ADDRESSING DESIGN MANAGEMENT CHALLENGES THROUGH THE DEVELOPMENT OF A WEB-BASED PLATFORM

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Construction Design Management (DM) involves the coordination of design process and activity to ensure quality project design, yet it involves many challenges. This work reports on a collaborative Knowledge Transfer Project (KTP) with a Case Study Organisation (CSO) that - in the spirit of the 'Building Back Wiser' ARCOM 38 call - innovatively tackles existing DM challenges. In doing so, selected DM processes were digitalised to improve efficiency, and productivity. Mixed research strategies were employed. Qualitative analysis of semi-structured interviews with purposively identified design managers uncovered real world concerns around design coordination, and designer performance monitoring. Then, through design science research (DSR), a web-based design management prototype platform was developed. This uses typical project data to aid design coordination activity and facilitate DM task prioritisation and reporting functionalities. Its visual reporting capability enables design production to be monitored; trends in designer performance to be assessed and focus to be retained on technical queries (TQs) and requests for information (RFIs). Construction productivity and effectiveness can therefore be enhanced if supported by appropriate digital platforms.

Keywords: design management; digital; information management; innovation

INTRODUCTION

High quality asset design provides value to organisations, owners, and end users in the construction sector. Design creation involves managed interactions between project stakeholders and takes participants from an initial vague-unknown position to a subsequent known-and-desired solution. This process results in a set of collated information, involving drawings, specifications, schedules, and digital models, from which tangible assets can be constructed. Design management (DM) therefore involves the management of project-related design activities, processes, people, and other resources to enable the effective flow, and production of design information.

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However current project-delivery approaches regarding the management of design, remain problematic. One persistent concern regards the separate perspectives held by project actors around what successful project delivery is, because of various project time, cost, and quality targets.

Hence, without effective decision support systems, DM approaches may not always be focused on realizing desired project outcomes (Eynon, 2013). An additional issue revolves around how achieving such collaborative and integrated working across a temporary project organisation (TPO) has usually been a messy, and 'analogue' coordination process involving process waste. Bolpagni *et al. (*2022) discuss how in Industry 4.0, because of an increasing adoption of digital design through the likes of Building Information Modelling (BIM), such information-rich content could be much better managed through more digital means. In brief, BIM involves creating a digital version of what is to be built, and then using it as the basis for construction. Using specialist computer software, designers create a three-dimensional (3D) model, that is an exact, rather than approximate representation of the asset. Succar, (2009) initially suggested that BIM would provide "…technological and procedural shift" within construction, and Gledson (2016) later identified its impact as "the most prominent radical, transformative and disruptive innovation to hit the construction industry".

Again, because of the increasing adoption of digital design through the likes of BIM, information-rich content can now be much better managed using more digital means. The aim of this work therefore is to report on the development of a bespoke digital web-based platform intended to enhance the efficiency, productivity, and ultimately the effectiveness of the design management function. It intends for better realisation of construction projects, through digitally supported design management (DsDM) functions, by way of a standalone dashboard, that uses data processing to better manage information, facilitate good evidence-based decision-making and drive project performance. Before discussing the discrete DM functions targeted by the prototype dashboard, some inherent problems in the conventional design process, the value of the design management role, and how it could be enhanced through use of project data analytics, are now discussed.

LITERATURE REVIEW

Gledson (2017) summarises various inefficiencies in design processes that, ultimately leads to inherent problems in the existing design management process. At project inception, lead designers first establish the nature of the design problem at hand be it 'well-defined', 'ill-defined' or 'wicked' (Churchman, 1967; Emmitt and Ruikar, 2013). To do this, they extract early non-formalised requirements through guided client interactions, to try to ensure their needs will be met. Tisani (2007), describes the information flows that occur in current design processes and identifies inefficiencies including: poor capture of formalised building requirements; rigidity of design process flow; compartmentalised decision making; lack of fidelity; minimal opportunities for design experimentation; lack of accommodation for late design changes and lack of design automation.

Dictated by selected project procurement strategy, a set order of the design activities to be carried out, before the information can be transferred down to other project participants is undertaken. This fragmented approach to managing design flow was criticised by Anumba *et al. (*2002) who notably referred to this as the 'over the wall' approach. Once each area of design has been produced, the recipient of design information must interpret the information to be able to make judgements. Because of

the quality of design available to them, they may also have to make several assumptions which may lead to misinterpretations. The receivers of information will also need all the multiple project views available and correct to the latest versions to fully understand the design. Checking is done to ensure the design is 'clear', 'correct', 'consistent', 'coordinated' with the associated design information (which may have been created by another producer) and is 'complete': To carry out these checks properly is time consuming and requires expertise, discipline, and judgement. Such talents are rare and on fast-moving projects, fundamental mistakes are often made (Crotty, 2012). More effective digital project decision-support systems could therefore benefit the process of checking and coordinating design information.

