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PLATFORM DESIGN FOR MANUFACTURE AND ASSEMBLY (P-DfMA): A UK REVIEW

Mikela Chatzimichailidou
Arup, Arup University, Global Research Faculty, London, UK
UCL, the Bartlett School of Sustainable Construction, London, UK

Abstract: *The UK government has been encouraging the adoption of digital and manufacturing techniques in government-led building projects to help drive better performance in the construction sector. The government's proposed approach to addressing these criteria is called "a platform approach to design for manufacture and assembly" or "P-DfMA". P-DfMA builds on the progress already made in several sectors, which use offsite construction. P-DfMA means that the construction sector will use a set of standardised and interoperable components and assemblies, the requirements for which will be part of a digital component catalogue. P-DfMA is underpinned by some initial yet significant research. This paper includes findings and future considerations based on the literature review in P-DfMA in the UK region. Despite the focus of this work being on the construction industry in the UK, there are lessons to be transferred across sectors and countries as well.*

Key Words: ***Construction, Information Management, Innovation, Modular Construction, P-DfMA***

1. INTRODUCTION

In 2017 in London a fire broke out in the 24-storey Grenfell Tower block of flats. 72 people died, more than 70 others were injured, and 223 people escaped. The investigation report [1] affirmed the exterior cladding was the primary reason the fire spread out of control, and that it did not comply with the building regulations. Accidents like the Grenfell Tower fire have shifted the way construction professionals see construction, at least in the UK; it is now recognised that there is an imperative need to consider construction systemically – as opposed to a series of competing or isolated objectives – and embrace its social relevance as well.

Following the Grenfell tower fire accident, the UK government appointed Dame Judith Hackitt to lead an independent review of building regulations and fire safety. In her report, 'Building a safer future' [2], Dame Hackitt recommended the introduction of a 'golden thread of information' as a tool to manage buildings as systems and allow people to use digital records to safely and effectively design, construct, and operate residential buildings. The UK government set out that the golden thread, as a digital platform, will apply to all buildings within scope of the new more stringent building safety regulations, being introduced through the Building Safety Bill [3].

The post-Grenfell reformed regulatory regime in Great Britain further established the importance of a holistic, lifecycle approach to drive a more responsible building industry [3]. These upcoming regulatory changes indicate that construction, either this is led by the government or by private firms, will have to change considerably both technically as well as culturally in order to be able to abide by the new legal requirements. In an attempt to prepare for such a radical change in the construction industry, the UK government has been publishing a series of reports as a roadmap for construction to adapt to the new reality. High quality, sustainable, resilient infrastructure is central to this government's vision for the future of the UK, as set out in the National Infrastructure Strategy and the Plan for Growth [4].

In one of the UK government's reports, the Infrastructure and Projects Authority (IPA) [5] argues that adopting digital and manufacturing techniques wherever appropriate in government-led building projects will help drive better performance in the construction sector and ultimately achieve the following key goals:

- increase productivity;
- drive innovation;
- develop and train workers in the skills they will need in the future;
- and improve the delivery, performance (including sustainability targets such as energy use) and information management of built assets to build a globally competitive sector.

Specifically, to meet the above criteria, IPA [5] have called their proposed approach "a platform approach to design for manufacture and assembly" or "P-DfMA". P-DfMA builds on the progress already made in a number of sectors which use offsite construction.

DfMA is a broad term that describes the process by which building products, or components, are designed in a way that enables them to be made on a large-scale

using machinery and then put together in one place. A platform approach to DfMA (P-DfMA) means that the construction sector will use a set of standardised and interoperable components and assemblies, the requirements for which will be part of a digital component catalogue. These digitally designed components will be used across multiple types of built asset wherever possible, thereby minimising the need to design bespoke components for different types of asset [5]. Contracting authorities should collaborate to find opportunities not only for their own platform solutions but also for ways in which cross-sector platform solutions can be applied, for instance, by using platforms that enable interoperability of components across different sectors [6]. For example, a single component could be used as part of a school, hospital, prison building or station [5].

