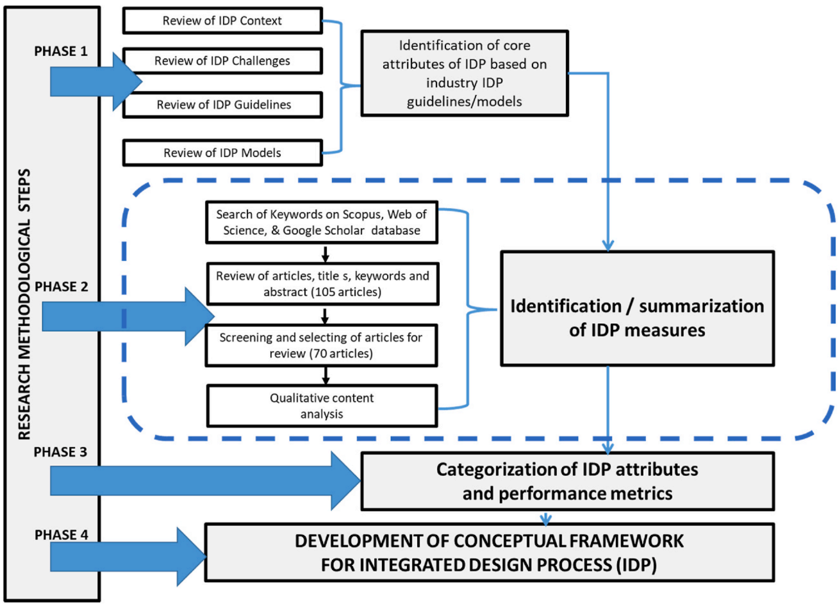

Fig. 1. Flow chart of the methodological approach.

3.1. Overview of IDP concept

3.1.1. IDP practice on GB projects

IDP is a concerted and collaborative process that focuses on achieving sustainable building through proper project definition, design assessment, design detailing, and documentation. The principal aim of IDP is to make the right decision at the right time, as opportunities for integration tend to diminish throughout the delivery phases [1,3]. Most successful GB projects usually commence with an IDP. The process allows the project stakeholders to plan and achieve well-defined goals for building social, environmental, and economic objectives.

The IDP concept is a product of well-proven improvements observed in the design process as a result of high-level collaboration at the beginning of the process. In a pilot project developed in Canada through the IDP approach (C-2000 Program), it was observed that projects reached the desired performance targets with capital costs lower than expected owing to the right choices made in the design and technologies [8,13]. Several other evidences of the successes of GB projects completed through IDP have emerged. MaTrID [17] documented lessons from 27 ID projects across Europe. Besides some flaws and irregularities experienced within the IDP approach, the ID process was found to be the most cost-effective strategy for GB projects.

Five low-energy buildings created through integrated design, one each in Austria, Canada, Denmark, Germany, and the United States, were explored by the International Energy Agency as demonstration projects [20,21]. Lessons learnt brought to the fore the need for high cooperation between architects and engineers right at the inception, close collaboration of the design team, persistence of the architect, and extra effort in achieving innovative design. Yudelson [1] presented case studies of 50 LEED-certified projects in the US. A key highlight is that IDP is in the "DNA" of GB. However, for IDP to be successful, the right people and the right mind must be involved.

In Canada, Ng, Liao [31] presented a case study of a 12-storey apartment building in Toronto completed through IDP. The performance of nine low-energy envelope design strategies was evaluated to determine the heating and cooling energy consumption. Using a process modeling tool, it was found that the design goals were achieved while process waste was drastically minimized. Owing to this well-established evidence, IDP has become a dynamic design management procedure, potentially facilitating projects' sustainability achievements while limiting the expenses incurred.

3.1.2. IDP challenges

Despite the success and benefits attributed to IDP, the process is still characterized by constraints and challenges. IDP interdisciplinary teamwork is quite challenging owing to task harmonization that occasions difficulties among the stakeholders. The relatedness of work, unclear roles, goals, and boundaries (especially as to who does what and at what time?), decision making, the technical aspects of modeling, simulations, and architectural quality trade-offs for sustainability performance are some of the issues design teams contend with [7,18,32,33].

The early design stage of GB projects may be characterized by setbacks in relation to the usage of energy optimization tools, inadequate requirements for making design decisions, frequent changes to designs, and insufficient understanding of building constructability [4]. Skill limitations among professionals to achieve passive and integrated systems, as well as insufficient knowledge of assessment tools, may lower the efficiency of the process [24,33,34]. The understanding of workflow, information and knowledge management, collaborative processes, and skills for integration often affects process outcomes [35]. Likewise, challenges of unfamiliarity with procedures, limited understanding of team members' roles, communication bottlenecks, higher design fees, time demands, and lack of understanding of tools (e.g., simulation, energy modelling) are frequently noticeable in most IDP approaches [24]. In Canada, Leoto and Lizarralde [34] uncovered hindrances affecting innovation and collaboration during IDP, suggesting that risk perception, inadequate stakeholders' commitment, and competence are some of the critical obstacles affecting the process.

3.1.3. IDP practice guidelines

There are several guidelines and documents prepared across countries to aid in the implementation of the IDP, particularly for sustainable building projects. For instance, in the United States, the "Integrated Project Delivery Guide" and "Architect's Guide to Integrating Energy Modeling in the Design Process" were prepared by the American Institute of Architects, to guide architects' practice on integrated energy modelling [9]. It is aimed at enhancing the architect's competency in managing design teams and provides a platform for collaboration. The guide has been broadly acknowledged in the construction industry. Another IDP guideline, "TASK 23″, was developed by practitioners (architects, engineers, and contractors) from the USA, Canada, Germany, Norway, Sweden, the Netherlands, Spain, Switzerland, Japan, Denmark, Austria, and Finland [7,20,21].

Across Europe, IDPs have gained traction. The Integrated Design Process (TASK 23) was first developed as a sustainable architecture approach based on academics and industry collaboration. This metamorphosed into the Integrated Energy Design (IED) which was intended to address energy use in buildings right at the early design phase [20]. With the goal of tackling energy demand right from the project definition stage through to subsequent design phases, it was again developed into the INTEND project [12]. Subsequently, MATRID-Integrated Design Process Guide was created to broadens the scope of INTEND, focusing on the whole design process. INTEND and MATRID guides are products of European Commission founded projects, grounded on the assessment of effective practices in UK, Norway, Denmark, Austria, Greece, and Poland [16].

