PROSPECTS FOR INTEGRATED DESIGN PROCESS (IDP) IN IMPLEMENTING CONSTRUCTION WASTE PREVENTION (CWP) PRACTICES

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This study presents a preliminary proposal for the use of Integrated Design Process (IDP) at the design stage of construction projects, to implement Construction Waste Prevention (CWP). A systematic review of purposively sampled literature on IDP, waste management, and construction waste management, was used. CWP, IDP, and the theoretical angle used to relate the CWP to an IDP setting via the concept of integration are the key themes. The research process includes the formulation of a research question, definition of keywords, and selection of relevant studies from databases to arrive at findings. Content analysis was used to determine supportive practices and conditions, to arrive at propositions for implementing CWP through IDP. Being relatively new, the lack of an articulated integrated procedure for applying CWP at the design stage is a major gap. Findings suggest the possibility of using IDP to achieve CWP, and opportunity for a systematic method that uses IDP as a vehicle for CWP in projects, at the design stage. The study extends the research in CWP and explores other opportunities related to IDP.

Keywords: integrated design process; practice; prevention; waste

INTRODUCTION

Advancements in sustainable construction exist, which demand more environment-friendly and resource-efficient operations (Chen *et al.,* 2018). Improvements in construction practices to minimise negative environmental impacts of resource depletion and waste deposition has been emphasised (Sev, 2009). However, existing practices focus on the reactive treatment of waste (Povetkin and Isaac, 2020). Traditional approaches to waste management have limited impact (Affan, 2017), handling only existing wastes, and relying on collection, treatment, and disposal of wastes (Skinner, 2004). However, some earlier studies highlight the need to improve production systems for improved waste management (Skoyles, 1976). Such improvement often refers to construction waste prevention (CWP), which is a proactive, systematic approach to construction waste management (Mbadugha *et al.,* 2021).

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Waste prevention are actions taken before an element turns to waste, including strict evasion of waste; reduction at-source; and reuse of products, excluding recycling and other measures applied to existing waste (Corvellec, 2016; Lilja, 2009). Waste prevention in construction highlights the need for a more integrated framework for sustainable consumption and production, waste management, and resource efficiency, to address waste at source (Lilja, 2009; Singh *et al.,* 2014). Therefore, CWP is viewed here as initiatives taken to prevent and eliminate the occurrence of waste in construction operations. The common approach is to develop more technologies and methods (Van Weenen, 1990). A few studies emphasise design as the main stage for CWP while noting most waste as resultants of poor design practices (Turkyilmaz *et al.,* 2019; Mbadugha *et al.,* 2021).

A design process that includes an innovative approach, active collaboration, and commitment of relevant stakeholders is needed for CWP (Chiocchio *et al.,* 2011; Turkyilmaz *et al.,* 2019). Improvements are often limited due to the fragmented and sequential nature of current design process (Fadoul and Tizani, 2017), However, integrated design process (IDP) has emerged as an alternative (Attia *et al.,* 2013), in the field of sustainable design and construction, for more integration and collaboration, and constructability and operability. The concept relies on the integration and collaboration of different professionals, collective decisions and goals, and combination of different approaches into a systematic process, without compromising flexibility in design and decision-making process (Düzgün and Aladağ, 2015). More recent discussions have highlighted the benefits of IDP for enhancing waste reduction and prevention efforts in construction (Cheng *et al.,* 2015). While not originally purposed for waste prevention, the nature of IDP and recent speculations, suggest its potential for achieving waste prevention. In the literature survey thus far, many studies on integrated approaches do not use a clear terminology that refers to IDP. Such studies resulted in ad-hoc and tool-based processes (Akinade *et al.,* 2018; Laovisutthichai *et al.,* 2020). Few studies have highlights that point directly towards CWP. Such studies sway between minimisation, reduction, and suggestions that may, or may not be articulated to CWP (Al-Hajj and Hamani, 2011). Regardless of the gaps in extant literature on CWP, reducing the possible quantity of waste produced, remains the most dominant perspective (Mbadugha *et al.,* 2021). Also, studies such as Laovisutthichai *et al.,* (2020; Osmani *et al.,* (2008), which focus on waste reduction to achieve prevention. The gaps in literature have probably added to the inhibitions of achieving CWP through IDP. There is therefore no articulation of the use of IDP for implementing CWP. This paper therefore examined existing studies and frameworks on the prevention, reduction, and management of waste, for a holistic understanding of CWP implementation through IDP.