In alignment with the above, the UK government published the Construction Playbook [6], which proposed solutions to "driving better, faster, greener". As an example, the Construction Playbook encourages the application of Modern Methods of Construction (MMC) [7] (e.g., modular construction) and the use of Building Information Modelling (BIM) solutions for a more efficient and sustainable construction sector. MMC and BIM are good examples of how P-DfMA can materialise in practice.

More recently, IPA published a report [4] around transforming infrastructure performance. Among others, it is argued that through platform approaches the government will generate greater societal outcomes from its pipeline, by enabling a disaggregated manufacturing industry that creates stable and inclusive employment across all regions of the UK. According to this report, P-DfMA approaches offer wider benefits than just improving project delivery. They open up the construction sector to a more diverse workforce by providing a safer and more controlled working environment than traditional building sites, particularly for women and people with disabilities, who have historically been underrepresented in the sector. With more work occurring in fixed factory and manufacturing facilities, fewer workers will experience the stress of leaving their families to travel around the country to work on building sites. This can provide a more stable working environment, regular income and employment, and reduce the stress and mental health issues associated with traditional construction site working which have been serious issues for the sector. Furthermore, future accidents like Grenfell Tower can be prevented as P-DfMA can address, among others, the serious problem of poor compartmentation and whole lifecycle accurance even in the simplest of construction forms.

Looking beyond the UK government's efforts and mandates, P-DfMA is already underpinned by some initial yet significant research. This paper includes results, findings and future considerations based on the literature review in the area of P-DfMA in the UK region. Despite the focus of this work being on the construction industry in the UK, there are valuable lessons to be learned and transferred between different industry sectors and countries as well.

2. PLATFORMS EXPLAINED

The term platform has been applied at a variety of scales including products, product systems, industry supply chains, markets, industries, and even across groups consisting of multiple industries [8]. Platforms present us with a new way of thinking about products, organisations and service delivery, drawing attention to a clear distinction between the stable core, variable peripherals and the interface between them [8]. Platforms can be physical or virtual, some are both and may vary significantly in size and scope. They can be contained within a single firm, or across a supply chain, while others are spread over ecosystems consisting of thousands or tens of thousands of firms. A platform approach is underpinned by the theoretical principles of open innovation, as participation in platforms depends on their 'openness'. More precisely, a platform is considered closed when it is hosted and exploited internally, i.e., within a single organisation. Accordingly, it is considered semi-open when it involves the supply chain and open when it encompasses a whole ecosystem [8]. Platforms provide organisations with the opportunity to create value by enabling them to meet market demand for variety, while still benefitting from economies of scale and scope.

According to the Transforming Construction Network Plus initiative [8], there are four types of platforms: platform organisations, product platforms, platform ecosystems and market intermediaries. The definitions are given in Figure 1 [8].

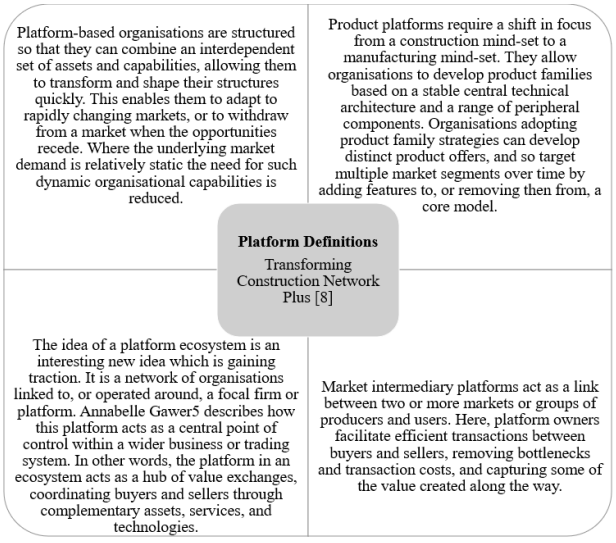

Fig. 1. *Definitions of platform types* [8]

In the construction sector, platforms are usually product platforms, but also require a culture and thinking, which resides in all types of platforms, especially when the product is a major or complex infrastructure system. To overcome the barriers – such as, lack of integration across the construction supply chain, lack of demand for modular structures, the risk averse culture, and skill shortages – posed by traditional construction practices [9], platform approaches should be encouraged and embraced.