The Danish building industry has been remarkable in the development of a series of IDP guidelines such as "IDP-AAU," "IDP-DTU" and "Integrated Design Build Method (IDBM MT" from the academic, engineering, and contractor's perspective [16,17]. The Canadian building industry has been passionate about achieving a higher level of sustainability on projects over the years. An Integrated Design Process (IDP) guideline "C-2000″ was developed by Natural Resources Canada (NRCan) [8,19,24]. While efforts on IDP guidelines have been remarkable, there are limitations across all the guidelines on issues relating to practice application [16]. Brunsgaard [18] analyzed the strength and weaknesses of various guidelines and found that, though IDP facilitates interaction among stakeholders, the application of diverse passive and active strategies, in addition to different calculation and simulation tools, often leads to a frustrating process. A comparative mapping of eight IDP guides indicates a common problem that exists across them all in that, while the anticipated inputs and outputs were identified, details were not given on how to enhance decision-making within a multidisciplinary design team [16].

3.1.4. IDP models

IDP models have been developed over the last three decades to elucidate IDP theory and practice approach. In a study by Sanvido and Norton [22], a practice model "integrated design process model" (IDPM) was developed. The model describes the major tasks and processes required for effective delivery of the design. It categorized activities across developmental phases of the design and presented flow patterns as well as hierarchical trees. The four key phases included in the model are conceptual design, schematic design, detailed design, and working drawing phases.

Based on lessons from the C-2000 program, Larsson [6] proposed an IDP model for delivering sustainable buildings, describing the critical and generic steps required to achieve the project goals (Fig. 2). This model is a product of well-proven evidence which indicates that by applying the appropriate design process, cost and environmental performance can be realized. As a follow-up, another detailed model was presented by Larsson [19], which sub-categorized the components and described the interaction of the components.

The TASK 23 report presents a series of IDP models. At least 3 charts, namely, the actor flow chart, workflow, and superimposition of IDP elements, were presented in the document [7]. This model categorized IDP multidisciplinary activities and explored the

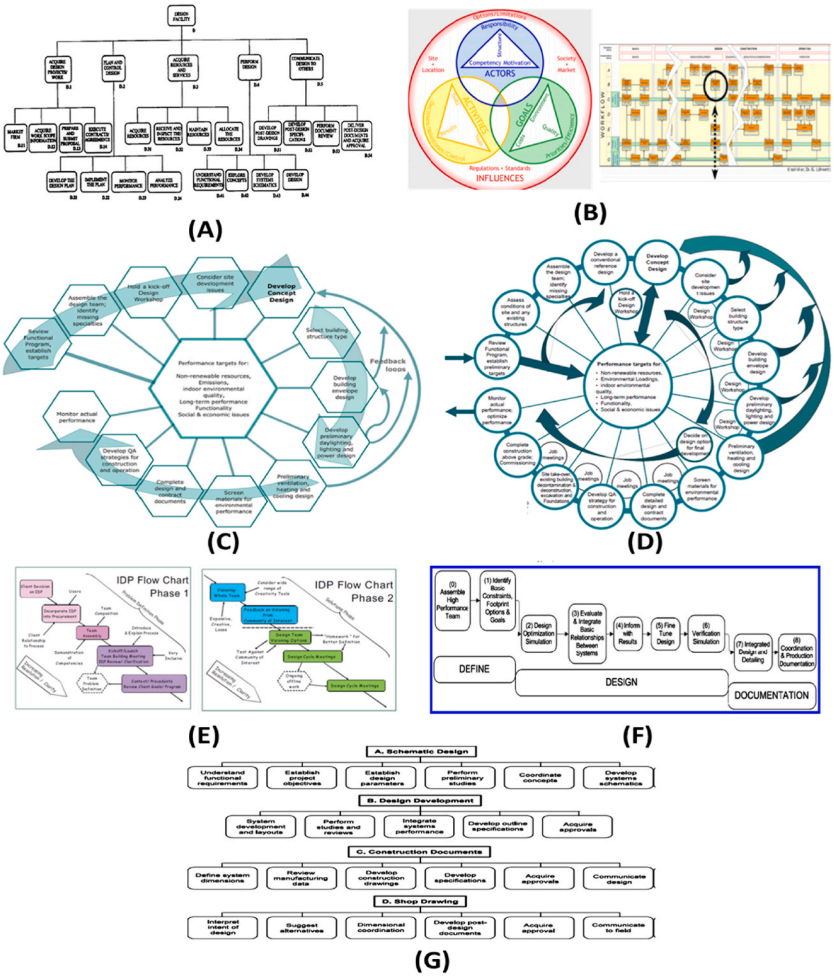

Fig. 2. (A) IDP model (Source: Sanvido & Norton, [22])
(B) IDP model by "TASK 23" (Source: Löhnert et al., [7])
(C) IDP Process Model from C-program (Source: Larsson, [6])
(D) IDP Model Process from C-program (Source: Larsson, [19])
(E) IDP model developed at Toronto IDP Workshop (Source: Zimmerman, [8])
(F) Integrated Design Process Model for High Performance Buildings (IDPMHP): Energy Optimization Process. (Source: Horman et al., [4])
(G) Building Design Process Model for High-Performing Projects (BDPMHP) (Source: Riley, Magnet and Horman, [36]).

operational methodologies used in practice by architects and engineers. Another model presented at the Toronto IDP workshop exemplifies the process as a linear process, involving iterative decision making and stakeholder's participation [8]. A model by Horman, Riley [4] focused on the energy optimization process across three critical stages of the design process, namely, define, design, and document. Basic competencies needed to execute each of the phases were presented in an iterative manner. Fig. 2 shows an overview of the seven (7) IDP models, while Table 1 shows a comparative analysis of the models, particularly the strength and weaknesses of each model.

