EXPLORING THE ADOPTION OF PLATFORM-BASED DESIGN FOR MANUFACTURE AND ASSEMBLY IN THE UK CONSTRUCTION SECTOR: A STAKEHOLDER PERSPECTIVE

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Platform-Based Design for Manufacture and Assembly (P-DfMA) is identified as the future of offsite construction and potentially a panacea to achieving the UK's construction 2025 target. However, the general understanding of P-DfMA's processes, techniques, methodology, and design is still in the infancy stage. The paper aimed to investigate the rate of awareness, benefits, and barriers of adopting P-DfMA within the UK construction sector linked to the construction 2025 targets. A triangulation mixed method was deployed using a quantitative online survey as the primary data collection instrument complemented by qualitative semi-structured interviews to corroborate and reinforce the credibility of the findings. The questionnaire revealed that 31% knew about P-DfMA, though only 6% had ever used it. The interviewees also lamented the lack of awareness. Therefore, stronger implementation strategies from the government plus stakeholders' awareness initiatives are recommended to facilitate adoption and success rate and maximise the benefits of the technique.

Keywords: BIM; construction 4.0; DfMA; lean; platform design

INTRODUCTION

The construction industry is often compelled to embrace approaches from the manufacturing industry to derive a better value. But there is little scope for substantial improvement in the current trajectory of technology and delivery process. Most of the designs are unique and require bespoke solutions. Although many components and elements of it can be standardized and automated. We generally know the requirement of space, material and typical layout of any school or hospital. Then why not generate standardised design to enhance safety, productivity, and efficiency (Kier 2019).

Design for Manufacture and Assembly (DfMA), evolved from the automobile industry aimed at improving manufacturability and assemblability. Lately, the concept of standardized platform system is visualized for the construction industry, blended with the DfMA approach to achieve ‘Platform approach to Design for

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Manufacture and Assembly' (P-DfMA). The term was initially coined by Jamie Johnston (Bryden 2017b). However, understanding the essence of competitive platforms is essential to consider the competitive trends of digital economies. In the year 2020/21, the UK government allotted around £37bn for the procurement of infrastructure and construction projects (IPA 2020). According to Construction Manager (2020) P-DfMA has the potential to meet these demands and accelerate innovation if adequately engaged.

P-DfMA are specially designed kit of parts combined to form an object (Mosca, *et al.,* 2020; Carlisle and Webb 2021). Hence same element(s) of a module or assembly can be replicated and used for different kinds of projects viz., Prison, Hospital, Residential building, etc., and curtails the need to design new components every time for a new building. Beaumont (2019) concluded that if Prisons are built on a platform approach, then it could save 33% cost and trim the construction time by 50%. Additionally, it can minimize CO2 emissions by 50% and improve the import-export trade gap by 50%. IPA (2018) and Alfieri *et al.,* (2020) also emphasized that P-DfMA can boost onsite productivity and minimize waste approximately by 90%.

However, P-DfMA presents some challenges and barriers. First, the boundaries of each platform must be defined to maximise the applicability of the component parts on platform projects. However, if the project is too complex and has too many specific components, the platform approach may be difficult to actualise (Bryden 2018). However, P-DfMA would be successful if implemented at a larger scale (Cao and Hall 2019). For this, the pipeline of projects should be stable to allow a mass production and standardisation of components (Construction Manager 2020).

LITERATURE REVIEW

Evidently, there are sufficient literature on DfMA and how it helps the construction industry in various ways. However, literature relating to 'Platform approach to DfMA' is still in infancy, being a new technique. Even though literature seem to reiterate the potentials of P-DfMA in achieving the Construction 2025 targets, it's only been implemented in very few UK government projects. Perceiving the current lack of knowledge and information about the technique amongst industry practitioners regarding its success, adoption rate, and associated challenges to help relevant stakeholders make adoption decisions. The paper attempts to breach this gap by investigating the rate of awareness, benefits, and barriers of adopting P-DfMA within the UK construction sector linked to the construction 2025 targets. Findings will contribute to the argument on adopting the technique and support the emerging discussion on enablers, drivers, and strengths of this techniques now gaining momentum within the industry.