As shown in Figure 2, a construction product platform consists of a kit of factory-made components

products and sub-assemblies with defined connections and interfaces. It generally includes a kit of parts and a kit of rules, which define how the parts combine and work together [10]. The parts fall into two categories: a set of core components which are re-used many times; and a set of peripheral components which can be changed or customised but adhere to the 'rules' in how they interface with the core components. Core components are standardised to meet a range of different user needs, allowing them to be configured for different structure types and sizes. The peripheral components are used to provide mass customisation, ensuring each structure is tailored to the specific needs of its users [10]. Furthermore, because the interfaces are defined already, there is less uncertainty and risk. When this is done digitally, many more options can be considered, each with the same high level of certainty [10].

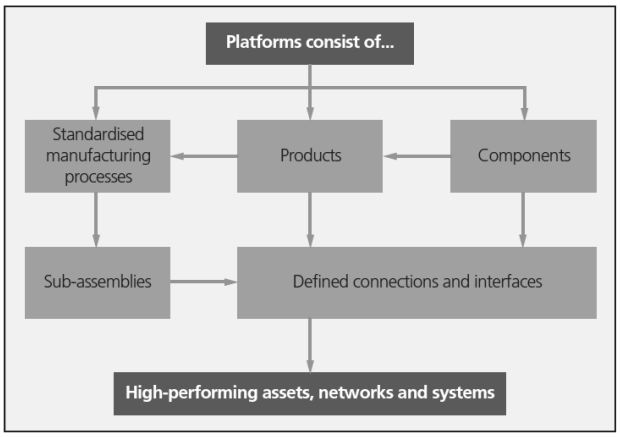

Fig. 2. *Constituent parts of a platform* [10]

Innovation changes the practices of design for on-site construction to component-based project delivery, changing skills requirements in the industry, reconfiguring manufacturing platforms and production systems to suit the fabrication of standardised components and presenting a significant shift from bespoke designs for projects towards undertaking designs within new parameters for interoperability. Innovation also changes existing logics for design and construction processes in the industry [11].

3. LITEARATURE REVIEW

The UK, Singapore, and Hong Kong are among the first countries to have identified DfMA as the way to transform the construction industry. Leading organisations and institutions are collaborating around DfMA as a philosophy and a methodology whereby products are designed in a way that is as amenable as possible for downstream manufacturing and assembly [12][13]. In the UK, the Royal Institute of British Architects (RIBA) [14] and the Infrastructure and Project Authority [5], are laying out the principles, processes and standards to achieve DfMA, but digital-enabled platforms for DfMA (P-DfMA) are just starting to emerge [15]. In the literature, there is only a handful of peer-reviewed scientific papers that investigate P-DfMA. The list of papers reviewed for the purpose of this paper is presented in Table 1.

Table 1. *List of per-reviewed scientific papers focusing on P-DfMA*

#	Title	Year	Publisher
1	Automated construction: boosting on-site productivity using a platform-based approach	2019	Institution of Civil Engineers
2	Inside the government's plan to standardise school design for offsite	2019	Journal of Construction Research and Innovation
3	BIM-enabled Design for Manufacture and Assembly	2020	International Workshop on Intelligent Computing In Engineering
4	Construction kits: a platform for improving how civil engineers deliver infrastructure	2021	Institution of Civil Engineers
5	Digitally enabled modular construction for promoting modular components reuse: A UK view	2021	Building Engineering
6	Transforming the construction sector: an institutional complexity perspective	2021	Construction Innovation

A high-level observation from Table 1 is that relevant literature is very recent (i.e., since 2019) whereas all scientific papers succeed reports published by the UK government, proving that research traditionally leads the way.

3.1. Applications

At the Autumn Budget 2017, the UK government announced an investment of £170 million to support innovation and skills development in the construction industry via a platform approach to design for manufacture and assembly, called "P-DfMA" [5]. In the same year, the UK government committed to "use its purchasing power to drive adoption of modern methods of construction". This culminated in the announcement of funding by the Construction Innovation Hub. The Construction Innovation Hub[1] is currently developing a toolkit and guidance on how to implement value-based procurement that promotes social, environmental and economic value across the life cycle of the asset [10]. The government also announced a call for evidence[2] on its proposal for a new approach to building.