Although the models have dissimilarities across the process diagrams, one commonality is that the models describe the generic structure and flow pattern of IDP functions. It presents guidance on who should take up what task, when and why. These models also explain the critical activities that must be completed during each stage of the IDP. The fundamentals of the IDP models include early stakeholders' involvement, thoughtful team selection, and extensive interaction through meetings/charrette, clear goal setting and iterative decision-making.

3.2. Development of integrated design process metrics for GB projects

Earlier, the phases that depict IDP are presented based on the review of existing models. Undoubtedly, it is worthwhile to explore the overarching factors that are required to implement an IDP successfully. There are previous attempts to quantify IDP, for example [10,11,25]. However, these studies focus largely on Net Zero Energy Building (NZEB). Moreover, the indicators used were predominantly developed based on evidence from conventional building projects. Given that GB has higher performance requirements (such as sustainable site, sustainable location and transportation system, water efficiency, energy efficiency, innovative design, indoor environment quality, materials and resources quality), this study contextualizes the IDP metrics and conceptualizes the IDP framework

Table 1
Comparative analysis of IDP models.

N	Source	Bases for model development	Description of model Components	Strengths	Weaknesses
1	Sanvido and Norton [22]	Review of literature and US building practices	Tree nodes and flowcharts were used to describe activity patterns within IDP. The model consists of 4 main functions and 15 sub-functions	Key IDP functions and activities are covered	Sustainable building practices are not considered
2	Löhnert, Dalkowski [7]	TASK 23; an European Union (EU) commission funded project on IDP	The model described the activity pattern using a grant chart and flowchart. It presents the elements of IDP using a Venn diagram with 3 interlocking circles illustrating the superimpositions between IDP elements It comprises of three models, namely, actors' flowchart, workflow, and superimposition of IDP elements	The model considered the IDP elements/attributes It presents a comprehensive description of three aspects of IDP	Performance indicators were not included
3	Larsson [6]	C-2000 program in Canada	The model organized 13 sequential activities in circles around a hexagon shaped core. The core represents the performance benchmarks.	The performance indicators were included	Limited to activities pattern
4	Larsson [19]	C-2000 program in Canada	An improvement on the previous one. The model arranged the activities in circles around a hexagon shaped core. The core represents the performance benchmarks. In contrast to the previous, the activities were divided into sections. It describes 16 sequential activities.	It is a simple flowchart, easily applicable in practice, and presents the performance indicators as a component in the IDP	Limited to activities pattern
5	Zimmerman [8]	Toronto IDP workshop in Canada	A flowchart which described step-by-step approach within the IDP 10 sequential activities	It is a simple flow chart, easily applicable in practice	Performance indicators were not included Limited to activities pattern
6	Riley, Magent [36]	Review of extant models & reflecting on other considerations	It consist 4 main processes: schematic design, conceptual development, construction documents and shop drawings. The principal processes were divided into 23 sub processes	It described the activities levels	Performance indicators were not included Limited to activities pattern Illustrated in segregated form showing no connection among components
7	Horman, Riley [4]		A flowchart consisting of 8 sequential activities grouped into 3 sections, namely define, design, and documentation, is described with a linear flowchart. It describes eight sequential activities	It is a simple flowchart, easily applicable in practice	Performance indicators were not included Limited to activities pattern.

based on evidence from industry models and prior GB studies.

Since the goal of this study is to identify key indicators of IDP for GB projects rather than activity pattern, the TASK 23 model was found to be instructive as it presents a clear perspective on principal elements of IDP [7]. The model graphically illustrates the interrelationship of key elements of the IDP for GB projects, including the actors (allocation of responsibility, team formation, risk assumption, goal, and payments); goal priorities (cost, environment, and quality), activities (tasks, tools, and results) and influences (market trends and site potential). Also, the C-program model [6,19] was found to be instructive as it presents the performance indicators as the central focus of the IDP.

Reflecting on these models, and considering the interrelatedness of the key elements, this study categorized IDP elements for GB projects into four distinct components, namely, project attributes (i.e., scope, goals, and external influences), process attributes (i.e., activities), team attributes, and client attributes (as the actors) and included the performance indicators as the core focus (see Fig. 3). With this approach, it will be possible to establish the linkages between IDP elements and performance benchmarks.

In developing a full set of metrics for IDP, relevant studies on GB that addressed these five IDP components were reviewed, and variables of interest were identified. The next section presents details of the reviews and the identified IDP metrics.

3.2.1. Project attributes

Typically, every project has a scope that defines building targets and choices. Project attributes are defined by factors such as project type, nature of project, number of floors, complexity, cost, and size of project [37] and may significantly influence delivery performance. Design decisions are made based on the scope and attributes of a project, which may differ across project types and clients' goals. The site location, geographical context, and local regulations/standards are also critical project attributes that can be influential forces that drive the project delivery process.

Within the context of GB, numerous sustainable systems and techniques are required to achieve the sustainability goal of the project [38]. The effective combination of these systems is critical for GB design; thus, GB designers seek optimum solutions through complex design processes that combine these systems. Broadly, these techniques are classified as active or passive strategies. While the passive approach involves achieving sustainable solutions through architectural design, the active involves adopting engineering techniques to compliment the architectural solutions.

In most cases, passive approaches are considered first since they are required to be implemented during the early design stage and they normally inform the building configurations [39]. Passive strategies usually determine the building orientation, spatial layout as well as the architectural form. It entails careful placement of building components such as walls, windows, and overhangs in a bid to minimize dependence on mechanical equipment or engineering solutions. Besides, it entails effective utilization of resources that are available in the project environment rather than those imported.

Researchers have identified various sustainable building attributes. Kwok and Grondzik [39] for example, identified 40 green design attributes and categorize them into six broad categories: envelope (insulation materials, double walls, and green roofs), lighting (daylight, shading devices, and electric lighting), water and waste (composting toilets, water recycling, bioswales, etc.), cooling (natural ventilation, cooling towers, and chillers), heating (solar thermal systems, heat pumps, etc.), and energy production (photovoltaics, wind turbines, micro hydro turbines, and combined heat and power). Ahmad, Thaheem [38] developed a green-building design approach and thus identified systems and techniques. The study generated 35 different green-building systems and techniques that were further sub-categorized into seven main groups, including indoor illumination systems, control systems, energy & water efficiency systems, renewable energy systems, energy & water recovery systems, systems to improve air quality, and systems for thermal comfort.