The UK construction industry contributed £117bn to the economy in 2018 (HM Treasury 2020) but is seen to be quite a low performing as compared to other industries (ONS 2021). It was identified that the construction industry of UK added around 200 million tonnes of waste and 50% of total carbon emissions in 2014 (NBS 2018a). Around 30% of building materials and 40% of man-hours are wasted during construction adding up the construction cost of building (NBS 2018c). Fragmented process and adversarial way of working have affected the client organisations (Latham 1994), due to which the product is left with a diluted value (Bryden 2020). Earlier, Egan (1998) had asserted that the industry needs to get rid of Silo-mentality and accept change to adopt emerging technologies. A series of reports published on the nature of industry highlighted issues like cost overrun, insufficient information, reduced quality, and low productivity (NAO 2001). Farmer (2016) reviewed the UK construction industry and highlighted strong issues such as lack of collaboration, low predictability, and dysfunctional delivery model of the construction industry.

As the industry shifted to the fourth generation, manufacturing approaches became relevant to the construction process (Arashpour *et al.,* 2015; Cao *et al.,* 2021). Farmer (2016) insisted on the use of Offsite Manufacturing (OSM) methods for project delivery to create a dynamic market for innovative technologies. It was also supported by IPA (2018), HM Government (2018) and Cabinet Office (2020). Conversely, Farmer (2016) argued that the construction industry has not even shifted properly to Industry 3.0. Latham (1994) had previously stated that there was a good scope for improving the construction industry through standardisation.

Government being the major client for the UK construction industry looked for ways to modernize by 'Standardisation' (HM Treasury 2020). Cabinet Office (2020) published 'The Construction Playbook' where it embedded the adoption of MMC and OSM, where prime focus was given to standardisation. The need to magnify standardisation as highlighted by many reports became necessary to increase productivity and reduce the cost of construction. Parallelly, Construction Innovation Hub (2020) had already started working with the government and industry to develop a standardized approach called 'Platform based DfMA'.

Anecdotal evidence suggests that P-DfMA can address the concerns of Poor productivity, Labour shortage, Design, and Coordination issues, etc. It can create standardisation at a component level apart from the design flexibility at an asset level (Carlisle and Webb 2021). To summarise, the construction industry of UK is seen as resilient. But in this unprecedented time of COVID-19 pandemic, embracing technology that provides digitalisation apart from a safe working environment is essential. With P-DfMA in place, projects can be tracked effectively with low wastage of time, less labour on-site, minimal coordination and increased performance (HM Treasury, 2020; Cao *et al.,* 2021). Despite the many advantages presented in P-DfMA not much information regarding its awareness, benefits, and barriers of adopting the technique to assist stakeholders such as the government being the major clients or contractors, private sectors, etc, make adoption decision. The next section presents the methodological design adopted in this study to investigate these issues.

METHOD

The research adopts a pragmatic philosophical position which sits well with the mixed methods selected for the study. Pragmatism was selected because it allows the use of pluralistic methods to investigate a phenomenon, and considering that DfMA is a new technique, it would be helpful to deploy a robust technique to capture the reality of the subject from different stakeholders. Firstly, a critical review of the literature was conducted to explore the subject of awareness, benefits, and barriers of adopting P-DfMA. Sources of the secondary data were derived from books, government reports, peer-review journals, and conference proceedings certifying their reliability for the study.

Emerging themes from the review are presented in Tables 1 and 2 respectively. The main benefits of adopting P-DfMA as revealed in the literature are health and safety, sustainability, labour, cost, productivity, time, and quality. On the other hand, the main barriers of adopting P-DfMA are project pipeline, government assistance, skills, standard guidelines, procurement, and resistance to change. Themes from the review were then designed into the questionnaires and interviews that were conducted for further investigation. A convergent triangulation mixed method was deployed using a quantitative online survey as the primary data collection instrument complemented by qualitative semi-structured interviews to corroborate and reinforce the credibility of the findings.

The online questionnaire was designed using google forms, and a link to complete the questionnaire was published on a professional social media platform. The study adopts a non-probability quota sampling technique, and the population targets are professionals within the construction sector, mainly architects, engineers, contractors, and clients, and sixty-four responses were received in total. In addition, four semi-structured interviews were conducted with highly experienced professionals identified via a snowballing sampling strategy. The snowball technique is a purposive sampling strategy and helps identify hidden population (Gray, 2018). This is justifiable because PDfMA is a new technology, and very few people are aware of it. Hence, targeting the unaware professionals was of no use in the qualitative data collection.