In response to this call for evidence, the Royal Institute of British Architects (RIBA)[3] has called on the

[1] https://constructioninnovationhub.org.uk/
[2] https://www.gov.uk/government/consultations/proposal-for-a-new-approach-to-building-call-for-evidence
[3] https://www.architecture.com/knowledge-and-resources/resources-landing-page/platform-approach-to-design-for-manufacture-and-assembly-consultation-response

government to work with architects to ensure that its approach to developing P-DfMA is not prescriptive but builds in flexibility, facilitates the creativity of designers and supports innovation. According to RIBA, understanding and adopting the P-DfMA approach requires all professionals across the built environment to develop the necessary skills more widely.

P-DfMA was developed to support off-site construction and build on the progress already made by a number of sectors that use this method of construction. Since 2017, assets such as schools, hospitals, and prisons have been constructed using modular construction methods, giving suppliers confidence to expand into the market while supporting the delivery of high quality, energy efficient buildings [9].

P-DfMA was first developed and prototyped in the UK prison estate transformation programme for the UK Ministry of Justice, although for commercial expedience (i.e., commercial behaviours and procurement models) it was not implemented [16]. As part of this programme, Beaumont [17] performed an independent review based on data provided by the Ministry of Justice on capital projects completed using pre-cast concrete modules. According to this study, a platform approach adopted for prisons could reduce capital cost of assets by 33%, reduce the overall time from inception to completion by 50%, reduce greenhouse emissions from the built environment by 50% and improve exports by 50%. While benefits like improved cost and speed of projects are important, it's crucial that the government recognises the primary importance of also improving the quality of what is delivered.

Bryden Wood, a UK-based international company of architects, engineers, technologists, designers, and analysts developed the idea behind P-DfMA, which is now supported by the UK government as part of its drive towards the greater use of offsite manufacturing mainly in public sector construction projects. The UK Ministry of Justice appointed Bryden Wood as an integrated designer – incorporating architecture and structural, civil, mechanical and electrical engineering – for its UK prison estate transformation programme in 2017. This created an unprecedented opportunity to master platform approaches, as the Ministry of Justice is an advocate of building information modelling (BIM) and lean construction and has a large pipeline of construction over a long period [16].

The plan originally was to build 10 new prisons, built with just two principal platforms. Platform 1 was specifically designed to create accommodation blocks, which make up 63% of a typical prison estate. Built to accommodate the prisoners, these blocks shared many features. The grids and corridor size were always the same, with the flexibility to add a wing or a floor during design development or for later expansion. Platform 2, comprising 18% of the estate, had to be more flexible and respond to a wider range of building typologies; for example, the entrance building, health centre or a light workshop [16].

Moreover, virtual reality allowed exploration of the proposed building layouts so a governor, for example, could look at lines of sight in a virtual prison, with live design changes being made there and then. Fully integrated three-dimensional models and consistent data helped in removing errors as early as possible and reducing cost by minimising risks. Intensive asset-information requirements were met through open BIM processes. This allowed the generation of data associated with each component inside the models and ensured that all other project teams were able to use the models, while a centralised BIM library helped ensure consistency of design and data [16].

By centralising government procurement through a platform approach, which is no longer constrained by building type, significant savings can be introduced [16]. High volume also makes the efficiencies of purpose manufacture possible, avoiding the waste involved in cutting stock lengths of beam to size, drilling holes and welding fittings. The standardised high-volume approach of P-DfMA warrants the investment in design to create high-yield material utilisation [16]. Besides, laser cut connectors enabled a faster and more accurate assembly and units could be used for multiple purposes. In this project, steel components were designed to be as light as possible, so in assembly this meant that two people could manually move steel items on site. This, together with DfMA, removes the use of expensive tower cranes which are slow to erect and dismantle, potentially reducing on-site productivity [16]. The platform also enables a catalogue of digital components with the structural performance range embedded within the software. Once the designer has picked a component, the software will identify others such as beams or connectors that can successfully work with it [16].