The building envelope strategies are critical features for achieving GB through the introduction of smart windows, energy efficiency using led lightning, photovoltaic foam for walls, vegetation roofing and photovoltaic roofs, double-gazed windows, and wall insulation. Scholars [40,41] also identified many sustainable building attributes. Indeed, these attributes are numerous and diverse in both

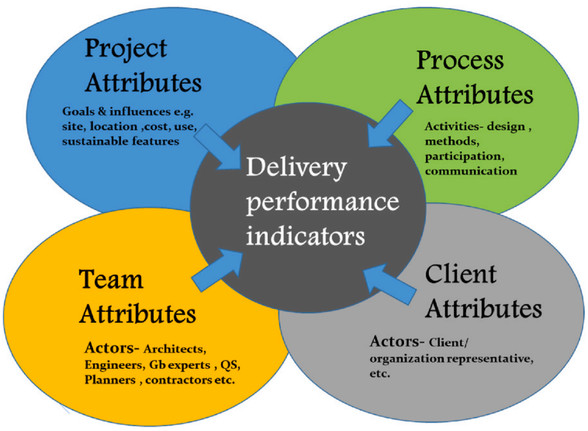

Fig. 3. Core attributes of integrated design process for green building projects. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

passive and active strategies, hence the need for critical reasoning and thoughtful decision making in GB projects. It is beneficial to understand the project characteristics as well as other factors within the project environment that are influential to GB project success. These items, as detailed in Table 2, are by no means exhaustive since the approaches can be diverse for both passive and active strategies.

3.2.2. Process attributes

The design process entails a series of activities through which the desires and intentions of the clients are established, quantified, and transferred to the constructor [22]. These activities are undertaken by the project stakeholders during the design phase towards achieving project goals. The importance of the design process has been echoed over the past decades since well-proven evidence suggests that cost, time, and energy demand can be reduced substantially through appropriate design procedures [3,7,11,13]. By identifying process attributes and exploring those that contribute most to effectiveness on GB projects, opportunities for higher performance are created [47–49].

One fundamental structure that defines project activities is the delivery system. The delivery systems dictate the timing and sequences of actions, team involvement, and contractual relations among stakeholders, amongst others. For GB projects, greater responsibility is placed on the design team within the context of IDP owing to increased design activities and engagements. Thus, it has been argued that a delivery system that allows sufficient opportunity for team interaction has greater potential for delivering a high-performing GB [50–53]. Goal setting is another fundamental step that is usually taken at the pre-design stage of an IDP. All owners' project aspirations and associated requirements must be efficiently incorporated into the requests for proposals (RFP), the contract documents, design and construction documents [1,11].

Training & education is another truism that cannot be ignored within IDP. All project participants, including the professionals, owners, contractors, and suppliers, need to be educated on the project and process demands [49]. Extensive research may be required to validate and substantiate basic standards for smart decisions to be made by the owner/developer and others on the design options. For most GB projects, extensive documentation is regarded as a basis for analyzing the work's progress, documenting best practices, and this is obligatory for projects seeking certification. It is vital to be accumulated and stored project information in a chronological manner, serving as a point of reference when needed. Within IDP, an appropriate documentation plan is expected to be established. Yudelson [1] avers that the project budget must contain potential capital for the purpose of documentation. The appointment of a sole specialist for the purpose of documentation has also been echoed [1,9,13]. Building Information Modelling (BIM) as a key process tool can enhance the entire process especially in terms of decision making, design form, construction material selection, system thinking, life cycle analysis as well as process documentation.

Studies have implicitly identified various design processes that potentially influence GB delivery performance. In a study by Palanisamy and Klotz [48], process attributes that contribute largely to success common to an Indian and a US project were explored using process maps and interviews of project stakeholders. All the process attributes identified in relation to the design process, including early commitment to sustainability, setting goals for sustainability early, and training and educating project stakeholders, contributed largely to success on both projects. Korkmaz, Riley [54] investigated the factors that propel GB projects. They found that process indicators such as timing of participants' involvement in the process, early goal setting, design integration, project delivery

Table 2
Project attributes.

S/N	Attributes	Measures	References
A	Basic feature		
1	Project cost		[1,10,11,13,23,25,42]
2	Project type	New Construction, Renovation, Remodelling, Retrofit etc.	
3	Project purpose	Office, Residential, Educational, Commercial, Worship centre, Recreational, Hospitality, etc.	
4	Project owner/financier	Public, Private, Developer, Higher Education etc.	
5	Project size & complexity		
B	Sustainability/Green features		
6	Passive features	Building orientation, external overhangs/shading, natural ventilation, day lighting, roof vegetation/, green roof, wall vegetation, green walls, double window glazing, geothermal insulation, vacuum/Insulated walls, aerogel/sealant for air leakage, ceiling/roof vents, shading devices, light colour wall paints, locally source material, reusable building materials, extensive landscape design, ventilated cavity wall, evaporative cooling tower, double envelope etc.	[1,2,5,23,38–41,43–46]
7	Active features	Photovoltaic solar panel, energy efficient lighting (LED), energy efficient, HVAC, energy metering/sub-metering, reuse/recycle of water, rainwater harvesting, water metering/sub-metering, water efficient appliances, water geysers, biogas digester, waste sorting system/recycling, smart windows, photovoltaic walls, window, door, wind turbine, sensors, smart control devices, indoor CO2 monitors devices, outdoor air monitors etc.	
8	Green credit priorities	Sustainable site, energy and atmosphere, water efficiency, indoor environmental quality, material and resources, innovation and design, environmental health and safety	[1,12,38,45]
9	Certification target	LEED (certified, silver, gold or platinum), BREEAM (pass, good, very good, excellent, outstanding), Green star (1-3star, 4star, 5 star, 6 star), Green mark, EDGE, Passive house, etc.	[1,5,12,41,46]

system, and procurement method are important factors for GB project outcomes.

