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Barriers to integrating lean construction and integrated project delivery (IPD) on construction megaprojects towards the global integrated delivery (GID) in multinational organisations: lean IPD&GID transformative initiatives

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Abstract

Purpose – The architecture, engineering and construction (AEC) industry encounter substantial risks and challenges in its evolution towards sustainable development. International businesses, multinational AEC organisations, technical professionals, project and portfolio management organisations face global connectivity challenges between business units, especially during the outbreak of novel coronavirus pandemic, to manage construction megaprojects (CMPs). That raises the need to manage global connectivity as a main strategic goal of global organisations. This paper aims to investigate barriers to integrating lean construction (LC) practices and integrated project delivery (IPD) on CMPs towards the global integrated delivery (GID) transformative initiatives and develop future of work (FOW) global initiatives in contemporary multinational AEC organisations.

Design/methodology/approach – A two-stage quantitative and qualitative research approach is adopted. The qualitative research methodology consists of a literature review to appraise barriers to integrating LeanIPD&GID on CMPs. Barriers are arranged into six-factor clusters (FCs), with a conceptualisation of LeanIPD&GID, GID strategy placements and FOW global initiatives with multiple validations. This analysis also involved semi-structured interviews and focus group techniques. Stage two consisted of an empirical questionnaire survey that shaped the foundation of analysis and findings of 230 respondents from 23 countries

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with extensive cosmopolitan experience in the construction of megaprojects. The survey examined a set of 28 barriers to integrating LeanIPD&GID on CMPs resulting from a detailed analysis of extant literature after validation. Descriptive and inferential statistical tests were exploited for data analysis, percentage scoring analysis, principal component analysis (PCA) and eigenvalues were used to elaborate on clustered factors.

Findings – The research conceptualised LeanIPD&GID principles and proposed GID strategy placements for LeanIPD&GID transformative initiatives and FOW global initiatives. It concluded that the most significant barriers to integration of LeanIPD&GID on CMPs are "lack of mandatory building information modelling (BIM) and LC industry standards and regulations by governments", "lack of involvement and support of governments", "high costs of BIM software licenses", "resistance of industry to change from traditional working practices" and "high initial investment in staff training costs of BIM". PCA revealed the most significant FCs are "education and knowledge-related barriers", "project objectives-related barriers" and "attitude-related barriers". Awareness of BIM in the Middle East and North Africa (MENA) region is higher than LC and LC awareness is higher than IPD knowledge. Whilst BIM adoption in the MENA region is higher than LC; the second is still taking its first steps, whilst IPD has little implementation. LeanBIM is slightly integrated, whilst LeanIPD integration is almost not present.

Originality/value – The research findings, conclusion and recommendation and proposed GID strategy placements for LeanIPD&GID transformative initiatives to integrating LeanIPD&GID on CMPs. This will allow project key stakeholders to place emphasis on tackling LeanIPD&GID barriers identified in this research and commence GID strategies. The study has provided effective practical strategies for enhancing the integration of LeanIPD&GID transformative initiatives on CMPs.

Keywords Lean construction, COVID-19, Integrated project delivery, Global integrated delivery, LeanIPD&GID, Organisation behaviour, Construction megaprojects, Organisations

Paper type Research paper

1. Introduction

The architecture, engineering and construction (AEC) industry encounter substantial risks and challenges in its evolution towards sustainable development (Evans and Farrell, 2021). International businesses, multinational AEC organisations (including enterprises and corporations), technical professional, architecture, engineering, construction, project and portfolio management organisations face global connectivity challenges between business units, especially during the coronavirus (COVID-19) pandemic, to manage construction megaprojects (CMPs). This raises the need to manage global connectivity as a main strategic goal of global organisations. This research introduces global integrated delivery (GID) as a transformative initiative in contemporary organisations. The main objective of the research to investigate barriers to integrating lean construction (LC) practices and integrated project delivery (IPD) on CMPs towards GID transformative initiatives in contemporary multinational AEC organisations. In the following sections, research will define, redefine and conceptualise concepts that have been introduced or redefined from an integrative perspective. The research investigates barriers to integrating LC practices through IPD principles on CMPs, known as LeanIPD and leading towards GID transformative initiatives in contemporary multinational organisations, called LeanIPD&GID. The research also investigates integration between LC practices and building information modelling (BIM) functionalities, LeanBIM, as a part of holistic IPD integration processes, LeanIPD, on CMPs at project and portfolio level and integration of LeanIPD principles and GID initiatives at organisational levels. Accordingly, the research conceptualises integration principles of LeanBIM, LeanIPD and LeanIPD&GID.

The delivery method adopted on construction projects impacts upon distribution of risks and responsibilities amongst different project stakeholders, the timing of their engagement and the nature of their relationships (Hamzeh *et al.*, 2019). A variety of project delivery methods have been used in the construction industry, the most popular being the "traditional" design-bid-build method. Researchers often attribute poor performance to lack of integration within project delivery systems, referred to as "segmental" project design and delivery, which manifests in a lack of coordination and collaboration, poor communication and reduced trust and teamwork (Evans *et al.*, 2020a; Evans *et al.*, 2020b; Harper *et al.*, 2016). Therefore, alternative delivery systems have evolved to cater for these deficiencies. BIM is a collaborative design sharing platform that helps facilitate the transfer of information and knowledge between trades, enhance communication and cooperation and reduce misunderstandings and errors (AIA/AIA CC American Institute of Architects and AIA California Council, 2007); BIM functionality as a collaborative design sharing platform helps in achieving LC principles; accordingly, adoption and implementation of BIM, LC and integration between BIM and LC jointly, as LeanBIM, is contributing to the achievement of IPD principles, so-called LeanIPD.

IPD is an alternative project delivery approach that integrates project teams, business structures, operating systems and practices into a process that promotes innovation (Hamzeh *et al.*, 2019). It differs from traditional delivery approaches by integrating principles such as early collaboration, trust-building, teamwork, collective risk management and profit-sharing throughout project life cycles (AIA/AIA CC American Institute of Architects and AIA California Council, 2007). IPD and its relational type of contractual agreement offers an alternative that addresses several deficiencies found in traditional approaches. For instance, projects using IPD are found to substantially increase productivity and reduce waste, thus offering better performance and increasing value for owners, contractors and designers (AIA/AIA CC American Institute of Architects and AIA California Council, 2007). The construction industry has been a slow adopter of innovative and smart technologies, such as BIM and integration with LC practices (Evans and Farrell, 2020; Evans *et al.*, 2020c; Evans *et al.*, 2021a; Evans *et al.*, 2021b). BIM and LC approaches have been introduced as two distinctive but integral initiatives (Sacks *et al.*, 2010; Sacks *et al.*, 2009). Developing modern standards for implementation of BIM is required (Olawumi *et al.*, 2018; Olawumi and Chan, 2018), whilst full integration between BIM and LC is necessary to achieve optimum LeanBIM synergy; integration between LeanBIM and IPD is also required to achieve LeanIPD synergies working towards LeanIPD&GID. Numerous studies have evaluated potential, barriers, risks, challenges, critical success factors (CSFs), critical failure factors of BIM and its influence on the successful delivery of construction projects (Olawumi and Chan, 2020; Olawumi and Chan, 2019a; Hamzeh *et al.*, 2016; Dave *et al.*, 2013; Ghaffarianhoseini *et al.*, 2017; Azhar *et al.*, 2012; Chan, 2014; Sacks *et al.*, 2010; Chan *et al.*, 2019; Elhendawi *et al.*, 2019; Evans *et al.*, 2020b; Saieg *et al.*, 2018).

BIM is a revolutionary design-based technology (Olawumi *et al.*, 2018), which provides tangible value when implemented and fully integrated with LC (Bui *et al.*, 2016). Apart from the United Kingdom (UK) and the United States of America (USA) which have witnessed an improved adoption and implementation of BIM and LC practices, most other countries are still lagging in its execution (Olawumi *et al.*, 2017). Gu and London (2010), whilst expounding on readiness and implementation level of BIM and LC practices, reported that it varies significantly across the world. Even countries considered to be early adopters and initiators of these concepts experienced a disproportionate level of knowledge (Evans *et al.*, 2020a, 2020b; Olawumi and Chan, 2019b; Bradley *et al.*, 2016). BIM implementation encompasses visualisation processes which enable users to analyse models and retrieve important information such as costs, schedules, clash detection and more (Sacks *et al.*, 2010; Sacks *et al.*, 2009; Sacks *et al.*, 2018a, 2018b; Giel and Issa, 2016). BIM's inherent characteristics are also compatible with LC principles (Hamzeh *et al.*, 2016; Zhang *et al.*, 2018; Solaimani and Sedighi, 2020; Shuquan *et al.*, 2020). Even though the construction industry has started the adoption of BIM and LC principles; there are still many barriers and challenges to achieve ultimate LeanBIM synergies.

1.1 Research objectives

Despite the obvious benefits of adopting the IPD approach in the USA and many countries worldwide, its implementation in the Middle East and North Africa (MENA) region faces a number of challenges which limit its adoption on megaprojects (Evans and Farrell, 2021; Rached *et al.*, 2014). The current construction literature associated with the integration of IPD, LC and or BIM is limited and existing studies mostly focus on qualitative approaches. There is no research that investigates barriers to integrating LC practices and IPD principles on CMPs, LeanIPD, towards the GID transformative initiatives in contemporary multinational organisations or LeanIPD&GID.

In terms of integration of BIM and LC, LeanBIM, much criticism has been raised about the separate implementation of either BIM or LC practices in the built environment (Olawumi and Chan, 2019b) due to difficulties and problems caused by its adoption. Hence, Olawumi and Chan (2020) advocated the implementation of concepts of BIM technologies to facilitate holistic LC development. More so, studies such as Evans *et al.* (2020c) and Evans and Farrell (2020) pointed out that there are still significant gaps in practice in the adoption of innovative tools such as BIM for implementation of LC practices and there are significant gaps in the literature regarding the integration of BIM, LC and IPD as LeanIPD on CMPs towards GID. Studies such as Olawumi and Chan (2019b) emphasised that without sufficient knowledge on the status (such as its barriers) of implementation of these concepts in the construction industry; it is difficult to improve and track aspects of its implementation.

Therefore, the current study will discuss BIM and the challenges of using it to enable the integration of LC practices in the built environment. Although previous research studies have highlighted profound barriers relating to BIM in the construction industry – none are yet to appraise impediments militating against adopting both LeanBIM and IPD principles on the construction of megaprojects. Accordingly, this study reviews existing literature to gather evidence of barriers faced by the built environment in integrating LC practices and IPD towards GID. Accordingly, this paper aims to bridge the gap in the literature, investigates barriers to integrating LC practices and IPD principles on CMPs, LeanIPD, towards GID transformative initiatives in contemporary multinational AEC organisations, as LeanIPD&GID. To achieve this aim, the research methodology consists of a literature review, a survey questionnaire and structured interviews. In the context of CMPs in contemporary multinational AEC organisations, research objectives are:

- *RO1:* To build a comprehensive background through reviewing the nature of the construction industry in CMPs, traditional procurement approaches and IPD, LC thinking, including BIM as a smart tool, as well as barriers of implementation and integration between LC and IPD, LeanIPD, on CMPs towards GID, as LeanIPD&GID, transformative initiatives and FOW in contemporary multinational AEC organisations;
- *RO2:* To identify and assess LeanIPD&GID barriers, and examine the perception of AEC industry professionals and academics towards the barriers of integrating LeanIPD and LeanIPD&GID, on CMPs in GID context; and
- *RO3:* To establish the significance of LeanIPD&GID barriers and the relative weight and significance of *factor clusters (FCs)* associated with LeanIPD integration – including LeanBIM – on CMPs working towards GID, GID strategy placements and FOW global transformative initiatives.

The paper is organised into seven sections. Section 1 introduces the topic. Section 2 is a literature review. Section 3 describes the research methodology. Section 4 introduces GID transformative initiatives and FOW global initiatives. Section 5 provides the research analysis, findings and discussion of results. Section 6 presents the conclusions. Finally, Section 7 is recommendations.

2. Literature review

A number of recent research studies have discussed the use of IPD, LC and or BIM in the construction industry whilst there is little work focussing on investigating integration between lean principles, BIM and IPD and implementation of this integration towards GID integration at the organisational level. Also, there is very limited research that introduces project performance metrics, such as cost and schedule performance along with this integration. In this section, the definition of each component of IPD, LC and BIM as described in the construction literature is provided and then recent research concentrating on the use of all three components in projects is discussed. Research also will define, redefine and conceptualise integration principles of LC, BIM, IPD, LeanBIM, LeanIPD and LeanIPD&GID. In addition, definitions of project, portfolio and CMP are provided. Figure 1 illustrates the hierarchy of integration of BIM, LC, IPD, LeanBIM, LeanIPD, LeanIPD&GID concepts, noting that all concepts originate at the project level but GID concepts are at organisational level.