This project also added considerable social value. The platform construction work allowed prisoners to be trained in assembly techniques, gaining accredited skills and qualifications for future use. The skills learned are applicable to all other projects built with that platform, regardless of the building type. Those involved were highly engaged with the work and gave positive feedback, which could have huge implications for rehabilitation [16].

There clearly is a balance between working within the constraints of a platform system and the creation of a new one. Despite the innovative design of the platform approach, the Ministry of Justice decided to revert to a traditional construction approach [16]. This was partly due to the scope of works for the platform being reduced from ten prisons to just one, resulting in a loss of scale, but a mismatch with traditional procurement and commercial models played a bigger part [16].

Schools in the UK were also used as a testbed for P-DfMA. A consortium called Seismic[4] was launched in 2019 and funded by public body Innovate UK[5]. The consortium comprises construction consultants Blacc, technology-led design practice Bryden Wood, major offsite construction firms Elliott and The McAvoy Group, and state-funded innovation organisation the Manufacturing Technology Centre[6].

[4] https://gtr.ukri.org/projects?ref=106165
[5] https://www.ukri.org/councils/innovate-uk/
[6] https://www.the-mtc.org/

The consortium has developed an open-source web app to let teachers configure new primary school buildings based on P-DfMA, or other forms of offsite construction. And in a major break from proprietary offsite solutions, each protected by intellectual property rights, Elliott and The McAvoy Group co-developed interoperable steel frame components with common dimensions for use on school projects. In a similar manner, as in the UK prison estate transformation programme, the resulting standardised arrangements were uploaded to a digital library for users to draw on when preparing designs. Different overlays provide feedback on the suitability of different construction systems, whether schools are being delivered traditionally, or as a volumetric or P-DfMA solution.

P-DfMA was also investigated by the Greater London Authority, which commissioned a "Manufactured Housing Design Code"[7] to catalyse the uptake of standardised offsite manufacturing in response to the housing crisis. Benefiting from Innovate UK funding, a partnership – the COLAB consortium[8] – led by L&Q (alongside Virtual Viewing, Hawkins\Brown Architects and HTA Design) has set out to develop a digital design for manufacture and assembly (i.e., P-DfMA) toolkit that has the potential to transform the way homes are designed and built in the UK. The toolkit demonstrates how DfMA methods and technologies can be used in practice to solve the housing crisis, advance the uptake of off-site manufactured products and bring the benefits of design standardisation in the construction sector.

The UK government has taken the industry to a point where it can make a leap forward. The better value for money, productivity and certainty the government wants is within reach, as are lower carbon dioxide emissions, less waste, more high-quality jobs and a safer consturction sector both for workers and the end-user as well. All that can come from P-DfMA and, if the industry gets it right, the UK will become a world leader in technology driven construction [16].

3.2. BIM-enabled P-DfMA

Homes England [18] suggested that the uptake and development of innovative and modern methods of construction, alongside developments such as digitalisation in the design and construction processes, have the potential to transform the construction processes. The integration of modular construction and BIM can be a vital measure for adapting to the changing environment, which demands better management of resources and assets, and higher productivity in the sector [9]. This statement was building on the momentum established by the Level 2 BIM programme that was designed to operationalise this integration using BIM technology mandated in the 2011 Government Construction Strategy [19], and later embraced by Construction 2025 [20] and the Construction Strategy 2016-20 [21]. BIM is a smart technology that has the ability to digitally represent the physical and functional characteristics of a built asset, and to enable the coordination of information regarding the design, construction, and handover to operation/maintenance of the asset [9][22].