Several other scholars [10,11,25,55] have also expanded knowledge regarding process factors, bringing to the fore insights into key aspects of the IDP. Broadly, these factors are either tangible or intangible. In that sense, this study categorized these attributes into the objective (Table 3) and the subjective (Table 4) design process attributes.

3.2.3. Team attributes

The GB design process is a collaborative process in which input is sourced from diverse multidisciplinary experts and stakeholders towards achieving highly optimized results. Thus, success depends on the level of team integration, interaction, and commitment, amongst other factors. The GB design team typically comprises a wide range of multidisciplinary experts. The architect, the service engineers (including plumbing, HVAC, and energy), the structural/civil engineer, cost consultants/quantity surveyors, the IDP facilitator/project manager, and the builder/general contractor are usually the core participants in IDP teams [8].

For strong input, other participants, such as commissioning agents, energy modellers, accredited professionals, system experts, landscape architects, interior designers, lighting designers/consultants, and community representatives, are often involved in the design process. Depending on the complexity and scope of the project, the participants' lists can be very extensive [8]. Intuitively, there is a blurry variance between the design team and the construction team within the context of GB projects, since all project participants contribute to the project right at the project's commencement.

Within a typical project team, there are key factors and attributes which are necessary to achieve project goals. Many studies have investigated these teams' attributes and within the traditional construction system [37]. However, unlike conventional building projects, GBs require extra considerations for a team to attain anticipated performance goals. Consequently, GB researchers have also identified many team attributes that can potentially affect the success of GB projects.

The level of experience of core experts such as architects, HVAC/mechanical/electrical contractors, and others on GB projects can be very influential on the project delivery performance [47]. A study by Attallah, Kandil [73] considered no certified projects by consultants and no accredited professionals (APs) as some of the key consultant attributes which can determine GB credit point

Table 3
Objective process attributes.

S/N	Attributes	Objective Measures	Key References
1	Extent of design period	Days, months or years	[1,56,57]
2	Green concept facilitator	Owner/client, Architect, Builder/Contractor, Developer, GB Expert etc.	[7,10,11,25,47,49,51,54,58]
3	Motivation for the green concept	Vision of project, Mandated by client, To improve client image, Marketing strategy, Energy saving etc	[47,49,54,59]
4	Timing of green goal initiation	Pre-design stage, Conceptual design stage Design stage, Working Drawing. stage Construction Stage, Post construction	[7,10,11,49,54,58,60,61]
5	Contractual relation/support on the green goal	Contractually, Verbally, Not defined	[49–51,53,54]
6	Green goal in brief/request for proposal (RFP)	Specified Not specified	[50,51,54,62]
7	Principal Communication mode	Physical (co-location), Telephone, Email, Visual meetings etc.	[10,25,31,47,49,56]
8	Delivery method	Design, Bid & Build, Design and Build, Construction manager at Risk, Integrated project delivery, Partnering (e.g. DBOT; PPP)	[10,11,13,19,24,25,36,47,49,52,54,63–65]
9	Procurement method (Primary selection criteria)	Reputation of firm, Experience of firm, Previous performance, Lowest bidder, Best budget, Sole-source selection	[49,51,52,54,62,65]
10	Contracting method (Payment system)	Fixed price (Lump/Unit price), Cost reimbursable (cost-plus), Guaranteed Maximum price (GMP)	[10,25,48,49,51–54,58,66]
11	Simulation tools used	e.g., Autodesk app, Ecotech, EDGE online, LEED online etc.	[9,15,24–27,34,43,47,54,56,66,68,69]

Table 4
Subjective process attributes.

N	Attributes	References
1	Earliness of goal	[1,3,7,47–49,51,54,58,59,62,70]
2	Earliness of project participants	[3,4,10,11,25,47,48,50,51,54–56,58,60,62,70]
3	Clarity of RFP/contract on green goals	[4,11,48–50,54,62]
4	Tracking and monitoring of goal	[49,53,54,57–59]
5	Team assembly	[7,10,25,47,49,53,54,57,58]
6	Participant's recruitment criteria	[3,7,8,10,47,51,54]
7	Documentation and record keeping process	[7,8,13,25,36,47,50,51,54]
8	Resources allocation process	[1,3,4,13,48,61]
9	Use of BIM tools for Life cycle analysis (LCA), energy modelling, and simulations for system thinking	[5,10,11,24–27,34,43,45–47,54,55,57,67–69,71,72]
10	Charrette, meetings, and workshop	[10,13,25,47,48,50,54,58,70]
11	Training & education of participants	[3,10,13,25,47,48,50,54,58,70]
12	Timing & frequency of communication	[3,7,25,47–50,54,58,62]
13	Extent of emphasis on targets throughout the process	[1,3,4,36,48,49,51,58]

NB: Measurable in Likert type scale.

achievement. The presence of accredited professionals (APs) was also considered as a major issue that influenced project delivery performance.

Effective team leadership is another well-recognized and valued quality for GB projects. It is important to minimize the tendency of drifting back to a "business as usual" approach during the design process. Therefore, an active leadership role is required throughout the IDP to stimulate, scrutinize, and motivate the design team at every stage. With excellent team coordination, the project goal can be progressively sustained throughout the entire delivery stages [47,50,51,58].

Yudelson [1] stated that success factors in relation to team attributes includes commitment, leadership, accountability, process management, experience, selection of the right minds, communication, documentation, and training of participants. For Azari and Kim [25], team elements required for successful delivery of GB projects include team's communication, education and training of participants, trust, mutual respect, leadership, system thinking and operations. Lu, Sood [10] highlight issues such as experience, expertise, communication, collaboration, accountability, commitment, mutual respect, trust, compatibility, and synergy of team members. Like process elements, the team attributes can be tangible or intangible, that is, objective or subjective in nature. In that sense, this study categorized team attributes into two groups as presented in Tables 5 and 6.

3.2.4. Client attributes

To achieve GB projects, every stakeholder must take responsibility for sustainability practices [2]. Particularly, the role and personality of the client is fundamental to effective project delivery. Typically, clients are the building demanders. As such, their desires and requirements on projects and processes from the very start of building projects are influential on projects' success. The decisions, activities and personal attributes of the owners are likely to promote sustainable design and construction [60,61]. Thus, clients are regarded as key drivers of GB, as a lack of demands and specifications was regarded as the main impediment to GB growth [76].