FINDINGS

Online Survey

The link to the survey questionnaire was posted on a social media platform, therefore there were few respondents out of the UK, even though it was highlighted that the survey is only for UK construction professionals. 64 responses were received but only 53 responses were UK based which was considered for this study. Respondents were asked to mention their level of education to understand the intelligence and reliability of the responses. 12.5% of the total respondents were PhD qualified, 39.1% were Master's degree holders and 34.4% had Bachelor's degree depicting that respondents were highly qualified personnel. Respondents were asked questions relating to their job title and the sector they worked. Results revealed 20 respondents were architects, 20 engineers each, 14 were contractors, 9 were clients and 1 fell under the others category. In summary, majority of respondents were architects and engineers working in the consultancy and engineering firms respectively. Others were educators, planners, builders, QS working for contractors and client's organisation. In terms of experience, only one quarter (16) of participants had less than 7 years of experience in construction field. 19 (29.68%) respondents had 8 to 15 years and 16 to 25 years of experience respectively. Moreover, 13 (20.31%) participants had 26 years of experience indicating that highly experienced individual completed the survey, and their responses can be trusted.

Awareness and Adoption of P-DfMA

61% (n=39) participants were unaware of P-DfMA approach. 8% (n=5) respondents expressed uncertainty by selecting ‘Maybe’. Perhaps, they were aware of the typical DfMA only and not P-DfMA. Furthermore, 31% (n=20) participants indicated their awareness of P-DfMA as depicted in Figure 1. However, more than three-quarter of the professionals who were aware do not use it or have not yet adopted it. 16 out of those 20 were "just aware" and remaining 4 have adopted this innovative approach in their organisation.

The question therefore acted as a checkpoint designed to end for the ones who selected ‘NO’ or ‘MAYBE’ because surveying respondents without an awareness of P-DfMA approach will not be beneficial for this study. Hence, the survey continued only for those who were aware, i.e., 20 participants who responded ‘YES’.

Table 1: Benefits of adopting P-DfMA

Theme	Benefits And Literature Sources
Health and Safety	Platform approach improves H&S at both on-site and offsite construction Increases safety on-site; Minimized manual lifting onsite keeps workers safe; Improved H&S due to offsite construction; Reduces the need to work at heights
	(Oti-Sarpong and Burgess 2020); (Bryden 2017b; 2020)
Sustainability	Pre-tested and quality-controlled components prevent on-site waste generation; Environmental impact is reduced due to less CO2 embodied components; Considerable reduction in embodied carbon per square metre; Supports low carbon designs; Will help in achieving Net zero well before 2050; Greenhouse gas emissions are reduced
	(Bryden Wood, 2017b; 2020); (Carlisle and Webb, 2021); (IPA, 2018)
Labour	Setting manufacturing hubs in underprivileged areas can address skill deficit by utilizing local workers; On-site labour-intensive work is reduced; Less requirement of on-site skilled workers
	(Bryden Wood, 2017b); (Carlisle and Webb, 2021); (IPA, 2018)
Cost	P-DfMA follows Design to Value; Cost-saving due to manufacturing mindset; On-site skilled labour is more expensive than off-site low skilled labour
	(Bryden 2017b; 2020); (Carlisle and Webb, 2021)
Productivity	Improved productivity: The logistics of the supply chain are streamlined; Highly efficient manufacturing and on-site productivity
	(Bryden Wood, 2017b); (Carlisle and Webb, 2021); (IPA, 2018)
Time	Components arrived on site can be installed quicker with snap-fit or plug; Embracing Lean construction facilitates JIT delivery with no breaks in the supply chain; Increased speed of construction
	(Mosca *et al.,* 2020); (Bryden, 2020); (IPA, 2018)
Quality	Using common standards and platforms improves the quality of material produced
	(Bryden, 2020)

The survey however prompted respondent who answered "just aware" with a follow question to probe their use of contemporary construction methods. Results reveals 43.75% (n = 7of 16) respondents of these respondents were still stuck on traditional methods and only 25% (n=4) and 18.75% (n=3) were using typical DfMA respectively, and 12.5% (n=2) used componentised panelised solutions. The results therefore indicates that just awareness does not translate to use, or adoption as traditional methods of construction are still predominately in use.

