

Sustainable Solutions for Enhancing Efficiency, Safety, and Quality of Construction Value Chain Services Integration

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Abstract—In view of the increasing speed and quantity of the housing supply, building, and civil engineering infrastructure works triggered by the pandemic across the globe, contractors, professional services providers (PSP), including consultants (e.g., architect, project manager, civil/geotechnical/structural engineer, building services engineer, quantity surveyor/cost manager, etc.) and suppliers have faced tremendous challenges of the fierce market, limited manpower, and resources under contract prices fluctuation and competitive fee and price. With qualitative analysis, this paper is to identify the available information from the industry stakeholders with a view to finding solutions for enhancing efficiency, safety, and quality of construction value chain services for public and private organisations/companies' sustainable growth, not limited to checking the deliverables and data transfer from multi-disciplinary parties. Technology, contracts, and people are the key requirements for shaping the construction industry. With the integration of a modern engineering contract (e.g., NEC) collaborative approach, practical workflows are designed to address loopholes together with different levels of people employment/retention and technology adoption to achieve the best value for money.

Keywords—Sustainable solutions, contract, construction value chain, Building Information Modelling, BIM integration.

I. INTRODUCTION

THE COVID-19 pandemic has led to an increase in construction projects worldwide, posing several challenges to contractors and professional service providers (PSP). The construction industry requires a collaborative approach involving different stakeholders, including consultants, engineers, suppliers, manufacturers and PSPs. This paper aimed to identify the available information and find innovative solutions for enhancing efficiency, safety, and quality of construction value chain services for sustainable growth.

The research aimed to provide innovative solutions to enhance efficiency and quality of construction value chain services deliverables, procurement processes, and experienced professionals for public organisations and private companies' sustainable growth in the construction industry.

This study employed a desk research approach to identify the available literature and information from industry stakeholders. A qualitative analysis was conducted to find sustainable solutions to enhance efficiency and quality of construction value chain services.

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A. Integration

The study found that the construction industry required collaboration among different stakeholders to achieve sustainable growth. The integration of modern engineering contracts (e.g., New Engineering Contract 4 (NEC4) Engineering and Construction Contract (ECC)) and practical workflows could address loopholes in the construction process. Additionally, people, contracts and technology were crucial aspects of shaping the construction industry and improving efficiency, safety, and quality while achieving best value for money.

The study contributed to the body of literature on sustainable growth in the construction industry by providing innovative solutions. And the integration of NEC4 ECC could foster collaboration among stakeholders for enhancing efficiency, safety and quality in construction value chain services.

B. Challenges

Contractors and PSPs have been facing challenges in dynamic environments of the construction industry, for example, labour shortage, aging workforce, multi-disciplinary teams towards business consultancy with different culture and language, design changes during the construction process, disruption to global supply chain under heatwaves, rising average temperature, sea level and drought of extreme weather, and post-pandemic era.

Digitalisation and sustainability are drivers of efficiency and quality changes globally with ecosystem such as energy-saving technology, tremendous time and paper consumption in photocopying machine printing tender documents, full-scale drawings, and climate resilience towards a low-carbon economy to reduce the environment impact of construction.

The assessment of embodied carbon dioxide is most appropriately undertaken by the cost consultants or quantity surveyors, and done building element by building element to tie the analysis to project cost data [1].

People, technology and process are required to deliver the value proposition to the customer. Recurrent tasks are addressed in a consistent way by ways of working together in the processes [2]. Different project stakeholders require different level of information details to suit their understanding and communication respectively. Human errors are easily incurred among the temporary or short-term collaboration

parties.



Fig. 1 Planning and review linking value of communication with interrelationship

The tasks of construction value chain are heavy with automation yet to be completely realised. For instance, the components not belonging to standard family libraries in Building Information Modelling (BIM) tool has not been classified easier in the process of identification rules [3].

As for a typical business case, different stakeholders involve in the construction value chain with market strategy and clientelling, project capex budget, financial planning, market analysis, products and services. The business case has to be presented with illustration for mutual understanding among each other.