It has been widely agreed that a higher level of clients' commitment is essential for GB projects as it can lead to better performance outcomes [48,49,54]. Owner commitment is multifaceted, and it has been linked to time commitment, provision of resources, rewards as well as willingness to take risk [60,61]. Commitment may also be dependent on the client's knowledge or anticipated benefits of GB projects.

Scholars have explored the implications of owners' commitment for GB delivery. For instance, Zhang, Li [77] examined GB owners' commitment & motivation empirically using data from 10 project owners in Australia. It was found that owners who are internally motivated (such as an interest in the environment or end-users' comfort) are more effective than the extrinsic types (those motivated by incentive policies and programs). Another study in Australia involving 150 GB project owners, Olanipekun, Xia [60], discovered that a direct positive relationship exists between owners' commitment (especially as regards the integration of project participants, early green goal setting, and clear vision statement on GB projects) and traditional delivery performance (such as cost and schedule). The internal motivation (such as pro-environmental behaviour, green advocacy, reputation) showed positive linkage with sustainability performance (such as green/energy rate).

Essentially, it is concluded that the client-related issues identified can be measured in both an objective and subjective context;

Table 5
Objective Team attributes.

S/N	Attributes	Objective Measures	Key References
1	No (s) of prior certified GB projects by experts	Number	[47,73]
2	No of year of experience in GB design/construction	Number	[47,54,73]
3	No of accredited professionals (AP) on the team	Number	[47,49,54,58,73]
4	GB Accreditation status of experts	e.g., LEED AP, LEED BD + C, BREEAM, EDGE AP etc.	[49,54,58,62]
5	IDP facilitator/Team coordinator	Owner/client, Architect, Builder/Contractor, Developer, GB Expert etc.	[1,7,8,10,13,47,54]

Table 6
Subjective Team attributes.

N	Attributes	References
1	Architect experience on GB	[47,62,74]
2	Mechanical/Energy Expert experience on GB	[47,62,74]
3	Contractors experience on GB projects	[47,50,62,74]
4	Technical competence/familiarity with GB requirements	[7,10,25,47–50,54,58,62,74]
5	Team commitment to green goal	[10,25,34,54,58,62,70,74]
6	Team compatibility, team spirit and team chemistry	[10,11,25,54,58,74]
7	Transparency and trust	[10,25,48,53,58,74,75]
8	Team leadership and control system	[1,7,8,10,13,47,50,74]
9	Innovation and creativity capability	[10,11,25,47,62,70,74]
10	Effective decision-making process and consensus	[49,54,58]

NB: Measurable in Likert type scale.

thus, Tables 7 and 8 show the list of indicators of client attributes measurable in both contexts.

3.2.5. Delivery performance

Delivery performance, or project success, is a measure of the level at which a project meets the desired goals [79]. Project success has been assessed based on conventional performance metrics such as cost, schedule, quality, clients' satisfaction, and team satisfaction, amongst other over the decades [79,80]. Chan and Chan [79] classified criteria for project success into objective measures (such as time, cost, safety, and the environment) and subjective measures (such as quality, functionality, client satisfaction, and team satisfaction).

Al-Tmeemy, Abdul-Rahman [80] identified three categories of project success, namely, project management success (meeting budget, schedule, and quality targets), product success (client satisfaction, functionality, and meeting technical benchmarks), and market success (profit and revenue, improved reputation, and competitive advantage). Additional sets of metrics are included for gauging GBs' delivery performance. Prior studies have examined GB delivery based on sustainability performance such as level of sustainability, level of certification, The evaluation of this metric used by Swarup, Korkmaz [49] includes level of green, level of high performance, and level of GB certification, which classified project success criteria into project performance measures (cost, quality, schedule, process efficiency) and sustainable building performance measures (safety, health, maintainability, resources used, and LEED credit).

Korkmaz, Riley [54] included cost growth, construction speed, delivery speed, unit cost, green rate, and energy rate as the performance metrics. The delivery performance metrics used by Olanipekun, Xia [60] cover both traditional delivery performance (quality, cost, and schedule) and sustainability delivery metrics (green rating, indoor air quality) in assessing performance on GB projects. Many other studies also included various sustainability performance measures when investigating the extent of success of GB projects, as presented in Tables 9 and 10.

3.3. Conceptual framework for IDP attributes

The major thrust of this study is to propose a conceptual framework that will guide IDP in theory and practice. Reed and Gordon [3] assert that when the GB stakeholders are presented with operational and cost-effective models, it will be easier to implement and assess the flaws and benefits of the design process. Based on the literature review, several IDP attributes have been identified. These sets of attributes are the critical considerations when applying IDP. Therefore, a conceptual framework is developed as presented in Fig. 4. These elements and attributes included in the IDP framework are here presented.

In this framework, the four major IDP metrics are defined as project, process, team, and client attributes. The project attributes define the basic project characteristics such as the project size, scope, complexity, project location, type of project, cost of project and targets, local regulations, and standards. These are project-related elements that can be influential on the success of any construction project. In addition, the intended sustainability features (passive and active sustainable building features) for the project are added characteristics of GB projects.

The second set of metrics is the process attributes. These are the fundamental activities undertaken by the project stakeholders during the design phase towards achieving the project's goal. It represents the core of the IDP, defining the approaches and methods adopted during the design process. The process attributes include the goal-setting process, project delivery system, procurement approach, contract condition, level of integration, design integration, communication etc.

The team attributes refer to design team characteristics which are critical to the project delivery. Here, the team members represent

Table 7
Objective Clients' attributes.

S/N	Attributes	Objective Measures	Key References
1	No(s) of prior certified GB projects by client	Number	[47,73]
2	No of accredited professionals (AP) in the clients' team	Number	[47,49,54,58,73]
3	GB Accreditation status of clients' experts	e.g. LEED AP, LEED BD + C, BREEAM, EDGE AP etc	[49,54,58,62]
4	Organization size/status of the client		

Table 8
Subjective Client attributes.