2.1 Global integrated delivery

The "globally integrated enterprise" (GIE) business model emerged from massive socioeconomic changes that were occurring throughout the world in the 1990s. A key factor was the emergence of the internet. There are some earlier contributions in the GIE intuitive by Palmisano (2006), IBM100 (2006), IBM and the Lisbon Council (2007). Maerki (2008) introduced IBM's business model and strategy by explaining how the enterprise transformed from an international corporation model of the nineteenth century to the multinational corporation model of the twentieth century. This was a response to globalisation, its subsequent impact of governance and technological advances in the nineteenth century. Lubowe *et al.* (2009) discussed comprehensive strategies for globally integrated operations. Bramante *et al.* (2010) discussed IBM's case study in transforming to GIE between 2000 and 2010.

There is a gap in the literature to link the transformation of business models from GIE towards the integration of BIM, LC practices, as LeanBIM and considering holistic, integrative processes between LC – including BIM functionalities – and IPD, as LeanIPD to achieve full optimisation of these principles on CMPs working towards GID, as LeanIPD&GID. GID could be defined as a transformative initiative in contemporary multinational organisations (or enterprises or corporations) that redefines what is possible by connecting and collaborating global delivery units or teams; it allows teams to grow and achieve opportunities worldwide (Evans and Farrell, 2021). GID encourages inventive

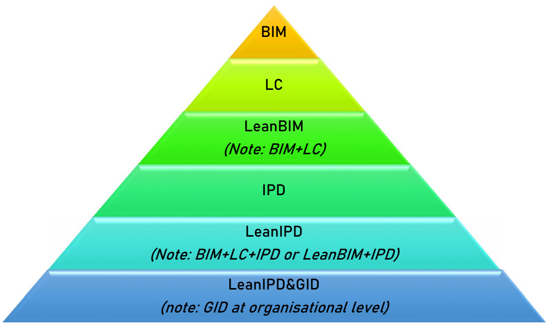


Figure 1. Hierarchy of integration of BIM, LC, IPD, LeanBIM, LeanIPD and LeanIPD&GID concepts on CMP at organisational level

thinking, exploration and brings innovative ideas and sustainable solutions to CMP clients and owners that lead to profitable growth and shared success with multinational AEC organisations (Evans *et al.*, 2021b).

GID redefines how work is delivered in the AEC industry. It promotes global connectivity and GID standard delivery approaches increase digital capabilities and enhance integration between Line of Business (LoB) services. GID benefits are: leveraging time zone benefits and extending working days to fast track delivery of projects to meet schedules, improving project financials combining scalable solutions from LoB for cost benefits, facilitates access to global talent, core services in each LoB and expand markets and broaden LoB capabilities, efficiently delivering word-class services bringing the global experience to local projects, swift team mobilisation, facilitation of advances in technology and delivery innovation, connecting teams globally and increasing diversity, enhancing competitive advantage for LoB through competitive pricing and offering value for money to clients, thus winning more work.

2.2 Integrate project delivery

AIA/AIA CC American Institute of Architects and AIA California Council (2007) defines IPD as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses talents and insights of all participants to optimise project results, increase value to owners, reduce waste and maximise efficiency through all phases of design, fabrication and construction". Figure 2 shows the relationship amongst BIM, LC and IPD principles and GID initiatives.

The principles of IPD, as its name suggests, is integration or collaboration between the different participants involved in projects. For efficient collaboration to take place, project delivery systems must encompass several core features, including:

- early collaboration during design where owners, architects, contractors, subcontractors, consultants and suppliers provide their expertise early in projects to drive innovation and improve performance (AIA/AIA CC American Institute of Architects and AIA California Council, 2007);

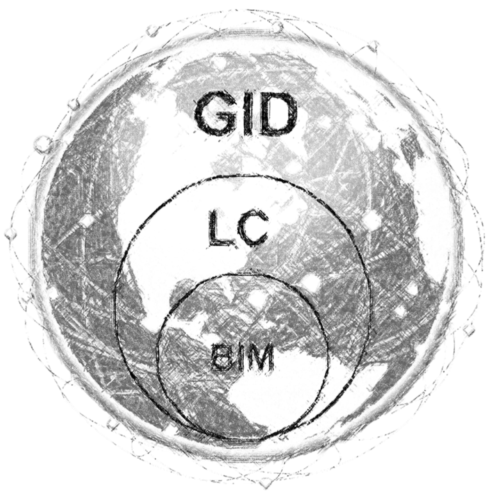


Figure 2.
Staked Venn diagram shows relationship amongst BIM, LC, IPD principles and GID initiatives [vector artwork design using Adobe® Illustrator software]

- alignment of interests and objectives amongst project parties in line with overall project objectives (AIA/AIA CC American Institute of Architects and AIA California Council, 2007);
- trust and respect between parties and a "no-blame" culture within projects (Evans *et al.*, 2020b);
- high levels of teamwork, communication and collaboration, where knowledge and information is openly shared and exchanged (Evans *et al.*, 2020a);
- processes and tools that encourage cooperation, for example, BIM;
- pain-share/gain-share agreements, leading to the elimination of adversarial relationships; through this feature, different trades are compensated for their work based on a principle that rewards them together according to the ultimate benefit of projects (Evans *et al.*, 2020b);
- high levels of teamwork, communication and collaboration, where knowledge and information is openly shared and exchanged (AIA/AIA CC American Institute of Architects and AIA California Council, 2007); and
- the employment of collaborative planning systems, such as "Last Planner Systems" (LPSs) for production planning and control (Ballard, 2000).

This latter feature assists project teams in smoothing variability in construction workflow, reducing uncertainty in construction operations, developing planning foresight and encouraging proactive behaviour to remove constraints (Hamzeh *et al.*, 2015). Table 1 demonstrates principles of IPD according to (AIA/AIA CC American Institute of Architects and AIA California Council, 2007).

2.3 Lean construction

In the 1990s, recognised as an outcome of the Toyota production system, lean manufacturing (or lean production) was established and implemented with significant achievements, and this led to the original uses of lean thinking in the construction industry (Ballard and Howell, 1998; Koskela, 2000; Koskela *et al.*, 2002). Liker (2004) described principles and behaviours that underlie the operational philosophy of the Toyota Motor Corporation. As lean principles originally appeared as philosophies, it can be defined in many different ways in accordance with the purpose of the users (Forbes and Ahmed, 2010; Koskela *et al.*, 2019). Lean in construction is described as a method to design construction systems to lessen the waste of time, materials and effort in the interest of maximising possible project value (Sacks, 2013; Howell and Koskela, 2000).

2.4 Building information modelling

BIM is defined as a digital representation of a facility illustrating accurate geometry and pertinent data used for supporting design, procurement, fabrication and construction, of projects (Sacks *et al.*, 2018a, 2018b). Building information models also encompass exchangeable data or files used to assist communication and decision-making processes (Evans *et al.*, 2020c; Evans *et al.*, 2021b). The term four-dimensional (4D) BIM refers to the adding time dimension or schedule-related information into three-dimensional (3D) BIM models (usually 3D computer-aided design or CAD) of projects. With the use of simulation in 4D models, many construction conflicts, design clashes and constructability issues can be found and resolved in advance. Five-dimensional (5D) BIM is another variation developed to incorporate the cost dimension; 5D BIM is still in its infancy stage of practice and

#	IPD principle	Description
1	Mutual respect and trust	In an integrated project, owners, designers, consultants, constructors, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project
2	Mutual benefit and reward	All participants or team members benefit from IPD. Because the integrated process requires early involvement by more parties, IPD compensation structures recognise and reward early involvement. Compensation is based on the value added by an organisation and it rewards "what's best for project" behaviour. IPD use innovative business models to support collaboration
3	Collaborative innovation and decision-making	Innovation is stimulated when ideas are freely exchanged amongst all participants. In an integrated project, ideas are judged on their merits, not on the author's role or status. Key decisions are evaluated by the project team and, to the greatest practical extent, made unanimously
4	Early involvement of key participants	In an integrated project, the key participants are involved from the earliest practical moment. Decision-making is improved by the influx of knowledge and expertise of all key participants. Their combined knowledge and expertise are most powerful during the project's early stages where informed decisions have the greatest effect
5	Early goal definition	Project goals are developed early, agreed upon and respected by all participants. Insight from each participant is valued in a culture that promotes and drives innovation and outstanding performance, holding project outcomes at the centre within a framework of individual participant objectives and values
6	Intensified planning	The IPD approach recognises that increased effort in planning results in increased efficiency and savings during execution. Thus, the thrust of the integrated approach is not to reduce design effort, but rather to greatly improve the design results, streamlining and shortening the much more expensive construction effort
7	Open communication	IPD's focus on team performance is based on open, direct and honest communication amongst all participants. Responsibilities are clearly defined in a no-blame culture leading to identification and resolution of problems, not determination of liability. Disputes are recognised as they occur and promptly resolved
8	Appropriate technology	Integrated projects often rely on cutting edge technologies. Technologies are specified at project initiation to maximise functionality, generality and interoperability. Open and interoperable data exchanges based on disciplined and transparent data structures are essential to support IPD
9	Organisation and leadership	The project team members are committed to the project team's goals and values. Leadership is taken by the team member most capable with regard to specific work and services. Often, design professionals and contractors lead in areas of their traditional competence with support from the entire team. Roles are clearly defined, without creating artificial barriers that chill open communication and risk taking

Source: AIA/AIA CC American Institute of Architects and AIA California Council, 2007

Table 1.
Principles of IPD

six-dimensional (6D) BIM, which has all data of the lifecycle management of projects, but is still forthcoming in practice (Sacks *et al.,* 2018a, 2018b; Evans and Farrell, 2020). Table 2 shows LC principles BIM functionalities (Evans *et al.,* 2021a).

2.5 Governance of portfolios, programmes and projects

Projects exist and operate in environments that may have an influence on them. These influences can have a favourable or unfavourable impact on projects. Two major categories

Code	(10LC, PR)	Code	(10BIM, FN)
LC, PR, i	*The 10 LC principles*	*BIM, FN, j*	*The 10 BIM functionalities*
LC, PR, 01	Reduce variability of projects and processes by getting it right first time and improving upstream flow	BIM, FN, 01	High visualisations for aesthetic and functional evaluation of designs
LC, PR, 02	Reduce cycle time and inventories	BIM, FN, 02	Rapid generation of multiple design alternatives
LC, PR, 03	Reduce batch size; strive for single-piece flow to assure continuous production	BIM, FN, 03	Predictive analysis of performance during designs
LC, PR, 04	Increase flexibility using multi-skilling	BIM, FN, 03	Automated cost/time estimation within the design stages
LC, PR, 05	Standardise methods and processes using convenient systems to control production	BIM, FN, 05	Evaluation of conformance to client value within the design stages
LC, PR, 06	Visualise production methods and processes whilst assuring continues improvement	BIM, FN, 06	Integration in design models based on single information source, multiple disciplines design and automated clash checking
LC, PR, 07	Parallel processing using a convenient system to assure flow by parallel and reliable technologies	BIM, FN, 07	Increase collaboration in designs and constructions via multi-user to edit and view a single model
LC, PR, 08	Focussing on concepts, strive to maximise value selection and ensure requirements flow down whilst continuously verifying and validating	BIM, FN, 08	Evaluation of alternative construction plans with 4D visualisation
LC, PR, 09	Go and see for yourself and taking decisions in consensus, considering all options for problem-solving	BIM, FN, 09	Online multidisciplinary communication and visualisations of process status for projects; on/off site during construction stages
LC, PR, 10	Encourage networks of partners to improve cooperation and maintain valuable long-term relationships with subcontractors and suppliers	BIM, FN, 10	Integration with project partners, supply chains and subcontractor' databases

Note: LC = lean construction; PR = principles; FN = functionalities; BIM = Building information modelling; (i;j) = numbers
Source: (Evans *et al.*, 2021a)

Table 2.
The 10-LC principles and ten-BIM functionalities

of influences are enterprise environmental factors (EEFs) and organisational process assets (OPAs). EEFs refer to conditions, not under the control of project teams, that influence, constrain or direct projects. These conditions can be internal and/or external to organisations. EEFs are considered as inputs to many project management processes, specifically for most planning processes. These factors may enhance or constrain project management options. In addition, these factors may have a positive or negative influence on outcomes. OPAs are the plans, processes, policies, procedures and knowledge (PMI A., 2017). Governance of portfolios, programmes and projects involves aligning organisational project management, portfolios, programmes and project management. There are four governance domains of alignment, risk, performance and communication and each domain has the following functions: oversight, control, integration and decision-making (PMI A., 2017). PMI A. (2017) defines a project as: "a temporary endeavour undertaken to create a unique product, service, or result" and a programme "as a group of related projects, subsidiary programs and program activities managed in a coordinated manner to obtain benefits not available from managing them individually". According to PMI A. (2017)

"a portfolio is defined as projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives".

CMPs can be defined as temporary endeavours undertaken to create unique products, services or results. Megaprojects can be characterised as large-scale, complex, ventures with typically a cost of the US$ value of one billion or more, involving multiple public and private stakeholders. The CMP definition aligns with that of the PMI A. (2017) definition of a project and (Flyvbjerg, 2014); accordingly, the PMI Project Management Body of Knowledge (PMBOK® Guide) key components are project life cycle, project phase, phase gate, project management process, project management process group and project management knowledge area. PMI A. (2017) defined project governance reference to a framework, functions and processes that guide project management activities to create unique products, services or results to meet organisational, strategic and operational goals. CMPs involve various stakeholders such as international consultants, multinational contractors and joint ventures, together with several design and construction teams. A formal definition of stakeholders is: "an individual, groups or organisations who may affect, be affected by or perceive themselves to be affected by a decision, activity or outcome of a project".