Cidik and Boyd (2020) recently warned against the narrow, but commonly held view of design coordination involving only the integration of separate design outputs by fragmented design actors, and instead emphasise the "shared sense of purposefulness" that the design team members should have. Regardless, because several design disciplines provide input into even the most basic of design activities, their co-ordination requires much time and skilled resource. Without a dedicated design manager to ensure fit-for-purpose design quality achieved, design coordination can be inefficient and ineffective. Current means of generating and managing construction project design - even when using the likes of BIM - can therefore be inefficient and ineffective without such a dedicated role providing the necessary oversight. Whilst the focused use of BIM can facilitate improvements in conventional design processes, concerns persist around how use of such design tools enhance design quality. Therefore, greater focus on the DM role, and how it can support design quality by better use of digital project information is welcomed.

Savolainen *et al. (*2018) recently acknowledged the role in value creation that design management plays. Depending on the procurement route used, and with reference to the RIBA Plan of Work 2020, Design Managers can be substantively involved across Stage 1 'Preparation and Briefing' through to Stage 6 'Handover' of projects. Again, depending upon procurement mechanisms, they can be involved in activities as diverse as: preparing and monitoring design programmes, undertaking design reviews, coordinating the development of technical designs, and resolving technical and site-based queries. Recently, various researchers (Jacob and Varghese, 2018; Sutrisna and Goulding, 2019) have reviewed design processes interactions, and identified concerns around quality of information flow and information exchanges in DM processes. Similarly, Uusitalo *et al. (*2019) and Uusitalo *et al. (*2021) investigated the roles between design and design management actors in construction project contexts, specifically regarding information flow and solving design quality problems. These researchers ultimately found that project teams should look to better enhance ways of communicating and collaborating when managing design. Ultimately, much of knowledge base has hinted at how better use of project information could be enacted digitally to enhance construction practice. To that end, this specific project makes use of Project Data Analytics to better support design managers in their role.

Project Data Analytics

Various forms of project data analytics exist. These include low autonomous/intelligence Robotic Process Automation (RPA) tools such as transactional 'bots' to much vaunted, high autonomous/intelligence narrow/general Artificial Intelligence (AI) solutions (APM, 2022). Application Programming Interface(s) (API), also enable data analytics to occur via connections between

computers and software applications. Given the range of design management processes it was identified that a range of DM functions could be digitally supported through Project Data Analytics by creating a DM solution. Specifically, this project made use of API analytics via a web-based project dashboard interface to digitally support a range of design management (DsDM) functions. In this work, we describe only a selection of these below, including opportunities to:

- Allow better coordination and management of design process interactions, as captured through Technical Queries (TQs) and Requests for Information (RFI) mechanisms
- Ensure that the design team are aware of and maintaining their design delivery programme and focusing on their critical design priorities, through better monitoring of planned design release against actual design production

METHOD

Descriptive research is to accurately portray the likes of events or situations (Saunders *et al.,* 2009). This descriptive research reports on the results of a collaborative industry-academia Knowledge Transfer Project (KTP) with a Case Study Organisation (CSO). This work involved mixed strategies, whereby survey research, was followed by design science research (DSR). To be exact, initial semi-structured interviews were held with 9 purposively identified design managers, to uncover first-hand, real world DM concerns and validate these against challenges identified in the knowledge base. Data from these interviews were analysed using Nvivo Software (See Table 1 for Themes). Then, by way of DSR, a web-based design management platform was developed. This tackled some of the identified challenges of the DM role by digitalizing selected design management processes to better manage data and information, facilitate good decision-making, and improve the efficiency, and productivity of this role. The specific results of each stage are reported separately below.

FINDINGS

Qualitative interviews

At the outset of the collaboration and to obtain funding, various supporting statements were obtained from design management or DM adjacent practitioners to justify the project. One important statement advised: “Design management plays an increasingly important role in projects as it uniquely crosses the boundaries between the quantitative/process related issues dealt with by project management colleagues, and qualitative design related issued being delivered by the design team. The benefits to the user that a central dashboard where project decisions can be made and presented to the client provide [include those of] challenging the delivery programme by utilizing data, and [of] digitizing analogue processes”.

This reveals that better project data analytics can assist the design management function. After project award and following an initial ‘Situational Awareness’ phase (Project Stage #1), ‘Problem Definition and User Requirement gathering’ (Stage #2) activities occurred. This involved a review of the knowledge base, followed by online interviews with 9 design managers. A mass of qualitative data was obtained from these interviews, which were then thematically analysed. As evidenced in Table 1, several interrelated DM challenges were revealed, however this present work focuses only on some of these, which were ultimately addressed by specific functions within the web-based design management platform. These being the creation of: digital

TQ/RFI systems (to support challenges of communication, coordination, information flow and decision making), and the digital tracking of designer performance in the production of their project deliverables (similarly, to support challenges of coordination, information flow, efficiency, and value):

Table 1: Identification of DM Challenges arising from interviews quantified via CAQDAS

Process	Parts.	Refs
Information Flow	9	112
Coordination	9	72
Decision Making	9	71
Communication	5	31
Efficiency (i.e., accomplishing output, minimising waste).	3	7
Trust	3	5
Value	3	5

The challenges of design coordination and information management
Participants revealed how better coordination and improvements in the management of design process interactions as captured via conventional 'Requests for Information' are needed: Participant 9 discussed one specific element of works on one of their projects was affected by this: "I've had 250 RFIs on site that I've had to deal with. Had, 20 days of site delay, and we've had to make 25 changes on site, to er, cable and drainage, and such". The impact of such, seemingly difficult to manage: "…you are sitting there, dealing daily with a million RFIs that are coming in from your site managers … I don't know how many days on site have been wasted, and I don't know how many RFIs have been generated from it…" (Participant 9).