N	Attributes	References
1	Remuneration and financial support	[7,53,60,61,78]
2	Effective performance monitoring	[47,49,50,60,74]
3	Effective information system	[47,49,54,60,74]
4	High level of project involvement	[50,53,54,60,74]
5	Resources and facilities support	[7,48,50,53,54,60,74]
6	Openness and transparency	[10,25,48,50,53,58,74]
7	Top management support	[3,47,49,54,58,60,61,74]
8	Organizational policy	[2,60,65,74]
9	Success oriented approach	[60,61]
10	Targeted becoming leader in sustainability	[1,47,60,61,77,78]
11	Focused on corporate image and reputation	[60,61,74,77]
12	Organizational participatory/team spirit	[25,34,60,61,65]
13	Sensitivity to end users' need and comfort	[7,10,60]
14	Encourages creativity, innovation, and novelty	[48,60,61,74,78]
15	Organizational structure, logistics and planning system	[48,49,53,54,60,77]
16	Focused on smooth and timely delivery	[47,49,60,77]
17	Owners' commitment to projects' green goals	[10,11,25,47,48,54,60–62,74,77]
18	Experience on GB projects	[10,11,25,36,48,53,54,58,60,70,77,78]

NB: Measurables in Likert type scale.

Table 9
Summary of indicators for traditional delivery performance.

N	Indicators	References from GB studies
1	Budget performance	[5,10,25,36,47,49,50,54,58,60,62,72,77,81]
2	Quality performance	[5,10,25,36,47,49,50,54,58,60,62,77]
3	Schedule performance	[10,25,36,47,49,50,54,58,60,62,77]
4	Client satisfaction	[10,25,49,54,58]
5	Innovativeness/novelty of design	[10,25,49,54,58]
6	Absence of conflict during or after the project	[7,10,12,24,34,75]
7	Functionality	[5,10,25,46,49,50,54,58,71,74]
8	Constructability, health, and safety performance	[5,49,50,54,58,71,74]
9	Social/community benefits	[47,54,77]
10	Team satisfaction & willingness to work together in future	[7,10,12]

Table 10
Summary of indicators for sustainability delivery performance.

N	Indicators	References
1	Energy performance and energy saving	[5,36,49,54,55,60,66,71,72,74,77,81]
2	Renewable energy strategies	[7,9,10,20,25–27,55,81,82]
3	Water efficiency	[1,12,38,45,50,55]
4	Sustainable material sourcing	[38,42,48,50,55]
5	Construction waste reduction	[24,34,36,50,62,67]
6	Optimized passive system	[12,31,38,44,46,68,81]
7	Optimized active/smart system (GB technology)	[11,12,38,44,46,66,67,81,82]
8	Sustainable site and location	[46,47,53–55,62,70]
9	Indoor environmental quality	[1,12,45,50,60]
10	Green rating/certification level	[12,54,55,58,60,77]

those individuals that contribute to the projects either as professionals, experts, consultants, community personnel, building operators, etc. As presented in Tables 5 and 6, the teams' attributes may be weighed in an objective and subjective manner, including matters such as experience, compatibility, chemistry, trust, consensus in decision, and leadership.

Client Attributes define the owners' qualities which can affect GB delivery success. The client denotes those individuals that represent the interests of the owner in the project, either as building experts or management staff. Human resources system, openness climate, coordination, motivation, top management support, and organizational culture, among other things, have been identified as influential factors by scholars. Again, these attributes can be measured with subjective and objective indicators as indicated in Tables 7 and 8

Finally, the measure of GB delivery performance refers to the extent to which a project meets traditional performance (regarding time, cost, construction speed, functionality, aesthetics, adherence to schedule, adherence to budget etc.) and sustainability performance (certification rating, level of energy, water, and resource efficiency etc.)

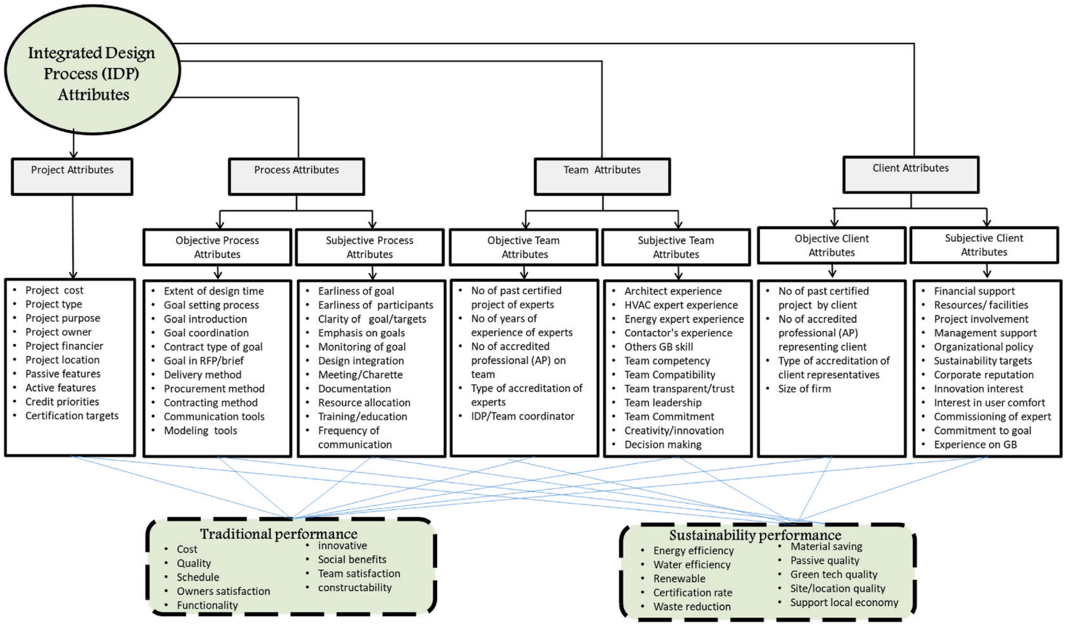

Fig. 4. Conceptual model for integrated design process (IDP) and green building delivery performance.