2.6 LeanBIM, LeanIPD and LeanIPD&GID concepts

LeanBIM. BIM and LC approaches have been introduced as two distinctive but integral initiatives (Sacks *et al.*, 2010; Sacks *et al.*, 2009). Developing modern standards for implementation of BIM is required (Olawumi *et al.*, 2018a), whilst full integration between BIM and LC, so-called "LeanBIM", is necessary to achieve optimal LeanBIM synergies (Evans *et al.*, 2020c).

LeanIPD. IPD is uniquely suited to put these principles into practice because it solves contractual issues that prevent true collaboration and sharing of ideas, materials and manpower. One of the cardinal principles of LC is that when a single step is optimised in a process, it de-optimises the whole. Unfortunately, traditional construction contracts divide all entities on projects into separate camps with each intent on optimising its own part, thus de-optimising the whole. Cost and profit-sharing approaches eliminate traditional contract barriers and incentivise team members to act unselfishly and make "project" decisions rather than "trade" decisions. Using the principles of LC and IPD processes offers two main advantages over the traditional design-bid and design-build processes; that is reduced waste and increased reliability of planning.

LC principles focus on attitudes, processes and techniques for continuous improvement, increasing value, eliminating waste in projects, loose supply chains and interactions with third parties, whilst IPD principles boost LC principles. IPD instead of introducing processes to reduce waste or optimising processes, concentrates on collaboration between contractual parties, and thus integration between IPD and maximising the value of using LC processes. Integrating with BIM enhances collaboration, open communication and the use of innovative technologies. BIM functionality is a collaborative design sharing platform that helps in achieving LC principles, as LeanBIM, whilst the implementation of LeanBIM achieves IPD principles. Those integrations between LeanBIM and IPD achieves the IPD principles, so-called LeanIPD (Evans and Farrell, 2021; Evans *et al.*, 2021a).

LeanIPD&GID. Projects, including CMPs, exist and operate in environments that may have an influence on them. GID redefines what is possible by connecting and collaborating global delivery units or teams; as it allows teams to grow and achieve opportunities worldwide. GID encourages inventive thinking, exploration and bringing innovative ideas and sustainable solutions to clients and owners of CMPs, which leads to profitable growth and shared success with AEC organisations. LeanIPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses talents and insights of all participants; this includes integration of

BIM, LC, as LeanBIM and integrating LeanBIM with IPD as LeanIPD working towards LeanIPD&GID transformative initiatives.

2.7 Barriers to integrating LeanIPD&GID on construction megaprojects

There has been a surge in recent years in the use of variants of BIM in the construction process and previous studies such as Evans and Farrell (2020), Evans *et al.* (2020b, 2020c), Olawumi and Chan (2019b) and Zhang *et al.* (2018) stressed the need to integrate BIM with LC practice to achieve LeanBIM synergy towards LeanIPD. However, as it is always the case when new techniques and concepts are introduced in the construction industry, the implementation of LC practices can face setbacks and challenges (Hamzeh *et al.*, 2016; Evans and Farrell, 2020). BIM has transformed infrastructure and building development within the AEC industry over recent decades (Sacks *et al.*, 2018a, 2018b; Cao *et al.*, 2015). A plethora of research illustrates the merits of BIM application through the development of the entire life cycle of projects (Olawumi *et al.*, 2018; Chen *et al.*, 2015). BIM adoption has gained momentum and attention from key stakeholders and decision makers in the construction industry (Sacks *et al.*, 2009; Sacks *et al.*, 2010; Evans *et al.*, 2020a; Evans *et al.*, 2020b; Carvajal-Arango *et al.*, 2019).

Evans and Farrell (2020) applied a Delphi study to investigate the critical barrier factors (CBFs) encountered by key construction stakeholders in their efforts to integrate BIM and LC on CMPs. The research concluded that the most significant barriers to integration of LeanBIM are: "lack of mandatory BIM and LC industry standards and regulations by governments", "lack of involvement and support of governments", "resistance of industry to change from traditional working practices", "high cost of BIM software licences" and "high initial investment in sta training costs of BIM". Whilst Evans *et al.* (2020c) applied a Delphi survey to investigate the CSFs that enhance integration between BIM and LC practices on CMPs and concluded that the five extreme significant BIM CSFs that boost LeanBIM synergy were "collaboration in design, construction works and engineering management", "senior organisational management support", "coordination and planning of construction work", "earlier and precise 3D visualisation of design" and "boosting implementation of LC and integrating project delivery". Evans *et al.* (2021a) introduced a framework for the interactions between BIM and LC on CMPs, detailing a comprehensive analysis of existing literature. This research included a conceptual analysis of interactions between BIM and LC on CMPs and yielded ten-LC principles and 10-BIM functionalities that are necessary for their integration. A framework of interaction between BIM and LC is then compiled.

Chan (2014) considered barriers of implementing BIM in the construction industry in Hong Kong, and Chan *et al.* (2019) investigated benefits and barriers to implementing BIM in construction. Dave *et al.* (2013) investigated LC implementation in construction. Sacks *et al.* (2018a, 2018b) introduced a guideline to BIM for contractors, owners, designers and engineers. Other researchers examined benefits, risks, challenges and barriers to the application of BIM such as Ghaffarianhoseini *et al.* (2017), Hamzeh *et al.* (2016), Hong *et al.* (2018), Jin *et al.* (2017), Olatunji *et al.* (2017), Olawumi *et al.* (2017), Olawumi *et al.* (2018), Olawumi and Chan (2019a), Olawumi and Chan (2019b), Chan and Chan (2011), Ding *et al.* (2015) and Tan *et al.* (2019). Ozorhon and Karahan (2017), Hong *et al.* (2018) and Hsu *et al.* (2015) examined CBFs of BIM implementation. Rogers *et al.* (2015) deliberated on the adoption of BIM in Malaysian engineering consulting services. There are a few studies that examined interrelations between BIM and LC, such as Sacks *et al.* (2009), Sacks *et al.* (2010) and Zhang *et al.* (2018). Whilst Abdirad (2017), Ahankoob *et al.* (2018) and Ahn *et al.* (2016) focussed on assessment and maturity models of BIM adoption in a built environment.

Ibrahim *et al.* (2010a, 2010b) analysed dynamics of the global construction industry with a focus on lean production systems in the Malaysian construction industry and concluded that it consumes large amounts of natural resources along with wastage, due to inefficient and improper utilisation. Numerous factors contribute to poor performance, but an efficient means of identification and reduction of waste has always been left aside. van Lith *et al.* (2015) found an increase in maturity of purchasing functions in general and in particular in the management of strategic relations, coordinated activities in supply chains and increased use of information technology (IT) solutions which enable better-integrated approaches in construction processes. Dubey and Gunasekaran (2015) investigated soft total quality management (TQM) and its impact on firm performance; research concluded that human resource, quality culture, motivational leadership and relationship management are important constructs that contribute to TQM validity. Tezel *et al.* (2018) evaluated the adoption of lean thinking in the UK construction industry and found that the existence of strong external motivational factors for lean thinking such as clients' push and companies' expectation of winning more contracts alongside lean's operational benefits. Zegarra and Alarcón (2019) investigated the coordination of teams and processes in construction projects using a lean complex adaptive mechanism and suggested behaviour involves complex, flexible and push features, focussed on execution. Meng (2019) studied lean management in the context of construction supply chains in the UK industry and the study concluded that lean could be enhanced if it synergises with supply chain collaboration. Demirkesen (2020) measured the impact of lean implementation on construction safety and concluded that implementing lean practices achieves better safety performance.

Table 3 illustrates 28 key barriers to integrating LeanIPD&GID on CMPs, as detailed in extant literature. This research seeks the opinions of an expert panel to rank, analyse and prioritise barriers recognised in the extant literature, to aid key stakeholders and decision makers in the construction industry, and to emphasise the most significant challenges hindering the integration of LeanIPD&GID on CMPs.

This research validates barriers of integrating LeanIPD&GID with industry experts, then arranged the barriers into clustered factors. Semi-structured face-to-face interviews via a video conference communications approach and focus group technique were adopted to validate barriers of integrating LeanIPD&GID with a heterogenous cluster consisting of nine construction experts from various disciplines in the AEC industry. Table 4 illustrates the FC structure of barriers to integrating LeanIPD&GID on CMPs; these barriers were categorised into six FC: FC1, technical-related barriers; FC2, attitude-related barriers; FC3, education and knowledge barriers; FC4, legal barriers; FC5, project objectives-related barriers; and FC6, market-related barriers.

The construction industry indicates a lack of collaboration and coordination that has led to barriers to LeanBIM synergy (Zhang *et al.*, 2018; Sacks *et al.*, 2010; Dave *et al.*, 2013; Evans *et al.*, 2020b). Olatunji *et al.* (2017) and Chan *et al.* (2019) debated support from senior management and that a collaborative work environment would lead to enhancing BIM benefits in construction practice. Nevertheless, the construction industry needs to confront numerous challenges and barriers related to the application of BIM tools, LC principles and LeanBIM (Chan *et al.*, 2019; Azhar *et al.*, 2012; Hong *et al.*, 2018; Ghaffarianhoseini *et al.*, 2017; Zahoor *et al.*, 2017). BIM is considered a facilitating tool to the construction industry that meets emerging challenges (Hamzeh *et al.*, 2016; Olawumi and Chan, 2019a). The level of readiness to implement BIM technologies varies from organisation to organisation, country to country and region to region (Azhar *et al.*, 2012). Abanda *et al.* (2015) and Olawumi *et al.* (2018) observed resistance to change from conventional practices. These challenges hindered optimum implementation of BIM technologies, LC principles and diminished full integration between LC and BIM (Olawumi and Chan, 2019a; Ozorhon and Karahan, 2017). Despite growing research and studies in LeanBIM initiatives, the construction industry has focussed

Code	Barriers to integrating LeanIPD&GID	Reference
B1	Increased workload for model development	1, 2, 7, 11, 13 and 22
B2	Lack of legal frameworks and contract uncertainties of BIM and LC	1, 11, 6, 3 and 23
B3	Incompatibility issues between various software packages	4, 24, 16, 1 and 13
B4	Varied market readiness across organisations and geographic locations	6, 26, 11, 14 and 26
B5	Resistance of industry to change from traditional working practices	5, 27, 11, 25 and 18
B6	Societal reluctance to change from traditional values or cultures	7, 11, 2, 27 and 28
B7	Lack of insurance applicable to BIM, LC and LeanBIM adoption	9, 11, 2 and 9
B8	Lack of initiatives and hesitance on future investments	8, 28,11 and 2
B9	Organisational challenges, project strategies and policies	10, 11 and 6
B10	Immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption	19, 29, 2 and 9
B11	Lack of awareness and collaboration amongst project stakeholders	13, 2, 27 and 26
B12	Fragmented nature of construction industry	20, 30, 2, 15, 20 and 21
B13	Negative attitudes towards data sharing	11, 2, 3, 6, 4 and 5
B14	User-unfriendliness of BIM analysis software programmes	2, 11, 10 and 31
B15	Lack of a well-established BIM, LC and LeanBIM workflows	15, 10, 17 and 27
B16	High costs of BIM software licenses	14, 11, 27 and 28
B17	Ambiguous economic benefits	18, 27, 28 and 2
B18	High initial investment in statraining costs of BIM	21, 27 and 28
B19	Lack of mandatory BIM and LC industry standards and regulations by governments	12, 11, 27, 28 and 9
B20	Lack of involvement and support of governments	12, 11, 26 and 9
B21	Lack of supporting LC analysis tools and software	12, 11, 27, 16 and 18
B22	High training and implementation costs and time of BIM	16, 11, 27, 31 and 22
B23	Intellectual properties rights, associated disputed and risks	17, 11, 23 and 3
B24	Lack of senior management commitment and clients demand	12, 24 and 25
B25	Difficulty in adapting to BIM technologies and processes	22, 25, 28 and 27
B26	Low level of research in industry and academia	25, 14, 10, 4 and 5
B27	Difficulty in allocating and sharing LC, BIM and LeanBIM risks	31, 13, 30 and 6
B28	Shortage of cross-field specialists in BIM, LC and LeanBIM	12, 9, 11, 8 and 22

Notes: 1 = Abanda *et al.* (2015); 2 = Azhar *et al.* (2012); 3 = Bradley *et al.* (2016); 4 = Bui (2016); 5 = Cao *et al.* (2015); 6 = Chan (2014); 7 = Chan *et al.* (2019); 8 = Chen *et al.* (2015); 9 = Dave *et al.* (2013); 10 = Ding *et al.* (2015); 11 = Sacks *et al.* (2018a, 2018b); 12 = Elhendawi *et al.* (2019); 13 = Ghaffarianhoseini *et al.* (2017); 14 = Hamzeh *et al.* (2016); 15 = Hong *et al.* (2018); 16 = Hsu *et al.* (2015); 17 = Jin *et al.* (2017); 18 = Olatunji *et al.* (2017); 19 = Olawumi *et al.* (2017); 20 = Olawumi *et al.* (2018); 21 = Olawumi and Chan (2018); 22 = Olawumi and Chan (2019a); 23 = Olawumi and Chan (2019b); 24 = Ozorhon and Karahan (2017); 25 = Rogers *et al.* (2015); 26 = Sacks *et al.* (2010); 27 = Sacks *et al.* (2009); 28 = Salleh and Phui Fung (2014); 29 = Shirowzhan *et al.* (2020); 30 = Tan *et al.* (2019); 31 = Zhang *et al.* (2018)

Table 3. Barriers to integrating LeanIPD&GID on CMPs

on particular aspects without paying attention to holistic views to achieve utmost LeanBIM synergy (Azhar *et al.*, 2012). The current approach in LeanBIM assessment is still immature and requires further research (Ghaffarianhoseini *et al.*, 2017).