Tan et al. [23] performed a literature review around DfMA design optimisation studies and explored their combination with BIM and intelligent technologies. This literature was mainly concentrated on the level of engineering efficiency of manufacturability and assemblability. This study showed that uses of BIM-based DfMA (i.e., P-DfMA) included the use of BIM: (1) to enable the process of DfMA; (2) as a tool for DfMA; (3) as an information source / model for DfMA. In addition, construction-oriented DfMA can adopt intelligent technologies which has been introduced into manufacture-oriented DfMA to tackle similar issues. However, Tan et al. [23] argue that further research is needed to:

- Combine historical data and machine learning algorithms, supplemented by expert opinions to form a hybrid approach.
- Optimise for whole building architectures (e.g., complex healthcare, airport, transportation hub and so on), rather than single building components.
- Compare different BIM-based DfMA strategies at different prefabrication levels (e.g. the higher the prefabrication, the higher the demand for manufacturing, and less on-site assembly).

3.3. P-DfMA considerations and benefits

The lessons learned from the different UK-based applications of P-DfMA are as follows [16]:

- It is easier to test and validate on a smaller scale, and work with a smaller, more agile group.
- Prototyping is very effective; it offers the luxury of trial and error. Moreover, it engages stakeholders by giving them something physical to interact with. For traditionally built buildings, such interface testing is not carried out, and when it is, it is carried out on the final building, correction of any errors is difficult, time consuming and costly.
- New ways of working must run through the whole supply chain. From steel manufacturers to carpet tile suppliers, risk must be managed so that all parties can make their best contribution and be rewarded for it through protected profit margins.
- Hiding risk is not the same as negating it. Risk has to be priced in somewhere and owned by someone.
- The design becomes a soft target for slower adopters to change but masks the cultural barriers which harbour silo-thinking.
- Open source is beneficial to create an approach that goes beyond a single project; collective users need to adapt and co-create new solutions.

[7] https://www.london.gov.uk/sites/default/files/london_assembly_osm_report_0817.pdf

[8] https://constructionmanagement.co.uk/lq-plans-offsite-growth-with-new-digital-toolkit/

- Digitally designed and factory made, platform components apply high quality manufacturing principles, so reducing waste [10].
- Designing and building using common standards and components means consistently higher-quality assets; structures can also be reconfigured to meet changing needs in future, whether that is a new use, extra space or downsizing [10].

There are also potentially far-reaching social benefits for communities. Where manufacturing hubs are located in deprived areas, P-DfMA can boost local economies and provide safe, secure and accessible employment in locations that desperately need it. They also help address the industry skills deficit, freeing up skilled labour for skilled work [10]. People can be trained to assemble components in weeks and develop those skills as they work, so training is much less lengthy than that required for traditional trades. That is transformational for groups such as the unemployed, the homeless, the disabled, military personnel and prisoners. The P-DfMA system, however, is not intended to displace skilled workers but to focus their skills on aspects of building which are in greater need of these skills, leaving much of the structure to be installed by a more general skilled work force, increasing productivity [16].

In the safety realm, P-DfMA reduces dangerous tasks, such as working at height. This is particularly important given that in 2018, the UK construction industry's mortality rate was four times the all-industry average and the trend remained the same until 2021[9] [24]. Instead, sub-assemblies such as a ceiling cassette can be put together at ground level before being lifted into position using simple lifting aids [16]. When it comes to infrastructure operations, P-DfMA can support the entire system's assurance. Approaches like P-DfMA, because they digitally enable the integration of many systems and stakeholders, can assure the whole infrastructure, not just the sub-system it is retrofitted with. For instance, in the case of the Grenfell Tower fire, an approach like P-DfMA could have anticipated safety hazards that arose from the interfaces between the new cladding system and the rest of the structure as well as the old fire escape plan and equipment. Moreover, the use of P-DfMA could have offered traceability of safety-related requirements, decision and regulations that adds transparency, sheds light to accountability and supports a real-time response to life-threatening conditions.

4. DISCUSSION

The UK government has been encouraging the adoption of digital and manufacturing techniques wherever appropriate in government-led building projects to help drive better performance in the construction sector in terms of increased productivity, innovation, upskilling and reskilling of workers, delivery improvement, social value and sustainability, better information management of built assets.

Moving to a P-DfMA approach could create significant benefits for British manufacturing. An important way of making this approach more acceptable to communities would be to ensure that the benefits are captured by local suppliers. There will inevitably be concerns about losses to traditional construction jobs through a new approach [14].