The stages of initiating, planning, executing, monitoring and control and close out cover budgeting, cost control and review from pre-tender, construction to post-construction states. It is not easy to coordinate with parties without location boundaries in reflecting post-pandemic, business case presentation and design submission to corporate of the required activities for getting the project approved, sponsored and resourced, project scopes and budget, team roles, communication plan, due diligence, tendering and sourcing, construction, checking and understanding the project's progress, cost controls, final account settlement, retrospective meetings, project closure report and key performance indicators review.

The roles of stakeholders in pre-contract and post-contract stages are budgeting about feasibility studies, capex estimates, life cycle costing and cashflow forecast, contract administration, establishing contract, agreement templates and dispute resolution, due diligence of consultants, contractors and suppliers, benchmarking about locality factors, cost reports, against other brands, governance about compliance with other departments and auditing, process review about establishing project, tender guidelines for companies and project trackers, and real estates about market studies in terms of locations and brand.

Common features are budgeting, tender, payment, final accounts and cost studies while different features are due diligence, benchmarking, sourcing, process review and real estates.

In the context of social distancing and lockdowns, Architecture, Engineering, Construction, and Operation/ Owners (AECO) sectors have to digitise their services to get access for individual and team interactions, over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, and

responding to change over following plan to the global value chain.

II. COLLABORATION

As for the challenges of global climate change in the Paris Agreement, the common platform or tools in collaboration with inclusivity in the enterprise culture saves time and costs of paper-based design, comments and revisions, procurement, project and contract administration not limited to eliminate waste, less embodied carbon and travelling time for meetings by streamlining communication, information exchange and giving incentives for inter-connected sharing among stakeholders from a variety of organisations including service providers, project and field teams virtually anywhere over the world.

AECO industry stakeholders involve in the rapid technological growth with staying abreast of changes including the flexible way of work, and hence collaborative mindset, inclusivity respect and competence in the breadth and depth of domain knowledge and experience of the industry.

Collaboration could be enhanced through contracts among different stakeholders to improve efficiency, safety, and quality in construction value chain services by creating better business outcomes.

BIM has been internationally adopted across the globe including Australia, Benelux, Canada, China, Czech Republic, France, Germany, Hong Kong, Italy, Japan, Korea, Morocco, Slovenia, Spain, Switzerland, Turkey, United Kingdom and Ireland, and United States of America.

BIM adoption helps coordinate a set of processes for creating and managing information of models [4] incorporated with graphical data, 3D models, 2D drawings, non-graphical data, commercial and environmental attributes throughout AECO industry asset lifecycle. Its interoperable use in openBIM, a collaborative process defined as sharable project information that supports seamless collaboration for all project participants [5], gives interactive advice and prepares documentation including warranties, manuals and specifications integration with supply chain for provision of sustainable, management and technological solutions.

With the adoption of BIM common data collaboration platform in the workflow, the BIM models can serve as a single source of truth for collaboration throughout the whole project life cycle including asset management stage [6].

NEC4 ECC is a collaborative contracting with its features of mutual trust and co-operation (Clause 10.2), plain English, its flexible and modular approach and Secondary Option Clause X10 Information Modeling which creates or modifies and shares an asset information model set out in the requirements of the contract scope [7]. BIM with digital transformation helps instant collaboration and communication, for example, information execution plan in connection with a NEC4 program between parties.

The BIM integrated collaboration platform, a common source for collating, managing and disseminating the information model, can be specified as its use of the communication system in the scope pursuant to NEC4 ECC

Clause 13.2 for facilitating collaboration between the client and the contractor. It also centralises the design changes, cost estimation, calculations, project and asset data and information in a single source with all types of models in BIM [8].

The BIM-based protocol could thus be developed for seamless collaboration among AECO stakeholders by inserting information including proactive sharing via openBIM, cost and time estimate of construction as digital twin and blockchain [9]. This platform is integrated with Geographic Information System (GIS) on project/site specific requirements/items, smart site safety system on safety performance [10] and digital works supervision system [11], for example, scheduled area, antiquities, culvert, adjoining buildings, party walls, etc. in managing risks.