3. Research methodology

The research attempts to investigate barriers to integrating LC practices and IPD on CMPs towards the GID transformative initiatives in contemporary multinational AEC organisations. It compares the research aim, objectives and characteristics with the aim, objectives and characteristics of different research approaches (Farrell, 2016). This research is both descriptive and inferential in nature and adopts an applied approach to achieve its aim and objectives. Quantitative and qualitative techniques were used for data collection and analysis. Semi-structured face-to-face interviews and the focus group technique via

Table 4.
FCs structure for barriers to integrating LeanIPD&GID on CMPs

Code	FCs structure for barriers to integrating LeanIPD&GID
FC1	*Technical-related barriers*
B1	Increased workload for model development
B3	Incompatibility issues between various software packages
B14	User-unfriendliness of BIM analysis software programmes
B16	High cost of BIM software licenses
B21	Lack of supporting LC analysis tools and software
FC2	*Attitude-related barriers*
B6	Societal reluctance to change from traditional values or cultures
B11	Lack of awareness and collaboration amongst project stakeholders
B20	Lack of involvement and support of governments
FC3	*Education and knowledge related barriers*
B15	Lack of a well-established BIM, LC and LeanBIM workflows
B25	Difficulty in adapting to BIM technologies and processes
B26	Low level of research in industry and academia
B28	Shortage of cross-field specialists in BIM, LC and LeanBIM
FC4	*Legal barriers*
B2	Lack of legal framework and contract uncertainties of BIM and LC
B7	Lack of insurance applicable to BIM, LC and LeanBIM adoption
B10	Immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption
B19	Lack of mandatory BIM and LC industry standards and regulations by governments
B23	Intellectual properties rights, associated disputed and risks
B27	Difficulty in allocating and sharing LC, BIM and LeanBIM risks
FC5	*Project objectives related barriers*
B8	Lack of initiative and hesitance on future investments
B9	Organisational challenges, project strategies and policies
B13	Negative attitude towards data sharing
B24	Lack of senior management commitment and clients demand
FC6	*Market-related barriers*
B4	Varied market readiness across organisations and geographic locations
B5	Resistance of industry to change from traditional working practices
B12	Fragmented nature of construction industry
B17	Ambiguous economic benefits
B18	High initial investment in sta training costs of BIM
B22	High training and implementation costs and time of BIM

Note: FC = factor cluster(s)

video conference communications was adopted as it indicates a high degree of reliability, high level of item response rate and gives opportunities to interviewers to explain complex questions and mitigate inappropriate responses (Farrell, 2016). Semi-structured face-to-face interview are discussions, usually one-on-one between interviewers and interviewees, meant to gather information on a specific set of topics, whilst focus groups are dynamic group discussions used to collect information (Harrell and Bradley, 2009). This strategy reduces the risk and bias associated with using specific methods (Fellows and Liu, 2015; Farrell, 2016; Bernard, 2000). To achieve the research goals, a two-stage research methodology is adopted. Stage 1 is qualitative research and Stage 2 is quantitative. Figure 3 demonstrates the research methodology stages.

3.1 Stage 1: Qualitative research methodology

The qualitative research method comprises a five-step research methodology as suggested by Farrell (2016). Step 1.1 is a comprehensive literature review to define key parameters and

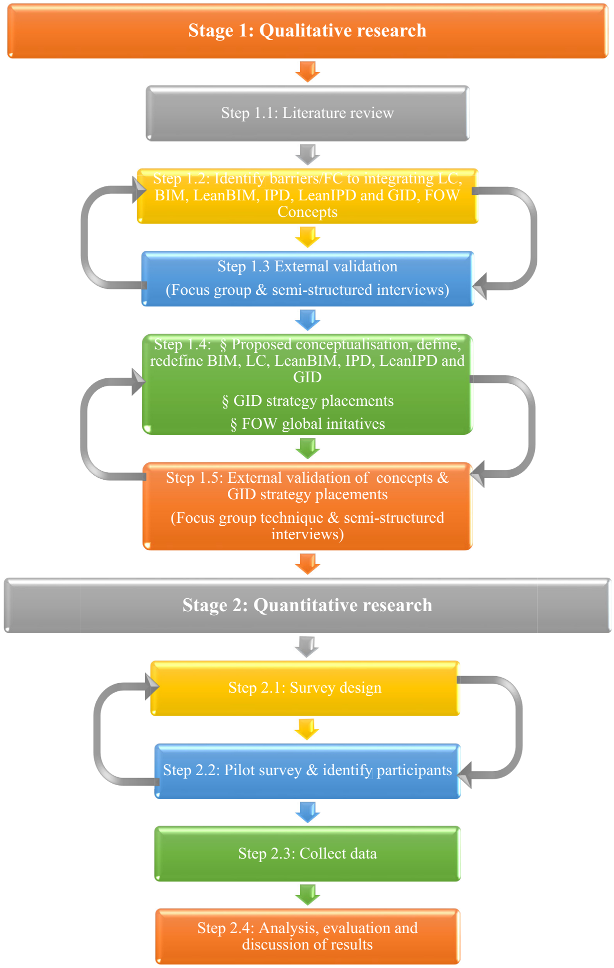


Figure 3.
Research methodology

criteria affecting barriers to integrating LC practices and IPD on CMPs towards the GID transformative initiatives in contemporary multinational AEC organisations. Step 1.2 identifies barriers to integrating LC, BIM, LeanBIM, IPD, LeanIPD and GID and integrate barriers to LeanIPD&GID into structured FCs. Evans and Farrell (2020) carried out research to investigate CBFs that hinders integration between BIM and LC practices on CMPs and adopted a Delphi technique. The research identified 28 barriers to integrating LeanIPD&GID on CMPs which were then categorised into six FCs. Step 1.3 is based on the critical review, outcomes were piloted with eight industry expert practitioners and senior academic researchers through semi-structured face-to-face interviews and the focus group technique to validate determined factors and interactions (Farrell, 2016; Taylor *et al.*, 2015; Harrell and Bradley, 2009). The response from professionals highlighted a lack of systematic exploration of all parameters in the literature and mixing concepts from production, quality, sustainability and safety, and led to a repeat of Steps 1.2 and 1.3 for multiple validations. In Step 1.4, there was conceptualisation, definition and redefinition of BIM, LC, LeanBIM, IPD, LeanIPD and GID. Step 1.5 encompasses multiple validations of concepts and GID strategy placements through semi-structured face-to-face interviews and focus group technique. Concepts and GID strategy placements were validated by ten professionals – six industry experts and four academic researchers – to qualify their relevance, correlation, logic and importance to the construction industry, specifically to CMPs. GID strategy placements encompass definition, benefits and integration between business units, geographic location, cultural difference, time zone leverages and analytics and cost comparison to identify the best locations for business units in GID. The experts selected for both semi-structured interviews and the focus group represented senior-level construction industry practitioners and academics based in Qatar. Experts were selected with more than 15 years of experience of successful delivery of CMPs, the level of seniority in experience, proficiency in project delivery methods, software familiarity, experience with various forms of contracts and knowledge of BIM, LC, LeanBIM, IPD, LeanIPD and GID. The participants have construction experience in many other countries, including, Qatar, Bahrain, Kuwait, Oman, KSA, Egypt, China, Germany, Spain, UK, Canada and the USA. The participants have awareness of LC, IPD and LeanIPD. This indicated that their responses shape a suitable idea of the LC, IPD and LeanIPD adoption in CMPs and its limitations.

3.2 Stage 2: Quantitative research methodology

Stage 2 encompasses a four-step quantitative research methodology. Step 2.1 comprises the design of a survey based on the literature review in Stage 1 of the research (Step 1.1). Table 3 lists barriers to integrating LeanIPD&GID on CMPs, whilst Table 4 structured FCs of LeanIPD&GID integration barriers. Step 2.2 involves the pilot survey and identification of respondents. Step 2.3 is the collection of data. Step 2.4 comprises analysis, evaluation and discussion of results.

3.2.1 Survey design. The questionnaire was arranged into two sections. The first section was used to collect professional data on participants such as areas of expertise, relevant experience, current position within their organisations and the size of projects that they are involved in. Additionally, the degree of awareness of BIM, LC practices and IPD principles, and the extent of implementation and integration of BIM, LC, LeanBIM, IPD and LeanIPD on the largest current project (Tanner, 2018; Taylor *et al.,* 2015). The second section reflected barriers in integration between LeanIPD&GID on CMPs that came from literature and interviews (Malhotra and Dash, 2019).

The 28 identified barriers to integrating LeanIPD&GID on CMPs, which were organised into six FCs (Farrell, 2016; Brown and Hauenstein, 2005; Fellows and Liu, 2015). Participants were asked to rate factors on a seven-point Likert scale: 0 = *very strongly disagree*, 1 = *strongly disagree*, 2 = *disagree*, 3 = *not sure or don't know*, 4 = *agree*, 5 = *strongly agree* and 6 = *very strongly agree*. Participants were given the opportunity to add any additional factors or remarks at end of the questionnaire. Scores are developed on the Likert scale, developed by the American Psychologist Rensis Likert (1903–1981). The seven-point Likert scale has been shown to be more accurate, easier to use and a better reflection of a respondent's true evaluation. In light of all these advantages, even when compared to higher-order items, seven-point items appear to be the best solution for questionnaires such as those used in perception evaluations. Whether academic and industry practitioners are developing a new summative scale, a satisfaction survey or a simple one-item post-test evaluation item, accordingly, research adopted to use a seven-point rather than a five-point scale (Farrell, 2016).

The sample size is important to obtain representative results. The population of this study comprised construction experts that have experience in BIM, LC, LeanBIM, IPD, LeanIPD and LeanIPD&GID on CMPs. Cochran's sample size formula for categorical data (Cochran, 2007) was used to establish the sample size that is seeking maximum possible responses within affordability.

$$n = \frac{(t^2) \times (p) \times (q)}{(d^2)} \tag{1}$$

where n is initial sample size estimate, t is confidence factor (1·96 for confidence level 0·95), p is population proportion (0·5), q is $(1 - p)$ and d is margin of error (0·1). Upon calculating [equation (1)] using assumed data ($t = 1{\cdot}96$, $p = 0{\cdot}5$, $q = 0{\cdot}5$, $d = 0{\cdot}1$) a sample size of 96 was determined.

The responses were obtained through an online questionnaire designed using "Google Forms" and distributed using various tools; i.e. e-mail, LinkedIn, WhatsApp and Microsoft teams. To ensure compliance with ethical protocols, a note preceded the questionnaire to provide guidance on the aims and objectives of the research, estimated duration to complete, to assure participants of their anonymity and confidentiality, and to advise that reply was not compulsory. A research ethics checklist was also used to ensure there was no breach of institutional codes. It was deemed there was no requirement to refer data collection instrument for board approval and informed consent was implied by participation. Requests were sent to 383 industry practitioners, and there were 230 (60%) replies from those with a variety of responsibilities such as owners, consultants, contractors and subcontractors organisations. Fellows and Liu (2015) indicated that "large number statistics require $n \geq 32$; and a usable data set of 100 responses for factor analysis;" given that 230 responses were received, it is asserted that results from the sample can be used to make valid inference back to the population. The requests were sent to construction industry practitioners in CMPs in Qatar, Gulf Cooperation Council (GCC) countries and the MENA region with good knowledge of BIM, LC, LeanBIM, IPD, LeanIPD and LeanIPD&GID (Farrell, 2016; Hasson *et al.,* 2000; Grisham, 2009).

3.2.2 Data analysis statistical tools. Several statistical tools and methods were used in analysing the data collected in course of the study. These include: Cronbach's alpha (α) reliability test; "Shapiro-Wilk" test of normality; mean score ranking and standard deviation (SD); inferential statistical tests such as analysis of variance (ANOVA), post hoc Tukey's tests and correlation analysis; percentage score analysis and factor analysis – principal component analysis (PCA) – and FCs significant (Farrell, 2016; Fellows and Liu, 2015; Field, 2018; Fang *et al.,* 2004; LeBreton and Senter, 2008). To accomplish research objectives IBM® SPSS® Statistics (SPSS) Version 27, Microsoft® Excel, Microsoft® Word software were used.

Reliability testing. The Cronbach's α reliability test is mainly used to verify internal consistency or reliability of construct of the questionnaire items under the adopted Likert scale of measurement. The range of Cronbach's α reliability coefficient is from 0 to 1, it implies that the larger the α-value, the better the reliability of the scale or the generated result (Cronbach, 1951; Nunnally and Bernstein, 1994; Hollander *et al.,* 2014; Field, 2018). Nunnally and Bernstein (1994) recommended a minimum Cronbach's α value of 0.70. Cronbach's α is computed from equation (2):

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} \sigma_i^2}{\sigma_X^2}\right) \tag{2}$$

where n is the number of variables, σ_i^2 is the score variations on each variable and σ_X^2 is the total variance of the overall score.