A theoretical lens was used to conceptualise the combination of CWP and IDP in an equally operational mode. Literature on CWP points to systems integration, to view design process as a channel. This is relevant to IDP and provides adequate perspective for understanding the infusion of CWP into IDP. Integration is the framework to systematically assemble and coordinate parts, iterative with verification to form a whole or new framework (Rajabalinejad *et al.,* 2020). While the parts that are assembled into an organised whole is a system (Nicholas and Steyn, 2012). For purpose of this research, CWP and IDP are regarded as systems to be integrated, and the integration represents the process of interaction and fusion.

RESEARCH METHODOLOGY

Based on the stated gap, the paper presents preliminary findings from a study to determine the potential of using IDP to implement CWP. The research question formulated is: 'What is the potential of IDP for achieving CWP in projects? A systematic review of extant literature was used. According to Schanes *et al. (*2018); Wuni and Shen (2020), a systematic review establishes the boundaries of existing research and highlights areas worthy of consideration in further studies. The methodology includes defining the research question, determining the required data, selecting relevant academic databases, conducting a systematic literature search, defining criteria for inclusion/ exclusion, analysing and synthesising the data.

Table 1: Studies selection process

	Scope	CWP	IDP
Initial search	Keywords: By Boolean search formula	"Design" OR "barriers" OR "systems" OR "challenges" OR "developments" OR "constraints" OR "need" OR "practices" OR "improvement" AND "construction waste prevention" OR "construction waste reduction" OR "construction waste minimisation" OR "construction waste management"	"Integrated design process" OR "integrated design principles" OR "integrated design practices"
Identification	Database/search: keywords on titles only	Scopus - 46	Scopus – 61, Science Direct – 3, Web of Science – 26
Screening	Filters: year range (2000-2020); publication type, subject area, and English language	Scopus – 41 Retrieval lapses - 2 Total retrieved - 39	Scopus – 42, Science Direct – 3, Web of Science – 12. Duplicates removed – 44; Retrieval lapses -5; Total retrieved - 39
Eligibility	Reading abstract and full text	Redundant papers removed –10	Redundant papers removed –12;
	Paper quality using CASP		CASP removed – 2
Inclusion	Data analysis	Included papers - 29	Included papers - 25

To cover the greyness in the definitions of CWP and IDP identified in the initial studies, key phrases were determined in a way that gives an extensive search in the area, including other studies not discussing the topic but highlighting relevant factors. The key phrases were combined into a Boolean search formula for titles only. Three databases were selected for the search, Scopus, Science Direct, and Web of Science. Four stages of information extraction were used to arrive at the papers reviewed: identification, selection, eligibility, and inclusion. Apart from the details in Table 1, publication types were limited to conference papers, review articles, and original articles. Five subject areas were considered: Engineering, Energy, Environmental Science, Materials Science, and Earth and Planetary Science. From an initial pool of 41 titles for CWP and 44 for IDP, two and five papers respectively were excluded due to restricted access. Out of the total remaining 78 papers, 22 were excluded because of the field of interest, focus, or context of study. To address the validity and reliability of findings, reliable databases and journal sources and authoritative literature on the topic were cross validated. The quality of selected papers was assessed, using the critical appraisal skills programme (CASP), based on rigor and consistency, effective analysis and synthesis, method selection, and demonstration of contribution. This resulted in the removal of 2 papers for IDP, due to their methodology. Ultimately, a total of 29 papers for CWP and 25 for IDP were included in the analysis.

RESULTS

For CWP studies, between 2004 and 2020, research interest dropped thrice and peaking at intervals in 2004, 2008, and 2018. There were 17 journal publications, 11 conference papers, and 1 review papers, representing over 10 countries. For IDP, between 2009 and 2011, research interest peaked twice, slumping in 2010. Regardless, 15 out of the 25 papers were journal articles. IDP studies focused most on energy efficiency, Net-Zero, and high-performance structures, theoretical frameworks, retrofits, and prefabricated façade. The geographical distribution of the publication spans over 10 countries.

Following the research question, the objectives derived for this study are, to identify CWP practices that call for IDP; to identify the current practices, requirements, key principles, and values of IDP; to describe the opportunities in using IDP to address the implementation of CWP practices. The results of the review are presented according to the stated objectives of the study and synthesised to highlight the prospects of using IDP for CWP.

CWP Practices and the Identified Conditions Requiring IDP

The common practice in construction waste handling mainly focuses on waste sorting, collection, and disposal (Ng *et al.,* 2018). Only few studies have considered using the project design stage for addressing waste before generation. Such studies mostly concentrate on reduction and minimisation measures (Laovisutthichai *et al.,* 2020). This study used prevention, reduction, minimisation, and other measures that are relevant to CWP, for identifying current efforts and associated factors that highlight the need for IDP. See Table 2.