The use of BIM common project collaboration platform enhances the centre of data analysis, strengthens project management capability, adoption of the alternative procurement method NEC4 ECC with Secondary Option Clause X15 The Contractor's design throughout the contract including delivery of the clash free Modular integrated Construction (MiC) modules off-site [12], and hence better resource or less manpower in different contexts, low risk of time and cost overruns, build-up skills and ingenuity for coordination work efficiency, effectiveness, quality and productivity along and across value chains.

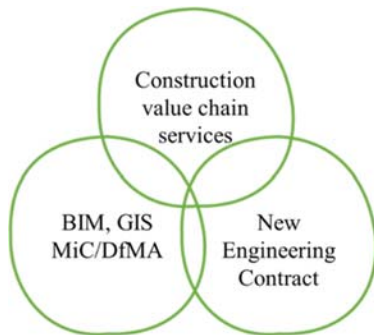


Fig. 2 Construction value chain services integration

Process, product and system twin are the types of digital twin for safety design, diagnostic, prediction and maintenance which help optimisation the temporary works, MiC and Design for Manufacture and Assembly (DfMA) (NEC4 ECC Short Schedule of Cost Components 6/Schedule of Cost Components 6 Manufacture and fabrication (SSoCC6/SoCC6)) [7], end-to-end process, new business, improved quality and cost saving to a single interconnected network developed to provide digital trust and full traceability.

III. SUSTAINABLE SOLUTIONS

Sustainable solutions could enhance efficiency and quality in project services deliverables and procurement processes. As per *Another Day in Katerradise*, it is hard to have different business units facilitated working together ended up with systems in place [13].

With linking chains of communication, process, transfer and connection through all stages of the project, the parties are

connected and modularity such as MiC/DfMA could be information-based and standardised with improved mechanical performance and volume stability.



Fig. 3 How it gets started

The digital platform facilitates an enhanced project management framework for public and private sectors, improve complexity of multiple projects by increasing multi-disciplinary inclusivity under NEC4 Secondary Option Clause X12 Multiparty Collaboration, identifying data, sharing information and hence better decision making among government departments, specialists, contractors, consultants and clients in collaboration with professional and educational institutions for increasing interdisciplinary research activities locally and internationally, for example, ISO 19650 and commonly defined work processes [14]-[17].

The BIM platform also boosts collaboration and transparency under NEC4 ECC Options C and D, Secondary Option Clause X22 Early Contractor Involvement which focusses on the approach of sharing the benefits gained, experience, expertise and promoting the contractor's taking part early in the design development and construction planning stage of a project through the construction process to facilities management and Secondary Option Clause X21 Whole life cycle assessment as appropriate.



Fig. 4 People, collaborative contracting and technology for sustainable solutions

While BIM is used as a quantity take-off tool, its integration into life cycle assessment is used in a native BIM environment to maintain a correlation between carbon results and BIM elements [18].

The timing and accurate value of work can be validated, determined and agreed collaboratively with clear, much easier

and quicker measurement, billing and payment including cost components assessment, program and S-curve monitoring. It improves efficiency, accuracy, productivity and cost saving in the AECO process by identifying right people, sharing correct information with respective parties, engaging project team with interpersonal relationship, flexible working with manageable workloads, learning and development under optimised schedule set out and manpower released from the repetitive tasks to attract talent and staff retention [19] with less work overtime.

With domain knowledge, skill set and experience, one's human behaviour is predicted in the unified platform, providing guidance to new recruits/less experienced parties with learning curve, educating project teams, answering queries, checking

and auditing mechanisms developed to automatically identify problematic BIM models or mistake elements [20]. It saves drawing production time with the use of execution plan, content regulatory compliance and data revalidation for tendering and contracts.