Mean score ranking and SD. The arithmetic mean is a measure of central tendency which indicates the average values of a set of figures [equation (3)]. Whilst SD [equation (4)] is a quantitative measure of the differences of each value from the mean and it is a measure of variability. A low SD indicates that the values are close to the mean, whereas a high SD implies the data points are spread out over a large range of values.

$$\overline{X} = \frac{\sum x}{n} \tag{3}$$

Equation

$$SD = \sqrt{\frac{\sum (x - \overline{X})^2}{n - 1}} \tag{4}$$

Equation where

$\overline{X}$ = mean score;
Σx = aggregated score of a set of values;
x = individual factor value;
n = number of values (this is, the number of respondents in this study); and
SD = standards deviation.

For the mean ranking, if two or more factors have the same mean value, the SD values are used to rank them; the factor with the lower SD value is ranked higher, however, if they have the same mean and SD value, they will have the same rank (Hollander *et al.*, 2014; Field, 2018).

ANOVA test. The ANOVA is an inferential statistical tool used to determine whether any statistically significant differences exist between the means of two or more independent data groups. Parametric ANOVAs requires normally distributed data points (Field, 2018). The post hoc Tukey's test is regarded as *a posteriori* test because it is only needed to confirm and reveal where the differences occurred between groups after an ANOVA analysis has identified statistically significant different groups.

Percentage score analysis. A score on a 0–100-point scale. The percentage score for questions and individual participants can be calculated according to (Farrell, 2016), for ease of interpretation. On the seven-point scale of 0 (very strongly disagree) to 6 (very strongly agree), very strongly disagree becomes 0% and very strongly agree becomes 100%. The intermediate points are 1 = approximately 16%, 2 = 33%, 3 = 50%, 4 = 67% and 5 = 84%. Similar principles are used in the multiple scoring scale. An overall low percentage score, thus indicates disagreement and a high score indicates agreement.

3.3 Factor analysis

The study adopted factor analysis to reduce a large number of the barrier factors to a relatively set of variables by investigating the interrelationships between the variables (Hair *et al.*, 2010). There are two types of factor analysis, PCA and Promax rotation method (Thompson, 2004); the PCA was used in this study. According to Field (2018), factor analysis – PCA – is a statistical technique used to identify the underlying clustered factors that define the relationships amongst sets of interrelated variables; and can be used to interpret "nonrelated clusters" of factors (Fang *et al.*, 2004) and explain complex concepts (Thompson, 2004). Meanwhile, before subjecting the 28 barriers to integration of LeanIPD&GID on CMPs to factor analysis, a Pearson correlation analysis was conducted as recommended by Field (2018) and Hair *et al.* (2010) who noted that these statistical method helps to eliminate the existence of any multiplier effects amongst the variables. Hence, the correlations of these factors were assessed. The PCA was conducted using the varimax rotation method (an orthogonal rotation method) on the 28 non-correlated barriers to integration of LeanIPD&GID on CMPs from a sample of 230 responses.

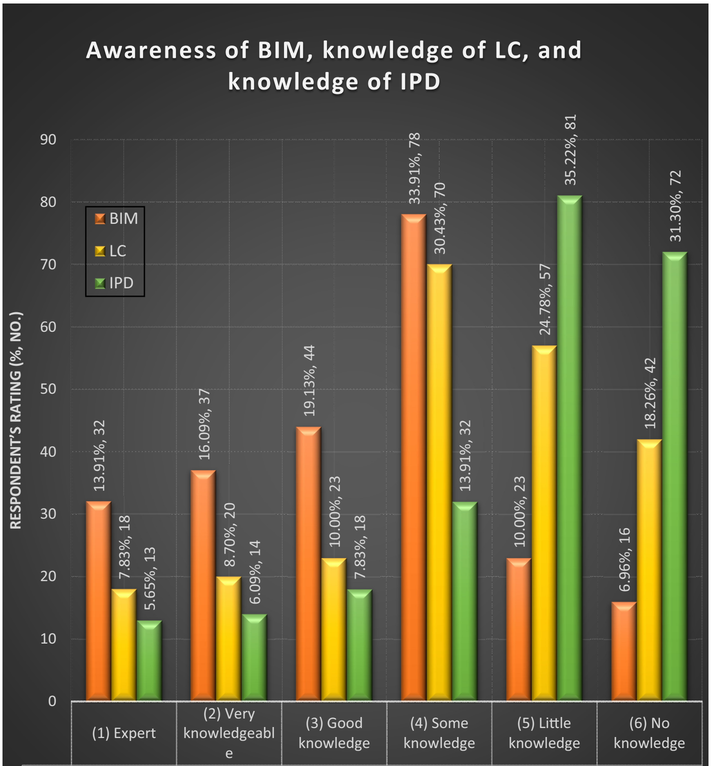
3.4 Summary of respondent demographics

This section describes and analyses the study's questionnaire survey form regarding the respondents' demographics. The respondents are from 23 countries working under diverse organisational types. The majority of survey participants are from consultant organisations (98, 42.61%), with the remaining respondents from contractors (72, 31.30%), clients (39, 16.96%) and academics (21, 9.23%). The diversity of the respondents' groups allows the capture of differing views from different perspectives. Moreover, on average, respondents have more than 15 years of working experience in construction. This result explains the fact that respondents not only have theoretical knowledge of operations in the AEC industry but also they have brought such knowledge into practice. Respondents were classified according to their career level: senior management (19, 8.26%), managers (56, 24.25%), senior-level resident engineers or client's consultants (97, 42.17%), mid-level engineering (35, 15.22%) and junior level engineering (23, 10.00%).

Meanwhile, respondents were asked about their level of awareness of BIM concepts and processes; the findings revealed the level of knowledge of BIM as follows: experts (32, 13.91%); very knowledgeable (37, 16.09%); good knowledge (44, 19.31%); some knowledge (78, 33.91%); little knowledge (23, 10.00%); and no knowledge (16, 6.96%). Figure 4 illustrates the awareness of BIM, knowledge of LC and knowledge of IPD. Respondents were asked about their level of awareness of LC practices; the findings revealed the level of knowledge of LC as follows: experts (18, 7.83%); very knowledgeable (20, 8.70%); good knowledge (23, 10.00%); some knowledge (70, 30.43%); little knowledge (57, 24.78%); and no knowledge (42, 18.26%). Respondents were asked about their level of awareness of the IPD; the findings revealed that the level of knowledge of IPD as follows: expert (13, 5.65%); very knowledgeable (14, 6.09%); good knowledge (18, 7.83%); some knowledge (32, 13.91%); little knowledge (81, 35.22%); and no knowledge (72, 31.30%). Results reflected that awareness of BIM in the MENA region is higher than LC and LC awareness is higher than IPD knowledge.

Respondents were also asked about the extent of implementation and integration of BIM, LC, LeanBIM, IPD and LeanIPD in their largest current project(s). Results reflected that BIM adoption in the MENA region is higher than LC, whilst LC is still taking its first steps whilst IPD is very slightly implemented in the MENA region. Results also revealed that LeanBIM is slightly integrated, whilst LeanIPD integration is almost not present. Figure 5 illustrates the extent of implementation/integration of BIM, LC, LeanBIM, IPD and LeanIPD on respondent's current project(s).

Respondents were classified according to the scale of their largest current project(s) to: megaproject(s) (>US$1bn) (186, 80.87%), large-scale project(s) (>500m to 1bn) (24, 10.43%), medium-scale project(s) (>100m to 500m) (10, 4.35%), small-scale project(s) (>50m to 100m) (5, 2.17%) and research or project(s) < 50m (5, 2.17%). The survey participants have considerable professional experience in the construction industry with (65) 28.26% of the respondents having more than 20 years working experience, the next (45) 19.57% of the respondents have between 16 to 20 years working experience, whilst (58) 25.22% of the respondents have between 11 to 15 years of experience, the next (47) 20.43% of the respondents have 5 to 10 years of experience and (15) 6.52% of the respondents (15) have less than 5 years of experience.

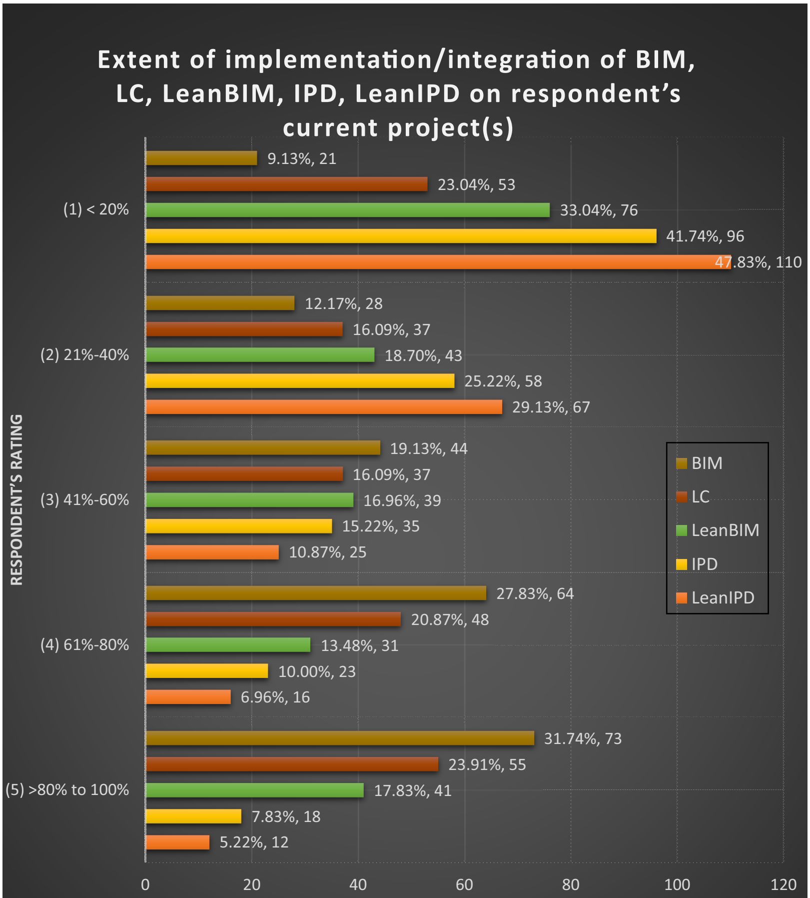


	(1) Expert	(2) Very knowledgeable	(3) Good knowledge	(4) Some knowledge	(5) Little knowledge	(6) No knowledge
BIM	32	37	44	78	23	16
LC	18	20	23	70	57	42
IPD	13	14	18	32	81	72

Figure 4.
Awareness of BIM, knowledge of LC and knowledge of IPD

Respondents were classified according to the type of the largest current project to: infrastructure (101, 43.91%), metro/light rail transit (95, 41.30%), building (24, 10.43%), industrial (4, 1.74%) and other types of projects (6, 2.61%). Respondents were classified according to the type of contract or procurement on their largest current project(s) to: lump sum contracts (26, 11.30%), measurement contracts (3, 1.30%), cost reimbursed contracts (3, 1.30%), design and build procurement (190, 82.61%) and other types of contracts (8, 3.48%).

The lead researcher consulted with industry professionals via semi-structured face-to-face interviews via video conference communications in the MENA region about GID implementation. The research concluded that some international AEC organisations working on megaproject are implementing GID through coordination with different branches to create BIM models and architectural, structural and MEP designs and taking advantages of the cost savings and improve project financials combining scalable costs and time zone benefits. International AEC organisations are taking advantage of carrying out designs in various branches in the MENA to distribute work and financial advantages. Also, international AEC organisations try to take advantage of cost benefits and time zone benefits in branches in Australia, India, the Philippines and GCC regions. For a decade, some giant local AEC organisations have started to create branches overseas for mainly



	(5) >80% to 100%	(4) 61%-80%	(3) 41%-60%	(2) 21%-40%	(1) < 20%
BIM	73	64	44	28	21
LC	55	48	37	37	53
LeanBIM	41	31	39	43	76
IPD	18	23	35	58	96
LeanIPD	12	16	25	67	110

NUMBER OF RESPONDENTS (NO = 230)

Figure 5. Extent of implementation/integration of BIM, LC, LeanBIM, IPD and LeanIPD on respondent's current project(s)

AutoCAD® drafting and later BIM production in the Philippines, Egypt and some extended locations in the GCC to attain cost savings. Research also revealed that attempts to take advantages of GID are still at their start and focus on cost-saving in BIM and production only, but does not yet reach implementation, nor integration between the three principles BIM, LC, LeanBIM, IPD and LeanIPD on CMPs.

4. Global integrated delivery transformative initiatives and future of work global initiatives

This section discusses GID strategy placements, FOW global initiatives proposed in this study.