There also implications for highly skilled construction professionals. Jones at al. [25] highlight some implications for project managers that can result from adopting a platform approach to the delivery of complex assets. Typically, projects deliver bespoke assets to clients' often emergent and changing requirements by designing, specifying, procuring and integrating multiple systems and subsystems. In an environment where multiple firms develop proprietary building platforms, the task of system integration is already done, and supply chains are already established. As a result, many key risks are already addressed. The project manager's role then changes, to become one of helping clients to choose between platforms (each with their own delivery managers), rather than selecting and integrating the work of specialists [25]. The implementation of platforms in delivering buildings depends on shifting from a project-based delivery to one that is more product-focused, shifting and changing the role of the project manager and potentially of other roles.

Looking beyond individual roles, the government's approach to procurement requires a radical overhaul. Existing preferred methods of procuring through design and build contracts will need to be replaced with something new that is appropriate to a P-DfMA approach. The government must lead in developing a new way of procuring that focuses on a holistic view of value, including social outcomes, over best price [14].

Intellectual property is another serious concern for organisations that take on a P-DfMA approach. There are issues in the context of individual small components as it's difficult to say where intellectual proporety (IP) lies. The key consideration should instead be on how each company exploits these components to deliver optimum results, which should be their IP. The value of an organisation should lie in how components are used, not the components themselves [14].

Regarding safety regulations, introducing simplified building standards to accommodate a P-DfMA approach needs further clarity as to what this means in practice. Currently in the industry, and following the Grenfell Tower fire, there are serious concerns that not enough is known about fire performance of the junctions between modular systems [14]. The Edinburgh Schools Inquiry, Grenfell Tower fire and various industry groups on build quality have highlighted the serious problem of poor compartmentation even in the simplest of construction forms. This is an area that requires greater attention if this approach is to be adopted on a large scale.

Digitally enabled P-DfMA can facilitate the concept of the 'golden thread of information'. By definition, P-DfMA is a system's approach to infrastructure development and management as it allows people to use digital records to safely and effectively design, construct, and operate buildings and infrastructure altogether. It is also an integrative approach because of its inherent capacity to deal with technical and organisational complexity. P-DfMA puts emphasis on systems

[9] https://www.hse.gov.uk/work-at-height/index.htm

integration by establishing conditions for success right at the start of a project, as opposed to identifying and mitigating failures late in a project life cycle.

5. CONCLUSION

Carlisle and Webb [10] said: *"Currently, most infrastructure is created by way of individual projects, each conceived and delivered using unique designs and supply chains, and constructed on site by workers who are out in the elements in all seasons. What if multiple projects were instead delivered together in coordinated programmes, to the same exacting specifications for quality and performance, using processes geared to be significantly more efficient and safer to construct?"* This could be possible through the adoption of P-DfMA as discussed in this paper.

P-DfMA aims to embed a more strategic approach to offsite that fully capitalises on the economies and efficiencies of scale offered by manufacturing processes. It is a digitally driven approach to construction that bridges the gap between manufacturing and construction, contributes to economies of scale, reduces waste by as much as 90% [16], increases productivity and at the same time retains sufficient flexibility for architectural freedom [16].

In the UK, the P-DfMA concept is being led by IPA and involves the development of a set of standardised and interoperable components that are digitally designed and manufactured for use across multiple building types, from homes to schools, to hospitals and prisons. The idea behind it is that the same components would be produced by different manufacturers, helping drive innovation and create a more sustainable market. Designs can be "mass-customised" to give architects greater scope for creativity, without having to compromise their designs to reduce costs, compared to existing MMC.

Ultimately, this paper is the first step to explicitly pursue the idea of adopting P-DfMA in government-led (and beyond) major and/or complex projects, without however overlooking the potential pitfalls. This paper presents the lessons learned from the UK experience so far and envisages to encourage similar or comparative studies across the world that consider regional nuances while aiming for a global alignment.

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CORRESPONDENCE

Dr Mikela Chatzimichailidou
Arup, Arup University
Global Research Faculty,
8 Fitzroy Street
W1T 4BJ London, UK
mikela.chatzimichailidou@arup.com