Adoption of augmented reality, virtual reality and digital twin technologies along the supply chain embrace collaboration and inclusivity to correct change of AECO industry needs against the set targets or standards under NEC4 ECC Secondary Option Clause X29 Climate change to carbon neutrality for health, safety and sustainability of environmental, social and governance (ESG) compliance in different cities, countries and the world.

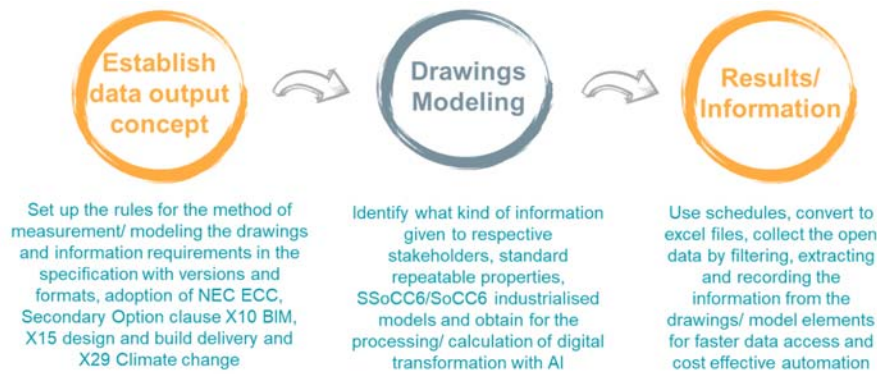


Fig. 5 Data processing



Fig. 6 Training is necessary for all entities

Organisation	Top Management	Focus Group	Test/ Use cases	Results	Audit	Sustainable Solutions
Action	Drive Lead by Example	Collaboration	Departments/units/ teams	Open data	Internal and external parties	Corporate and project teams
Salient points	<ul style="list-style-type: none"> Taking training accreditations with major multi stakeholders Support by active listening and providing resources Making decision: transformative measures to digitalisation including carbon neutrality 	<ul style="list-style-type: none"> Discussion, Teamwork Design, develop innovative solutions AI, ML BIM, GIS NEC KPI 	<ul style="list-style-type: none"> Customisation Digitalisation, Practice notes, Rules, e-form Infrastructure, generations Platform as a service Training and development anywhere 	<ul style="list-style-type: none"> Value each of opinions, address queries, resolve problems, coordination of intelligence Streamlining, review with process, people, tools/ technology Built assets Unified representation 	<ul style="list-style-type: none"> Audit check Compliance, governance including regulatory, contract and global standards Continuous review Efficacy Priority 	<ul style="list-style-type: none"> Sustainability, decarbonisation, whole life cycle assessment, ESG, data environment Construction value chain, efficiency, safety, quality Value for money Integrated platform anywhere

Fig. 7 Mapping action points

With AI, ML, knowledge model-based algorithms for automatic code-compliant rules and robust results [21] help achieve sustainable solutions, for example, controlling significant energy consumption first. In addition, its workflow

is further streamlined digitally for the process control, automation of routine tasks, data capture, supervision, system and information integrity, communication and management, auditing/analytics and e-delivery of services [22].

IV. CONCLUSION

The study highlighted the need for collaboration among different stakeholders to achieve sustainable growth in the construction industry. The integration of modern engineering contracts and practical workflows could address loopholes and promote efficient and high-quality construction value chain services. The study provided sustainable solutions for enhancing efficiency and quality in construction value chain services deliverables and procurement processes for public organisations and private companies.

Culture embraces team behaviour, project management, NEC4 contracting and ESG integration with the use of openBIM and GIS common platform for real time collaboration and inclusivity. Team engagement reinforces its ability to view, track, audit models and/or check implications to program and cost of changes critically from the above integration of time, cost and scope to the resources linked with project team's aligned services.

A single platform with user-friendly one-stop interface integrating different main components in the construction value chain facilitates its reliable usage in domain project stakeholders with resilience, decarbonisation, simplification and repeatable standardisation of industrialised construction processes to drive sustainable performance technologically, profitably and leanly, noting that it is impractical and of limited value incorporating all elements or information of the full pricing document into BIM models and related applications.

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