4.1 Global integrated delivery strategy placements for LeanIPD&GID transformative initiatives

The research conducted semi-structural interviews and focus group techniques with industry professionals and academics to discuss pillars of GID strategy, GID strategy placements for LeanIPD&GID transformative initiatives and how to maximise benefits and tackle challenges. The research introduced proposed GID strategy placements which consist of 4 core foundations: GID basics, culture and language, tools and communication. Enterprise business solution (EBS) harmonises systems, processes and tools. EBS may establish a GID steering committee to manage the entire GID transformation processes. The strategy brings people, processes and technology together in harmony to improve IPD. The first GID strategy foundation is GID basics which invests heavily in work-sharing; workshare takes time and effort, that require establishing clear expectation, building relationships and encouraging and celebrating success. Culture and language are very crucial; organisations should work to overcome language barriers, understand office structures, respect holidays, culture and working hours of each LoB and establish a well-defined strategy and common practice. Tools are an important pillar in GID strategy; project stakeholders must agree on software and hardware as early as possible, uses collaborative tools, use or develop tools that help streamline processes and or establish project templates or Web-based applications. Communication is the fourth pillar of GID strategy and organisations should establish consistency, structured meetings, use visual communication between LoB via modern telecommunications, communicate clear and consistent instructions and create action lists and task owners; this could be facilitated by developing a dedicated GID Web-based application. Figure 6 demonstrates GID strategy placements.

Locations of GID centres and the geographic region or market sector that centres cover is a strategic decision; this decision should be an outcome of work between the GID Steering Committee and operation leads. There are three main considerations to select GID centres as follows: the market sector and availability of talent in the centre, leverage of time zones to

Figure 6.
GID strategy placements

extend working hours with reasonable overlaps between GID centres and other business units and financial consideration to combine scalable solutions for competitive pricing. GID Steering Committees should balance these three items, which could be described as the "Project Management Triangle" or "Triple Constraint" or the "Iron Triangle" (PMI, 2017). Research through multiple interviews with industry professionals validated the GID strategy and discussed the best location in the globe for business centres that balances the triple constraints. Research puts Egypt and India at the heart of GID. This research divided the globe into five lead regions as follows: America, Europe, Asia, MENA and Australia and New Zealand. The research proposes five GID centres as the best fit that balance triple constrains thus: Egypt, India, Poland, Malaysia and the Philippines. There may be other locations on the globe that may balance triple constraints, so each AEC organisation should investigate possible options. Egypt should be at the heart of the GID strategy of any international AEC organisation due to its strategic location at the heart of the globe, availability of qualified talent, other resources and competitive cost compared to the Americas, Australia and Europe. Egypt is the largest country in the MENA due to its political weight and population of more than 100 million people. Egypt has an excellent record of achievement in CMPs. Proposed GID centres locations in Egypt could be Cairo, Alexandria, Port Said, Mansoura, Minya and Aswan. India is the second-most populous country in the world and the seventh-largest country by land area. India GID centres could serve the Asia region, with the proposed locations in India being New Delhi, Mumbai, Hyderabad, Kolkata, Pune and Bangalore. Poland could lead Europe; GID centres could be in Krakow (traditional know as Cracow), Warsaw and Łódź (written in English as Lodz). Malaysia in southeast Asia could have a GID centre in the national capital Kuala Lumpur. A Philippines GID centre could be in Manila. Figure 7 demonstrates proposed global delivery centres (GDC).

4.2 Future of work global initiatives

As the AEC industry continue its journey of transformation and growth, during the COVID-19 pandemic, there is a reflection point to innovate and create new ways of working. There are significant changes for enhancements of employees' experience, prioritising their professional development, well-being and benefits. During the COVID-19, many organisations have made substantial changes to how people live and work. However, before

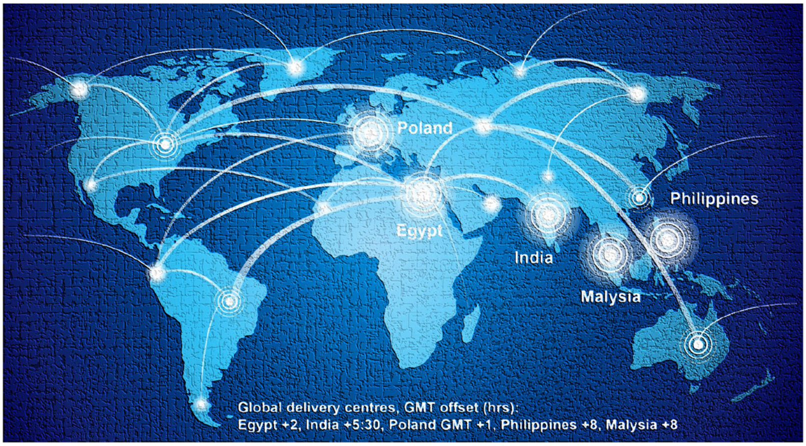


Figure 7. Proposed GDC locations [vector artwork design using Adobe® Illustrator software]

that, experts understood the importance of technological advancements and globalisation and the impacts regarding the evolution in working systems. The FOW global initiatives is transforming the behaviours, technologies and physical and virtual spaces as workplaces that influence working methods, creating modern, flexible work platforms tailored to people's unique needs. To attract and retain world-class talent, the AEC industry must provide flexibility: this includes a choice-based, work-anywhere approach in addition to dynamic work environments that encourage and enable collaboration and connection. The FOW rests on a foundation of three elements – culture, place and tools. Each of these elements is vital to creating effective work environments as follows:

- Culture of caring and inclusion is a foundation, organisation can celebrate the differences that drive collective strength. There is no limit to who you can be and what we can achieve.
- Place determines identity, imbues culture and connects people. The FOW is people-centric and requires places that prioritise work activities that are group focussed.
- Tools workstream is dedicated to exploring and defining the digital infrastructure to allow us to create, capture, track and deliver solutions across our markets and lines of business to support an increasingly distributed workforce.

People-centric work platforms fully embrace the culture of inclusivity by giving people the flexibility to choose how and where they want to work based on their needs, teams and clients. Traditional offices were "invented" to solve a problem: organisations needed to host several people in one place to enable both easy communication and access to documents and other information. Today, the technology effectively addresses most of those needs, so it is time for the purpose and function of offices to evolve along with that. Adopting a combination of physical hardware and new interactive virtual platforms will allow people to engage across organisations as never before and enhance the entire employee experience. These tools will improve the ability to meaningfully engage with colleagues and clients whilst helping to be more productive. This also reinforces the need to effectively store and share knowledge across the enterprise. Figure 8 represents employee "work modes; distributed by location and "the destinations" where it is a physical and virtual way to work.

In the past, people were often dedicated to individual workstations; whilst post-COVID-19 thinking shifting the use of space to support groups and teams at a variety of workstations that will be technology-enabled. This transformation journey will take several years as the AEC industry progresses from traditional systems to FOW systems and procedures. To achieve the aim of the research; the lead researchers consulted with various teams working in the AEC industry such as architects, disciplines engineers and practitioners, planners, IT specialists, focus groups across lines businesses and corporates functions. FOW concept divided the type of work in AEC organisations into five "work modes" ranges from active to focussed. The five "work modes" are structured as follows:

(1) *Learning/mentoring*. Group or one on one interactions, where employee training or learning takes place.
(2) *Group/team*. Meeting place for group work, idea sharing and presentations.
(3) *Social interaction*. Acts as a hub for both employees and the surrounding community fostering social connections.
(4) *Decompress*. Where an employee can unplug, unwind and seek respite from work.
(5) *Focussed*. Typically, individual heads-down tasks, where independent and deep work occurs.

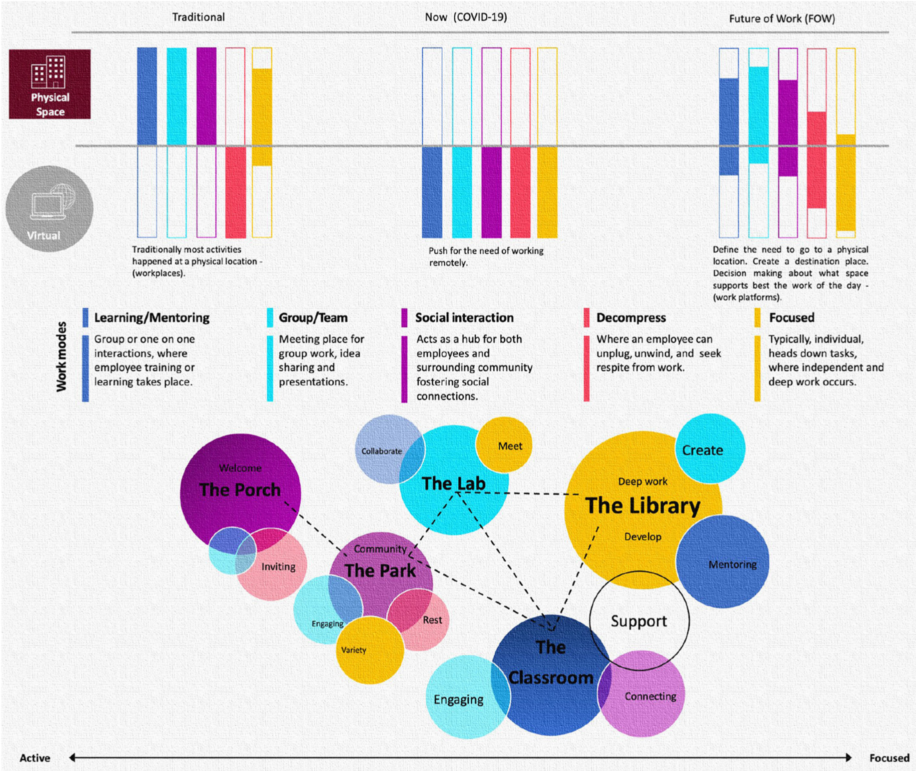


Figure 8.
The destinations and "work modes" distributed by locations

FOW concept designated some key office "destinations" associated with the five "work modes" – the porch, the park, the classroom, the lab and the library. The porch is a welcoming, inviting and safe landing point. A park is a place where you connect and socialise. The classroom is for teaching, learning, mentoring and connecting. A lab is a place for innovation, collaboration and ideation. Whilst the library is for heads down and individual work. The destinations are a range of settings and choice-based environment, whilst the "work modes" no longer need to be tied to a physical place and space type. The "destinations" are places that are furnished with appropriate furniture to accommodate different "work modes", such as power and Wi-Fi connectivity. There should be storytelling and brand integration in each space and modular components for flexibility, speed and sustainability. Acoustic and absorptive materials should be used and other materials and products that support sustainability goals. Tools are required to connect people virtually and physically to collaborate, innovate, learn and engage. Tools will serve people and places, such as upon entering "the porch" a contactless touch identification allows users to enter the space without human contact. "The park" could be equipped with virtual reality capabilities, broadcasts large gathering such as "town hall meetings". Whilst "the lab" will be equipped with tools that allow BIM, 3D design, full-scale virtual modelling supports real-time drawing, sharing, design and manufacturing and computer programming and coding for robotic construction arms.

Furniture will offer a range of setting and choice-base environment. A conceptual floor plan for focus work such as "the library" may be furnished with a combination of community tables with monitors incorporated, semi-open booths with monitors, mobile tables with monitors and task chairs, height adjustable desks and task chairs and individual focus desks. Collaborative work space floor plans may be furnished with a combination of communal tables with benches and chairs, semi-open 4 persons railway carriage booths, enclosed co-creations, full enclosed 1–2 person pods, semi-open 3–4 person technology-enabled, movable touch screen monitors and banquette seating. The comfort of employees is essential so specific considerations to office location is important, such as accessibility, gym/shower facilities, proximity to clients, outdoor space, cafes, restaurants, gender-neutral washrooms, lounges, parking and proximity to +15 walkway network (pedestrian skywalk systems, the system is so named because the skywalks are approximately 15 feet [approximately 4.5 m] above street level).

5. Research analysis, findings and discussion of results

This section discusses the results of the data collected via the questionnaire surveys and the findings of the statistical tools used in the study.

5.1 Reliability and normality testing

"Cronbach's α" reliability test was engaged in assessing the questionnaire tools and scale reliability to confirm that it gauges the accurate hypothesis and assesses its internal consistency. The Cronbach's α value for the survey was 0.958 and the scale is therefore found to be highly internally reliable. Furthermore, the "Shapiro-Wilk" test for normality was undertaken to work out the distribution of the data set and whether there is a normal distribution or not. The significance value (*p-value*) of the Shapiro-Wilk test is greater than 0.05; the data complies with the normal distribution.

5.2 Descriptive statistical tests and percentage score analysis

Percentage score indicates a score on a 0–100-point scale. The percentage score for questions and individual participants are calculated. Barrier 19 has an overall mean score of 5.24 given a range of 0 to 6. The percentage score values of "all respondents" was calculated for all barriers and included in Table 5; it ranges from 57.75% to 85.14%. The most significant barriers resulted from percentage score analysis matches the outcomes of the method of ranking the means used earlier. For example, barrier 19 overall percentage score is 85.14% as the most significant barrier whilst barrier 4 overall percentage score is 57.75% as the least significant barrier.