IDP and the Identified Characteristics

Current practices of IDP
The IDP framework is perceived differently among actors (Forgues *et al.,* 2017). This resulted in different variations of IDP that has different perspectives, orientation, and approaches peculiar to the core professions involved. This is because the existing guides are created by the agencies associated with the different professions (Landgren *et al.,* 2019). Most of the players are either engineering-focused which includes the Integrative process, Method for integrated design of low energy buildings; or architectural variants which include Integrated Project Delivery Guide, Integrating Energy Modelling.

There is contractor's perspective - Integrated Design-Build Method and industry variant - Integrated design and delivery solution (Ferrara *et al.,* 2018; Landgren *et al.,* 2019). IDP emerged as synergy between various existing variants (Landgren *et al.,* 2019), and has been described differently based on perceptions. The common features in all the variants are integration and interdisciplinary exercise (Forgues *et al.,* 2017).

The summary of the concepts of IDP revealed the level of flexibility in the framework. The concept has been described as; a collaborative and interdisciplinary work process; a whole system process; a management concept; a procedure as well as an approach; the integration of design and construction; the integration of information, knowledge management, and technology; and a discovery process. See Table 3.

Table 2: identified CWP measures requiring IDP

Causes of construction waste	References
Design and construction detailing complexities and errors; poor communication, commitment and coordination, design changes, increased client's requirements	Osmani *et al.,* 2008; Dainty and Brooke, 2004; Wang *et al.,* 2014
Limited knowledge, experience, and guidance; poor considerations of construction techniques and material used during the design	Li *et al.,* 2014; Wang *et al.,* 2014
Identified CWP practices	
Standardization of design, dimensional coordination, design management, fewer design alterations, modular design, designing-out-waste principles, design review	(Ajayi *et al.,* 2017; Li *et al.,* 2015, 2014; Wang *et al.,* 2014)
The use of low waste technology, off-site construction, prefabricated technology and components, material optimisation, and modular construction	(Dainty and Brooke, 2004; Li *et al.,* 2015; Wang *et al.,* 2014)
Suggested measures for CWP	
Consolidation of the existing design measures, regenerative design, a combination of architectural design and technology; flexibility and adaptability of design;	(Ajayi *et al.,* 2017; Laovisutthichai *et al.,* 2020)
The use of improved construction methodology; integrated prefabrication and modular construction; integration of parametric design and modular construction	(Akhund *et al.,* 2019; Banihashemi *et al.,* 2018; Laovisutthichai *et al.,* 2020)
Facilitation of communications among stakeholders, integrated and proactive supply chain partnering a solution, integration of design and construction stages	(Dainty and Brooke, 2004; Ding *et al.,* 2018; Osmani *et al.,* 2008)
Innovation in technology, BIM for 3D model visualization, information transfer and management capabilities, use of the various green evaluation systems; system dynamic approach for assessing the implementation of measures	(Aleksanin, 2019; Ding *et al.,* 2018; Laovisutthichai *et al.,* 2020)
Education and training programmes; evidence of CWP projects; provision of legislation and policies; provision of incentives and disincentives for defaulters	(Crawford *et al.,* 2017; Li *et al.,* 2015; Osmani *et al.,* 2008)
Challenges of CWP implementation	
Inappropriate use of technologies and materials, unfair competition, lack of means to integrate existing measures into the current design process; poor consideration of waste reduction measures during the design	(Laovisutthichai *et al.,* 2020; Osmani *et al.,* 2008)
Construction industry's culture and behaviour towards CWP; the use of the simple linear design process; poor coordination and communication among stakeholders, and the absence of assistive tools and integrated guidelines	(Akhund *et al.,* 2019; Laovisutthichai *et al.,* 2020; Ng *et al.,* 2018; Osmani *et al.,* 2008)
Barriers to CWP implementation	
Traditional construction methods, incomplete/confusing documentation, disconnection between design instructions and construction in real-time, insufficient attention to the construction process during design.	(Crawford *et al.,* 2017; Laovisutthichai *et al.,* 2020)
Drivers for CWP implementation	
Active communication among participants; training; research and development in CWP; competence; construction process; design strategies and technology, materials management plan, legislation, policies, and regulations	(Li *et al.,* 2014; Ng *et al.,* 2018)

DISCUSSION

CWP measures

It has been noted complex decision-making processes cannot be realised in isolation but integrated (Klaassen *et al.,* 2021). Many of the current suggestions thus far on CWP are focused on integrated practices in the construction work practices which refer to a change in current design practice as noted by (Osmani *et al.,* 2008). Based on analysis of the selected studies on CWP, most issues and practices highlighted point to the need for an IDP project.

They include more flexible method; early involvement of stakeholders, stakeholder/ discipline integration, coordination, and active communication; proactive partnering in supply chain solutions; non-linear design process; integration of design and construction stages; innovative solutions; and integration of relevant methods, technologies, and processes (Laovisutthichai *et al.,* 2020). According to (Ng *et al.,* 2011) Such activities usually give rise to an iterative process, whereby all the systems components - people, methods, technologies, and processes are integrated into the design process for effective results.