Strengths of P-DfMA linked to Construction 2025 goals

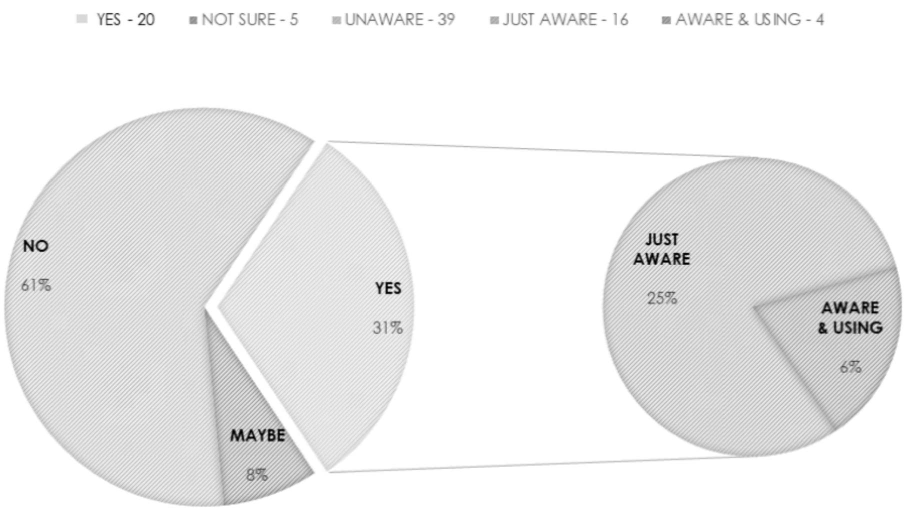
Only the 20 participants that indicated their awareness of P-DfMA were allowed to answer further question relating to the methods ability to attain the four Construction 2025 goals. The 20 participants were asked to rate their agreement to individual goals of Construction 2025. Each goal was measured on a five-point Likert scale to determine the level of agreement where ‘1’ represents ‘Strongly Disagree’ and ‘5’ represents ‘Strongly Agree’. The first goal is termed as ‘Cheaper’, the second as ‘Faster’, third as ‘Greener’, and fourth as ‘Better'. Statistical Package for Social Science (SPSS) and MS Excel were used to analyse the ‘Frequency Distribution’, ‘Central Tendency’ i.e., the mean and standard deviation and ‘Variance/Dispersion’. The central tendency and variance of the distribution results indicates that "Cheaper" had a mean of 3.85, "Faster"3.84, "Greener" 3.65, and "Better" 2.70. It is notable that all four goals have mean ranging from 2.70 to 3.85, which indicates that the agreement levels range from moderate to near high level of agreement. On averaging

(3.51) all four aspects, it can be deduced that respondents agree that P-DfMA can help achieve the Construction 2025 goals.

Table 2: Barriers to adopting P-DfMA

Theme	Barriers And Literature Sources
Project Pipeline	Long-term pipeline of work is required; Clear and coordinated plan is required by the government; Requires a huge pipeline and scale
	(IPA, 2018)
Government Assistance	The results must be awarding enough to take risk; Intellectual property rights need to be defined; Government needs to regulate intermediate authorities' agenda to adopt this at a wider scale
	(IPA, 2018)
Skills	Contractors need to upskill existing or hire new workers with manufacturing knowledge; Different job skills in the labour force; On-site tasks of assembly require new skillsets
	(IPA, 2018); (Oti-Sarpong and Burgess, 2020)
Standard Guidelines	Open-source standards are required for everyone's contribution; No information about warranty and insurance of products makes it risky to buy; Planning process like RIBA needs refinement to accommodate DfMA approach; Components should be highly repeatable to be manufactured by a wider supply chain
	(Bryden Wood, 2017b); (Oti-Sarpong and Burgess, 2020)
Procurement	Traditional procurement does not seem to work with the P-DfMA approach. Hence, new procurement method is required
	(IPA, 2018); (Oti-Sarpong and Burgess, 2020)
Resistance to change	Convincing contractors who are risk averse is difficult; Due to financial issues, Client and Supplier may hesitate to change; Radical change is required within organizations to adopt P-DfMA (Mosca *et al.,* 2020); (Bryden, 2020); (IPA, 2018)