Mean scores – x "x-bar" or μ "mu" – was used as a basis of ranking the 28 LeanIPD barriers and if two or more elements had an identical mean score μ, the SD – σ "Greek letter Sigma" – is used in the ranking. Descriptive analysis of "variance" – σ^2 "Greek letter Sigma Squared" – was also considered. Mean score, μ, values of the survey for the 28 barriers to integration of LeanIPD&GID on CMPs are indicated in Table 3 and categorised in FCs in Table 4. For the 28 identified barriers to integration of LeanIPD&GID on CMPs, the overall mean values range from 4.11 to 4.99 given a range of 0 to 6. Table 6 illustrates the significance of barriers to integration of LeanIPD&GID on CMPs ranked in descending order. Results show that "all respondents" rated the most significant challenges as follows:

- B19: Lack of mandatory BIM and LC industry standards and regulations by the governments.
- B20: Lack of involvement and support of the governments.
- B16: High cost of BIM software licenses.

Lean IPD&GID	Consultants		Contractors		Clients		Academics		Overall					
barriers	μ	R	μ	R	μ	R	μ	R	μ	σ	% score	R	F	Sig
B1	3.82	28	4.22	27	3.96	27	3.80	26	3.97	1.285	76.01	27	.971	0.119
B2	4.64	11	4.95	9	4.71	9	4.86	7	4.77	1.046	69.28	11	1.885	0.133
B3	4.24	18	4.65	18	4.37	18	4.53	14	4.42	1.149	80.07	18	2.601	0.053
B4	3.93	26	3.93	28	3.56	27	3.51	28	3.83	1.324	57.75	28	1.726	0.162
B5	4.91	4	5.08	2	4.86	3	5.10	3	4.97	0.958	65.00	4	1.025	0.382
B6	4.05	25	4.55	23	3.98	25	4.12	25	4.20	1.115	61.59	25	4.979	0.002
B7	3.92	27	4.32	26	3.91	26	3.71	27	4.03	1.230	70.51	26	3.067	0.029
B8	4.33	16	4.69	16	4.48	16	4.49	14	4.48	1.165	75.22	16	1.829	0.143
B9	4.61	12	4.94	9	4.59	13	4.77	9	4.72	1.064	66.01	12	2.189	0.090
B10	4.11	23	4.55	25	4.09	24	4.20	24	4.25	1.095	71.01	24	3.658	0.013
B11	4.38	15	4.71	15	4.44	17	4.53	14	4.51	1.141	67.68	15	1.692	0.170
B12	4.15	22	4.59	22	4.26	22	4.49	22	4.34	1.100	71.67	22	3.518	0.016
B13	4.39	14	4.75	14	4.55	14	4.53	14	4.54	1.114	68.41	14	1.986	0.117
B14	4.18	20	4.62	20	4.33	20	4.53	14	4.37	1.120	76.30	20	3.188	0.025
B15	4.70	10	4.93	11	4.71	9	4.82	7	4.78	1.024	82.17	10	1.094	0.353
B16	5.07	3	5.17	2	4.99	3	5.06	3	5.08	0.828	66.74	3	0.588	0.623
B17	4.13	23	4.57	23	4.16	23	4.33	23	4.29	1.096	81.52	23	3.519	0.016
B18	4.99	6	5.17	5	4.96	7	5.10	2	5.05	0.862	83.62	5	1.046	0.373
B19	5.27	1	5.18	2	5.23	1	5.26	1	5.24	0.621	85.14	1	0.466	0.707
B20	5.17	2	5.21	1	5.07	2	5.06	5	5.16	0.753	76.52	2	0.551	0.648
B21	4.74	9	4.93	11	4.71	9	4.73	11	4.79	1.010	78.55	9	0.879	0.453
B22	4.94	5	4.98	6	4.79	5	4.65	6	4.89	1.047	70.22	6	0.936	0.424
B23	4.29	17	4.68	17	4.51	14	4.53	14	4.47	1.146	77.90	17	2.316	0.077
B24	4.80	8	5.01	8	4.79	8	4.77	11	4.86	0.963	74.49	8	1.139	0.334
B25	4.54	13	4.92	11	4.68	9	4.61	13	4.69	1.072	68.91	13	2.433	0.066
B26	4.22	19	4.63	19	4.37	18	4.53	14	4.40	1.135	68.33	19	2.722	0.045
B27	4.18	20	4.62	20	4.29	21	4.57	14	4.37	1.127	79.49	21	3.354	0.020
B28	4.91	7	5.06	6	4.90	6	4.77	9	4.95	0.946	76.01	7	0.865	0.460

Average percentage scoring = 72.52

Notes: μ = mean; R = rank; σ = standard deviation; Sig = significance "p"; F = ANOVA F test "group means significance"

Table 5. Barriers to integrating LeanIPD&GID on CMPs: inter-group comparison

- B5: Resistance of industry to change from traditional working practices.
- B18: High initial investment in sta training costs of BIM.

5.3 Inferential statistical tests based on organisational setup

To further investigate differences in perception of respondents (consultants, contractors, clients and academics), an ANOVA was used to analyse the 28 identified barriers to integrating LeanIPD&GID on CMPs. Siegel and Castellan (1988) recommended that a post hoc Tukey's test be conducted on factors that are significant at $p < 0.05$.

The ANOVA analysis conducted on the results at the significance level (p) ≤ 5% showed some significant agreement in the opinions of respondents from diverse organisational setups on all factors such as "B26: low level of research in industry and academia" [F(26, 229) = 3.658 p = 0.020]; "B10: immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption" [F(10, 229) = 1.692 p = 0.013]; "B6: societal reluctance to change from traditional values or cultures" [F(6, 229) = 4.979 p = 0.002]; "B14: user-unfriendliness of BIM analysis software programs" [F(14, 229) = 3.188 p = 0.025]; "B12: fragmented nature of

Code	Significance of barriers to integrating LeanIPD&GID	Ranking
B19	Lack of mandatory BIM and LC industry standards and regulations by governments	1
B20	Lack of involvement and support of governments	2
B16	High costs of BIM software licenses	3
B5	Resistance of industry to change from traditional working practices	4
B18	High initial investment in sta training costs of BIM	5
B22	High training and implementation costs and time of BIM	6
B28	Shortage of cross-field specialists in BIM, LC and LeanBIM	7
B24	Lack of senior management commitment and clients demand	8
B21	Lack of supporting LC analysis tools and software	9
B15	Lack of a well-established BIM, LC and LeanBIM workflows	10
B2	Lack of legal framework, and contract uncertainties of BIM and LC	11
B9	Organisational challenges, project strategies and policies	12
B25	Difficulty in adapting to BIM technologies and processes	13
B13	Negative attitudes towards data sharing	14
B11	Lack of awareness and collaboration amongst project stakeholders	15
B8	Lack of initiatives and hesitance on future investments	16
B23	Intellectual properties rights, associated disputed and risks	17
B3	Incompatibility issues between various software packages	18
B26	Low level of research in industry and academia	19
B14	User-unfriendliness of BIM analysis software programmes	20
B27	Difficulty in allocating and sharing LC, BIM and LeanBIM risks	21
B12	Fragmented nature of construction industry	22
B17	Ambiguous economic benefits	23
B10	Immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption	24
B6	Societal reluctance to change from traditional values or cultures	25
B7	Lack of insurance applicable to BIM, LC and LeanBIM adoption	26
B1	Increased workload for model development	27
B4	Varied market readiness across organisations and geographic locations	28

Table 6. Significance of barriers to integration of LeanIPD&GID on CMPs ranked in descending order

construction industry" [$F(12, 229) = 3.518$ $p = 0.016$] amongst others (Table 5). Moreover, based on the post hoc Tukey's test evaluation of significant barriers, 17 barriers were found to be more important ($p > 0.05$). These include "B11: lack of awareness and collaboration amongst project stakeholders" with a moderate significance ($p = 0.170$) of which the respondents from the private clients (M = 4.25, SD = 1.141).

5.4 Factor analysis for factor clusters of LeanIPD&GID integration barriers

The results of the factor analysis are shown in Table 7, whilst the column "factor loading" illustrates the total variance explained by each factor. Field (2018) recommended that the sample size must be considered sufficient in the ratio of 1:5 (number of variables:sample size) which the current study fulfilled. That is, 28 barrier factors multiplied by 5 samples required for each factor = at least 140 samples needed to proceed with the factor analysis. Kaiser–Meyer–Olkin (KMO) tests for sampling adequacy and Bartlett's test of sphericity (BTS) was used to examine the appropriateness of PCA for factor extraction (Field, 2018; Fang *et al.*, 2004).

The KMO value for the study's factor analysis is 0.926, which shows an "excellent" degree of common variance (Field, 2018; Green and Salkind, 2016; Siegel and Castellan,1988) and above the acceptable threshold of 0.50 (Field, 2018). More so, according to Field (2018) and Malhotra and Dash (2019), a KMO value close to 1 indicates that a compact pattern of correlations and that the PCA will generate distinct and reliable clusters. The BTS analyses

Code	FCs of barriers to integrating LeanIPD&GID	Meanloading	Factor loading	Eigenvalue	Percentage of variance explained	Cumulative percentage of variance explained
FC1	*Technical-related barriers*	4.53		13.724	49.015	49.015
B1	Increased workload for model development		0.655			
B3	Incompatibility issues between various software packages		0.879			
B14	User-unfriendliness of BIM analysis software programmes		0.909			
B16	High cost of BIM software licenses		0.35			
B21	Lack of supporting LC analysis tools and software		0.672			
FC2	*Attitude-related barriers*	4.62		5.335	19.055	68.07
B6	Societal reluctance to change from traditional values or culture		0.849			
B11	Lack of awareness and collaboration amongst project stakeholders		0.866			
B20	Lack of involvement and support of governments		0.418			
FC3	*Education and knowledge related barriers*	4.70		2.003	7.154	75.224
B15	Lack of a well-established BIM, LC and LeanBIM workflows		0.891			
B25	Difficulty in adapting to BIM technology and processes		0.852			
B26	Low level of research in industry and academia		0.734			
B28	Shortage of cross-field specialists in BIM, LC and LeanBIM		0.76			
FC4	*Legal barriers*	4.52		1.343	4.798	80.022
B2	Lack of legal framework, and contract uncertainties of BIM and LC		0.649			
B7	Lack of insurance applicable to BIM, LC and LeanBIM adoption		0.758			
B10	Immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption		0.897			
B19	Lack of mandatory BIM and LC industry standards and regulations by governments		0.135			
B23	Intellectual properties rights, associated disputed and risks		0.848			
B27	Difficulty in allocating and sharing LC, BIM and LeanBIM risks		0.919			
FC5	*Project objectives related barriers*	4.65		0.989	4.798	83.553
B8	Lack of initiative and hesitance on future investments		0.859			
B9	Organisational challenges, project strategy and policy		0.854			
B13	Negative attitude towards data sharing		0.913			

(*continued*)

Table 7. Factor structure for the PCA analysis of barriers to integration of LeanIPD&GID on CMPs

Code	FCs of barriers to integrating LeanIPD&GID	Mean	Factor loading	Eigenvalue	Percentage of variance explained	Cumulative percentage of variance explained
B24	Lack of senior management commitment and clients demand		0.664			
FC6	*Market-related barriers*	4.56		0.652	2.329	85.882
B4	Varied market readiness across organisations and geographic locations		0.365			
B5	Resistance of industry to change from traditional working practices		0.803			
B12	Fragmented nature of construction industry		0.679			
B17	Ambiguous economic benefits		0.66			
B18	High initial investment in sta training costs of BIM		0.758			
B22	High training and implementation cost and time of BIM		0.781			

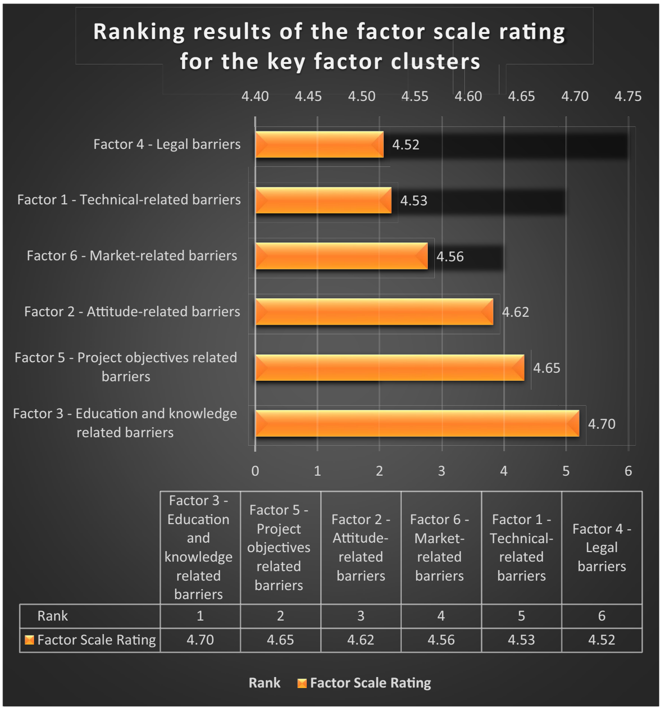
Table 7.

revealed a substantial test statistic value (Chi-square = 9304.945) and a small significance value ($p = 0.000$, degrees of freedom (df) = 378) which per Field (2018) implies that the correlation matrix is not an identity matrix. Therefore, as the various requirements needed to proceed with a factor analysis have been met, the PCA can be applied in this study for further investigation and discussion. This ensures the research can be conducted with better reliability and confidence. Six underlying clusters factors were extracted using PCA which represent 85.882% of the total variance in responses (Table 7) which is above the minimum threshold of 60% (Hair *et al.*, 2010; Malhotra and Dash, 2019).