Table 3: Identified practice for IDP

Requirements for IDP	References
Collaborative and interdisciplinary work culture, trust, description of the relevant stakeholders, the definition of the methodologies to apply	(Landgren *et al.,* 2019)
Emphasise integration; Technical knowledge during the design process	(Landgren *et al.,* 2019)
Early stakeholder involvement and commitment, Use of a systems approach	(Forgues *et al.,* 2017)
Active collaboration of the multidisciplinary design team, Clear and continuous communication; Rigorous attention to detail	(Chakraborty and Bahr, 2009; Forgues *et al.,* 2017)
Key principles of IDP	
Encouragement of an iterative process; flexible design framework; knowledge integration into the design process	(Ferrara *et al.,* 2018)
Active communication and collaboration among parties; attention to details	(Chakraborty and Bahr, 2009)
Key values from the application of IDP	
Evaluation of design methods and choices by the stakeholders; interactions of the interdependent systems of the building; opportunity for speeding up the design process	(Ferrara *et al.,* 2018; Ng *et al.,* 2011)
Innovative thinking, trust, rational decision-making; multiple systems and interrelationships over the lifecycle consideration; achievement of sustainability goals	(Chakraborty and Bahr, 2009)
Definition of the performance requirements	(Trebilcock-Kelly *et al.,* 2019)
Assessment of projects and verification of solutions; good communication framework for stakeholders; awareness of systemic measures to practice;	(Ferrara *et al.,* 2018)
Identified challenges to implementation of IDP	
Unclear roles, and boundaries among the stakeholders	(Koch and Haubjerg, 2011)
Lack of an appropriate decision-making tool to facilitate integration	(Landgren *et al.,* 2019)
Inability to simultaneously integrate technical knowledge with architectural qualities; incompetence among the stakeholders; different interpretations of goals and decisions	(Koch and Haubjerg, 2011; Landgren *et al.,* 2019)

Brand and Hertogh (2021), have identified the need to involve different professions, and achieve knowledge transfer in a real-world application. It must also be user-or stakeholder-driven, encouraging innovation, and overcoming barriers between research and practice.

IDP measures

The results revealed that IDP is flexible, involves an iterative process, and can be adapted to any field where sustainability issues are of concern. Among the benefits, it allows multi-stakeholder engagement in the design process, which facilitates whole system consideration of design issues, design variables, technologies, and possible solutions with many perspectives (Forgues *et al.,* 2017; Landgren *et al.,* 2019). Although it is yet to be explored, findings suggest that a framework based on IDP, which includes identified methodologies could be targeted at better waste management outcomes in projects.

Integration framework

Results show a pattern, which emphasises that implementing CWP to achieve prespecified goals and objectives, requires integration at the design stage. For the CWP mechanism to be effective, conformance to certain criteria is necessary (Nicholas and Steyn, 2012). The requirements for efficient implementation of CWP align with qualities of IDP (Brand and Hertogh, 2021; Ng *et al.,* 2011). Therefore, IDP features essentially constitute the qualities that can be engineered to implement CWP, making it the more suitable design approach for achieving CWP. IDP would therefore suffice as an ideal vehicle for integrating relevant practices, which facilitate waste prevention as highlighted by (Jin *et al.,* 2019). By converging relevant waste prevention practices in an IDP setting, exploiting the potential inherent in IDP to efficiently implement CWP, a new framework addressing waste generation is created. However, findings also highlight potential challenges, since IDP is not generally practiced, and not originally and currently waste focused. Such challenges, include a lack of predefined integrated design system and tools for adaptation and application of CWP.

CONCLUSIONS

The current study explored the relevance and need for using IDP to achieve CWP in construction projects. Though the need has been suggested in literature, there is yet no theoretical justification for the claims. The paper presents preliminary results, which build a more comprehensive baseline of understanding, regarding the use of IDP for CWP. The relevant limitation here is the inherent theoretical nature due to the stage of study in a wider research project. However, the findings thus far show that existing efforts to improve efficiency, including the development of waste prevention measures, generally highlight the viability of the project design stage. There is a need for an approach that rises above the hindrances of traditional work practices and approaches. It should be an approach with modalities that facilitate implementation of relevant waste prevention measures, at the design stage. Current findings show that IDP has the characteristics that can be adapted to facilitate the implementation of CWP. The said adaptation is essentially to purpose IDP for CWP by using its features and adapting features from other relevant approaches. Achieving such an evolved IDP, would require future studies along, which include more detailed theoretical analysis and empirical studies, and a design approach.

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