Figure 1 Awareness and adoption of P-DfMA



Benefits and Barriers of P-DfMA

Apart from the strengths, participants were asked to select top five benefits of P-DfMA. Figure 3 shows that all 20 participants aware of P-DfMA selected 'Minimized Waste' as one of their top benefits. As expected, "reduction in capital expenditure" was also selected almost by all (17). The remaining top benefits are Lower requirement of onsite workers (13), Increased productivity (12), and Improved H&S (9). Similarly, respondents were asked to select the top five barriers preventing the adoption of P-DfMA to understand the problems of non-adopters and adopters alike. Results are revealed in Figure 1 and indicates that "Lack of awareness" is a major barrier. Even though awareness does not usually translate to adoption as indicated earlier. Stemming from the fact that only a tiny percentage of those who claim to be aware of the technique are using it in reality. Many (19) expressed their concern on "requirement of project pipeline" for adopting P-DfMA, followed by "Lack of government assistance" (18), "Lack of government guidelines" (15), and "Lack of available training" (15), as a major barrier to adopting the technique.

Interviews

Four interviewees were interviewed in total. Demographics shows that two participants were a design manager and director with approximately 20- and 25-years industry experience. The other two were client relationship officer and computational designer with approximately 10- and 5-years industry experience respectively. Similarly, interviews were asked questions relating to adoption, benefits, and barriers to corroborate the findings from the survey. Emerging themes from the thematic analysis adopted are constraints, acceptance, and competence. For anonymity, respondents were denoted with Design Manager (AR), Computational designer (EN), Director (CO) and Client (CL).

Competence

All the interviewees agreed that the process saves considerable cost and time and is therefore very valuable. 'AR' exclaimed "This is a superfast process". However, 'EN' had an argument here- "The design process with P-DfMA took longer than the traditional way…But…Manufacture and Assembly phase ended before schedule". With respect to sustainability, there was a consensus that there is enormous reduction in waste, which was not so surprising as it was seen in both literature and questionnaire survey (IPA 2018; Alfieri *et al.,* 2020).

Constraint

Participants were questioned of any negative impacts of implementing P-DfMA. Based on nature of work, both 'AR' and 'EN' expressed their fear of structures looking very standardized in terms of aesthetics. Basically, their concern was to keep design very flexible and less prescriptive. 'CL' pointed out his fear saying, "few job/roles will be vulnerable to this change in approach". But later claimed that "…it will be mitigated with requirement to new roles". As expected, 'CO' was concerned with the blockage of capital cost and wishes a strong pipeline of projects where risk is worth. Interviewees expressed that this could be mitigated by government assistance. Though 'CL' disputed that Planning and building control bodies would need high level amendments to accommodate this. 'AR', 'CO' and 'CL' asserted also that government funding and incentives may help. Also, all of them mentioned that training and upskilling is highly required.

Acceptance

Participants were questioned about the success rate of this approach in terms of both awareness and adoption. There was consensus amongst all four respondents claiming that the awareness itself is very low. 'CL' emphasized that "…not a single client…has an existing knowledge about such thing". Keen to know what motivated them along with the changes and duration required for this implementation, productivity issue was raised. 'EN' and 'CO' highlighted their individual issues like lack of collaboration and repeated waste of time in coordination were the major reason that motivated them to change. 'CL' was convinced by an architect for his project estate as he had series of them upcoming. 'AR' reported that it took them nearly six months only after examining their internal organisational standards. He added, “We…implemented partially…it keeps on evolving over time”. Similarly, the organisation where ‘EN’ works embraced it quite rapidly. As ‘CO’ and his company were involved with the design of platform components, it took them 2 years in adopting it effectively. Incentives was highly concerning to all four respondents. ‘AR’ expressed that “…the risk is worth” if they get incentives for every project. “…incentives are required to lower risks”, ‘CO’ asserted.

CONCLUSIONS

A robust research investigation has been deployed to investigate the subject matter and fill the gap identified in the literature. After a thorough analysis, the awareness and adoption of P-DfMA approach is remarkably low and critical steps need to be taken to increase usage. There were surely some challenges and barriers observed in the literature and primary data, but many of them can be mitigated and the government has a critical role to play in actualising the wider use. The benefits of P-DfMA however cannot be over emphasised as demonstrated in the triangulated methods adopted and could help contribute to the delivery of the construction 2025 goal. A major recommendation, however, is a call for a stronger implementation strategy from the government plus stakeholders' awareness initiatives to facilitate adoption and success rate and could be a significant step in achieving the UK's build back better agenda if taken seriously.

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