The 28 barriers to integration of LeanIPD&GID on CMPs are represented in one of the 6 underlying grouped factors and all the factor loadings of each barrier factors are close to 0.5 or higher as suggested by Malhotra and Dash (2019). According to Hair *et al.* (2010), the higher the value of the factor loading of an individual factor (which is a maximum of 1.0), the higher the significance of the factor to the underlying clustered factors. The factor loading values also reflect how each factor contributes to its underlying clustered factors (Hair *et al.*, 2010; Fang *et al.*, 2004). The findings reveal a consistent and reliable factor loading and interpretation of the extracted individual factor.

5.5 Discussion of key factor clusters after factor analysis

The FCs are analysed in Figure 9 and ranked in descending order of significance towards interpreting the individual factors linked to them. An identifiable and collective label is attached to each grouped factor of high correlation coefficients; which are themselves a cluster of individual factors. The FCs are ranked using their factor scale rating. The factor scale rating is the ratio of the mean of individual factors within a cluster divided by the number of factors in the cluster. Discussion of the key FCs focusses on the most significant FCs. Also, one of the purposes of using the factor scale rating analysis is to highlight more significant FCs with relatively higher rating values for further discussion. The FCs representing the relationship amongst the underlying factors are designated with identifiable and collective labels to aid their description (Thompson, 2004). A metric known as factor scale rating was used to rank the FCs in descending order of relevance (Hair *et al.*, 2010). The factor scale rating (Table 7) adds up the mean scores of each underlying factor of



	Factor 3 - Education and knowledge related barriers	Factor 5 - Project objectives related barriers	Factor 2 - Attitude-related barriers	Factor 6 - Market-related barriers	Factor 1 - Technical-related barriers	Factor 4 - Legal barriers
Rank	1	2	3	4	5	6
Factor Scale Rating	4.70	4.65	4.62	4.56	4.53	4.52

Figure 9.
Factor scale rating ranking for the FCs of barriers to integration of LeanIPD&GID on CMPs

each cluster and divides the total mean score by the number of the underlying factor (Thompson, 2004).

5.5.1 Education and knowledge-related barriers. FC 3, this cluster consisting of four barriers to integration of LeanIPD&GID on CMPs (B15, B25, B26 and B28), is the highest-rated clustered factor with a factor scale rating of M = 4.70. The cluster is related to the experience and knowledge of construction organisation staff, the steep learning curve, inadequate understanding of smart, sustainable practices processes and the shortage of cross-field specialists in smart, sustainable practices. Whilst, Evans and Farrell (2020) rated the "education, knowledge and learning" class of barriers as the third class of significance after "legal" and "technical and software financing". Gu and London (2010) observed through their study that little or no attention has been placed on the training of construction professionals to improve their understanding and skills in the adoption of new technologies. Hence, professional bodies and construction firms should collaborate to improve the skillsets and capacity of their members and staff in smart, sustainable practices. Aibinu and Venkatesh (2014) noted that rapid technological change has reduced the ability of the workforce to adapt and that despite the benefits of these concepts, the current skills shortage in the industry has reduced the potential positive impact on construction processes.

Factors in this cluster are related to insufficient experience and lack of knowledge on approaches of BIM and LC and IPD, whereas a barrier factor relates to the lack of experience and specialism in software and technologies used in the simulation of LC parameters and creation of BIM models. Hence, there is a demand for corporate organisations and professionals to increase the aptitude, capability and quality of LC, BIM and IPD industry practitioners in the construction industry. Also, the establishment of capacity development and opportunity for skill programmes, such as seminars, extensive training and workshops, where industry practitioners can share experience and information in these two initiatives to assist in the mitigation of obstacles. Moreover, the government can support this initiative by training its staff in construction-related departments and parastatals and providing financial subsidies to private firms in the training of their workforce.

5.5.2 Project objectives-related barriers. FC 5, comprises of four barriers to integration of LeanIPD&GID on CMPs with a factor scale rating (B8, B9, B13 and B24) of M = 4.65. Project objectives-related factors are related to construction firms' hesitance to plan for future investments, challenges related to organisational policies and strategies, fragmented nature of the industry and the difficulties in implementing BIM and LC in CMPs. The BIM concepts, LC and IPD principles, despite its revolutionary effects on the built environment still requires the integration of human efforts and strategies which when lacking, can amplify its non-implementation in construction projects. The lack of investment in most organisations has affected their adoption of BIM, LC and IPD practices. Evans *et al.* (2020a, 2020b) addressed the uncollaborative environment nature of the industry and ineffective organisation strategies that have hindered the implementation of these concepts. Olawumi *et al.* (2018) revealed the lack of investment in most organisations, which has affected the adoption of smart, sustainable practices. Antón and Díaz (2014) described the construction industry as a project-based sector. The availability of BIM, LC and IPD related software and data is pivotal to the decision-making process of project stakeholders; whilst there is a need for the government and professional bodies to subsidise the cost of procuring related BIM, LC and IPD practices software to aid its adoption. Overall, the need for the development of sound and effective strategies by construction firms and stakeholders towards the adoption of smart, sustainable practices cannot be over emphasised.

5.5.3 Attitude-related barriers. FC 2 comprises of three barriers to integration of LeanIPD&GID on CMPs with a factor scale rating (B6, B11 and B20) of M = 4.62. Attitude-related barriers are related to stakeholder attitude towards the adoption and integration of BIM, LC and IPD practices. The resistance to change of construction organisations and key stakeholders in the built environment is a key impediment to the implementation of innovative concepts such as BIM, LC and IPD in CMPs. This has led to a disproportionate level of implementation and integration of BIM, LC and IPD practices in CMPs. Resistance to change has negatively impacted the skills, knowledge and experience of project stakeholders as regard BIM, LC and IPD practices and its adoption in a built environment. Hence, for the built environment to experience a full implementation of these concepts in CMPs, a significant change in stakeholders' attitude and perception is needed to increase the uptake of BIM, LC and IPD practices. Despite numerous advantages of implementing BIM and adopting LC in the built environment, there has been too little development in its implementation in the MENA region. It is essential to bear in mind that a lack of senior management and client commitment and the perpetual barrier of resistance to change still plays an important role in hindering the integration of BIM, LC and IPD initiatives. Therefore, this research recommends that construction key stakeholders such as senior management, clients, main contractors and engineering firms diminish their resistance and adopt dynamic and positive attitudes to change in the construction industry. Owners, clients and real-estate developers of CMPs are advised to be proactive in adopting BIM and LC approaches in their projects to improve LeanBIM synergy and to integrate LeanBIM with IPD towards GID.

6. Conclusion

The AEC industry encounters substantial risks and challenges in its evolution towards sustainable development. International businesses, multinational AEC organisations, technical professional, architecture, engineering, construction, project and portfolio management organisations face global connectivity challenges between business units, especially during the COVID-19 pandemic, to manage CMPs. That raises the need to manage global connectivity as a main strategic goal of global organisations. This research investigates barriers to integrating LC practices and IPD on CMPs towards the GID transformative initiatives in contemporary multinational AEC organisations. Although BIM, LC and IPD principles are being increasingly adopted in the USA and other parts of the world, the integration of LeanIPD&GID on CMPs in the MENA region has not begun. Despite the numerous advantages that integration of BIM, LC, LeanBIM, IPD, LeanIPD and LeanIPD&GID provides, no sign of its implementation nor integration can be identified in the MENA region. Moreover, no extensive research has been completed in this region. A total of 28 barriers to integration of LeanIPD&GID on CMPs were identified via a desktop literature review and factors outlined in a questionnaire which was ranked by 230 respondents from 23 countries who have direct and extensive experience in the construction industry. The survey participants came from diverse professional disciplines and organisational backgrounds, which lends credence to the data collected. The study conducted a comparative assessment of perceptions of study participants based on their organisational backgrounds towards establishing patterns of difference.

This research introduced GID as transformative initiatives in contemporary organisations and FOW global initiatives. The research defined, redefined and conceptualised concepts have been introduced in this research from an integrative perspective, such as GID, IPD, LC practices, BIM, LeanBIM, LeanIPD, LeanIPD&GID, governance of portfolio, programmes, projects, CMPs and stakeholders. The most significant barriers to integration of LeanIPD&GID on CMPs were "lack of mandatory BIM and LC industry standards and regulations by governments", "lack of involvement and support of governments", "high costs of BIM software licenses", "resistance of industry to change from traditional working practices" and "high initial investment in sta training costs of BIM". Whilst least significant critical barriers were "varied market readiness across organisations and geographic locations", "increased workload for model development", "lack of insurance applicable to BIM, LC and LeanBIM adoption", "societal reluctance to change from traditional values or cultures", and "immature dispute resolution mechanisms for BIM, LC and LeanBIM adoption". Research then clustered barriers to integration of LeanIPD&GID on CMPs to six-FCs. PCA concluded that the most significant FCs were education and knowledge-related barriers, project objectives-related barriers and attitude-related barriers.

A profound research finding is that awareness of BIM in the MENA region is higher than LC and LC awareness is higher than IPD knowledge. BIM adoption in the MENA region is higher than LC, whilst LC is still taking its first steps. IPD is only slightly implemented in the MENA region. LeanBIM is slightly integrated, whilst LeanIPD integration is almost not present. The research concludes that some international AEC organisations working on megaproject are partially implementing GID through coordination with different branches to create BIM models and discipline designs such as architecture, structural and MEP designs and taking advantages of the cost savings and improve project financials combining scalable costs and time zone benefits. International AEC organisations carry out the design in various branches in the MENA to distribute work and financial advantages. International AEC organisations use branches in Australia, India, the Philippines and the GCC regions. Another profound research finding is that for a decade, some giant local AEC organisations have started to create branches overseas for mainly AutoCAD® drafting and later BIM production in the Philippines, Egypt and extended locations in the GCC. The research revealed that attempts to take advantage of GID are still at the early stages of development and focus on cost-saving in BIM and production only, but do not yet reach implementation, nor integration between the three principles BIM, LC, LeanBIM, IPD and LeanIPD on CMPs.

7. Recommendations

Accordingly, the research comes to the following recommendations to industry key stakeholders, clients, governments and key decision makers to tackle barriers to integration of LeanIPD&GID on CMPs:

- Governments to provide and issue incentives, policies, regulations or legal frameworks to encourage the AEC industry to adopt and integrate BIM, LC, IPD towards LeanIPD&GID;
- Governments raise client awareness of benefits and strategies to integrate LeanIPD towards GID amongst key stakeholders;
- Governments and institutions to raise awareness to organisation's senior management and clients about commitment to an IPD, LeanIPD, approaches and GID, LeanIPD&GID initiatives;
- Governments and key industry stakeholders to raise construction industry awareness about the advantages of the integration of LeanIPD&GID to minimise the resistance of industry to change from traditional procurement to LeanIPD&GID;
- Governments to adopt the integration of LeanIPD&GID on CMPs and adopt pilot projects in each country to provide successful examples of the benefits gained through the adoption of LeanIPD; and
- Governments to provide training programmes, technologies, infrastructure and resources to enhance the technical skills of architects, design and construction managers for managing challenges of integrating LeanIPD&GID on CMPs.

The research identified the current underlying gap of literature of the integrative nature of adoption of BIM, LC and IPD concepts and integration of LeanBIM, LeanIPD on CMPs. This research introduced GID as transformative initiatives and FOW global initiatives in contemporary organisations and investigated integration between LeanIPD on CMPs towards GID transformative initiatives in contemporary multinational AEC organisations. More research in this domain is still required, and a framework for managing barriers to integrating LeanIPD&GID on CMPs is essential to create systems in which continuous improvement can be achieved in a well-organised and efficient way and conceptual combination developed to promote performance improvements. The research addresses barriers to integration of LeanIPD&GID on CMPs in the MENA region as one area and focussed on a comparison between inter groups of contractual parties, i.e. consultants, contractors, clients and academics. Academics may carry out studies and divide the MENA region to more manageable divisions such as country by country or to GCC countries, Egypt and North Africa or carrying out comparative studies of challenges integration of LeanIPD&GID on CMPs in GCC and Egypt.

The GID transformative initiatives and FOW global initiatives are essential elements of the LeanIPD&GID concept. Egypt should be at the heart of the GID strategies of international AEC organisations. The construction industry in Egypt has had long periods of growth due to stability, development, comprehensive renaissance, safety and security.

Egypt is characterised by talented experience in many industries and trades and has potential for stable investments. Considering GID transformation, due to its strategic geographic location, availability of talents and resources, especially AEC engineering and a good record of achievement in CMPs staring from the Pyramids of Giza and the giant and impressive temples of Medinet Habu, Kom Ombo, Philae, Edfu, Seti I, Hatshepsut, Luxor Abu Simble, Karnak to the contemporary CMPs of the Suez Canal expansion, Dabaa Nuclear Power Plant, Bernice Military Base, Concentrated Solar Power plants and many other megaprojects. For the reasons mentioned above, this research recommends that Egypt is placed at the heart of the GID transformative initiatives.

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