4. Discussion

When planning for a more effective project delivery strategy, a fundamental step will be to create a systematic, logical, reliable, evaluation mechanism that can efficiently weigh the existing and the proposed strategy. This study developed a set of metrics and conceptual framework for IDP within GB. Following a review of IDP models, guidelines, and extant GB studies, this study identified four categories of metrics, namely project attributes, process attributes, team attributes, and client attributes, which can be measured based on subjective and objective criteria. A framework was proposed to depict the relationship between the IDP metrics and delivery performance.

The proposed framework can be useful in many ways. First, the conceptual framework can guide empirical investigation into IDP. It is possible to explore the influential pattern of IDP attributes on delivery performance. It will also be interesting and worthwhile to check the level of correlation and interrelationship amongst these attributes. For future study, it may be beneficial to study the attributes separately and/or jointly, to gain full understanding of the inherent moderation or mediating effects among the variables on the delivery performance. Apart from the relational connections between IDP attributes and delivery performance, these attributes may also be mutually correlated. For example, team attributes may influence process attributes. Also, clients' attributes may correlate with the team attributes since the client makes decisions on whom they engage in projects based on organizational and individual criteria.

Additionally, while this framework specifies both the subjective and objective attributes within a single conceptual diagram, it is possible to study them jointly or separately depending on the methodology approach and the intended analysis. Within statistical analysis, the objective measures are basically on a nominal scale, while subjective attributes can be assessed on a Likert type or categorical ordinal scale. Subsequently, appropriate statistical analysis can be applied.

Second, this framework can guide the development of decision support models based on Multi-Attribute Utility Theory (MAUT) using techniques such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Artificial Neutral Network (ANN), Multicriteria Decision Making (MCDM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), or Elimination and Choice Expressing Reality (ELECTRE III). Based on this, decisions can be made on what processes and procedures are necessary and how the IDP attributes predict project success in areas such as schedule, cost and certification.

Third, this framework can be useful in developing digitalized process information modeling tool. It will be worthwhile to stimulate the design process. For now, most effort is directed towards simulating the building's performance based on design criteria using BIM [5,69]. With appropriate data transformation, the subjective data can be transformed into objective data for possible algorithm development. With process information modeling, it is possible to monitor process inputs, outputs, and direct results. Such tools can be used by practitioners, client organizations, policymakers, and institutions to enhance current methods and advance new approaches for better delivery systems.

This evaluative plan is essential for nearly all projects and is required for process accountability, assessing investment choices, and program improvement. As concepts related to sustainable development such as sustainable city, smart city, smart building, green city and GB continues to grow, the need for interoperability and interconnectivity is inevitable. Scholars [27,55,83] have begun to explore methods towards integrating sustainability and smart concepts using inclusive approaches. IDP approaches can offer a more holistic solution towards achieving project goals both at the building scale and city scale. Exploring the IDP indicators in greater depth can significantly propel effective design and planning processes. Process modeling and mapping will equally enhance outstanding decision-making for project participants, especially in documenting and gathering a large amount of data to fully keep track of the entire process experience. Thus, it is vital for future research to seek the interactions of these attributes and engage in constant discourse on IDP potentials.

5. Conclusions

With the advent of GB practices, the conventional design process has become less relevant, owing to an increase in the use of IDP, which guarantees higher delivery success. IDP is an innovative concept engaged to overcome the ills of the conventional design process. Nevertheless, the current IDP is challenged by workable metrics and a theoretical model upon which the process could be assessed for possible improvement. Efforts have been made to articulate and explore the design process for a functional and cost-effective activity pattern. This effort has led to the production of various guidelines, process templates, and flow charts developed by industry practitioners and academia through various forum discussions with leaders in the GB community.

Reflecting on extant guidelines, models, and peer-reviewed articles, this study identified 70 IDP attributes, which are subjective and objective metrics, as well as 20 performance metrics comprising traditional and sustainability project benchmarks. The IDP attributes were categorized into project, process, team, and client attributes. The project's attributes entail project size, cost, complexity, scope, as well as sustainability features. The process elements cover goal-setting, delivery systems, activity timing, and communication, among others. The team attributes include experience, competency, leadership, team spirit, and resourcefulness. The client elements relate to the organizational and managerial context of the project owners.

This study hypothesizes that the interrelatedness of IDP attributes can potentially influence GB project performance. To mainstream IDP practice and keep track of process inputs and output, a conceptual framework is developed. This framework is expected to potentially guide decision making by the clients and the consultants during the design phase. It can help practitioners to better understand factors that would hinder or aid the design process and GB project performance.

This research opened a lot of possibilities for further investigation. The conceptual framework provides a strategic paradigm that research can follow since it can be tested empirically by means of a cross-sectional survey. It is expected that a mix of the attributes in research can generate new knowledge which could help IDP practices such as the development of decision support models and tools. It is worthy of note that more context tools are necessary to monitor GB delivery process especially the IDP towards overcoming the current practice complexities and challenges. With appropriate algorithm development, the IDP metrics identified in this study will be useful in the development of a digitalized process information modelling tool.

In addition, it is important to continue to explore IDP practices across countries, given that IDP guidelines are domiciled in various countries. So far, effort on IDP guidelines and practices has largely skewed to Canada, Europe, and the United States. Other regions, such as Asia, Australia, and Africa, need to develop IDP guidelines to advance green building delivery. Examining the success of the IDP from a national, regional and international perspective will be beneficial.

Owing to the traditional contract patterns and the customary ties between contractors, engineering consultants, and architects, applying IDP demands a great deal of cultural and technical changes. Project stakeholders and academia must be willing to put in the effort to make integration a reality, as well as make necessary adjustments to the contract, timeline, and fees. Without a doubt, sustainable design and practice will continue to grow while IDP will become a standard feature in implementing them. Thus, stakeholders need to develop various skill sets and process structures that meet the demands of GB projects.

Credit author statement

Ayodele Emmanuel Ikudayisi: Conceptualization, methodology; investigation; data curation, formal analysis, and writing-original draft preparation. Albert P.C. Chan: Supervision and writing – review and editing. Amos Darko: Methodology, writing –review and editing. Olumuyiwa Bayode Adegun: Co-supervision, writing–review and editing.

Declaration of competing interest

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

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