Participant 4 also revealed the need for better digital management of project RFIs: "As an example, if I asked for a schedule of RFIs from a project, 'tell me how many there are', it will probably take them two weeks to extract those RFIs into an Excel sheet, [that] won't give you very much, whereas if I could get and use that data to influence and understand it, I can then link it to things like programme or whatever we need to do with it." Participant (#4) also understood how project data analytics could further aid the production process: "[Regarding] outstanding RFIs, TQs, from subcontractors, clients or whatever it is, if we can see those outstanding issues on a dashboard and their dates … if we can get everybody to think about the priorities in relation to time, and they can see those clearly through a dashboard … we can build it properly". Across the interviews, challenges of communication, coordination, information flow and decision-making concerned DM practitioners. These were ultimately addressed through the creation of a digital RFI system, as discussed in a below section.

The challenges of ensuring design team maintain their design delivery programme
Regarding the production of design programmes, existing situations were outlined: "I would ask the consultants to produce a list of deliverables, whether drawings, specs, whatever they are for each construction package and when they need to be released". (Participant 2). These are incorporated into an agreed design programme, or an Information Release Schedule (IRS) which is set out with activities and timings, "…then that would be monitored by the architects and myself. I would speak with the architect every 2 weeks [for a] progress update (Participant 1). This is then monitored: "If it's as the plan, everything's fine. If they're slightly behind we need to monitor the impact of that on the design coordination, making it all fit, which then

goes on to procurement … we then must monitor that and make sure procurement is linked into build." (Participant 1).

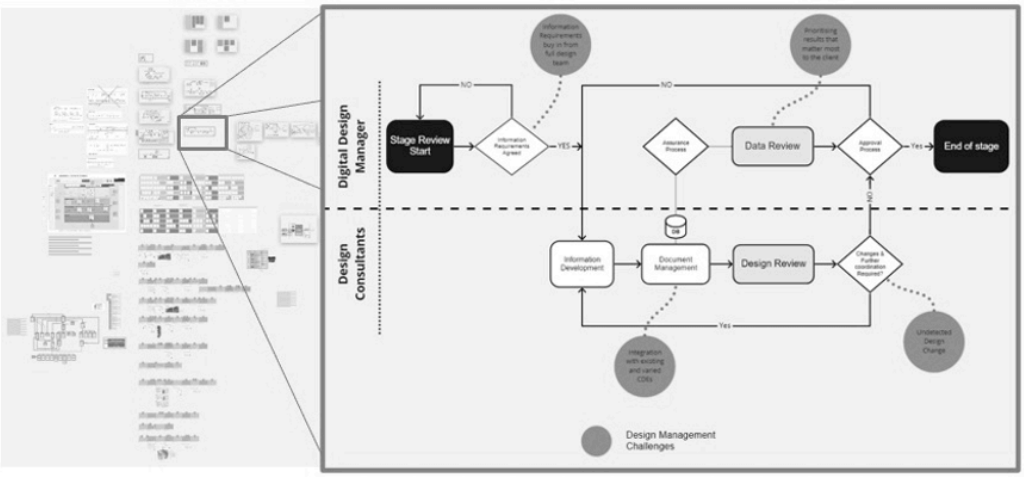
Once design information released: "…it would be a simple case of just going through the [common] data repository that they would upload it to, and it would be a simple matter of just going through and checking that those drawings and those schedules or specs have been received (Participant 2). As to any problems with existing process, designer performance in terms of design release against agreed design programmes was a frustration: "… and the day comes and the deadline comes and next Friday turns into Monday, turns into sort of Wednesday and by the next Friday … erm, if they're late, that's recorded." (Participant 1). Using current existing process, the design manager is often in a reactive state, whereas participants would prefer they were able to be more proactive: "The biggest challenge we've had consistently for the past two years has been design managers not being process managers, not really [being able to] actively influence procurement or design programme progress." (Participant 4).

Ultimately, what participants wanted was to be able to better track and manage designer performance: "I want to see [visibility from] the design manager, the key challenges they're having on the project. I would like to see how the design and procurement programme and the project programme is working, against the [designers] own actions, what they're doing, and I'd like to see [from designers], erm an element of compliance, (Participant 4). Again, across the interviews, challenges of coordination, information flow, efficiency and value creation concerned DM practitioners. These were ultimately addressed as discussed in a below section, through the creation of a digital system, for better tracking of designer performance in the production of their project deliverables.

Results of DSR: Platform Development

Following the prior 'Problem Definition and User Requirements' stage (#2), the present 'Problem Solving, System Design and Development stage (#3) occurred. The main activities in this stage involve the design of the DsDM process itself, and the iterative and agile design and evaluation of the bespoke DsDM platform, its functionalities and user interface occurred. Summary details are here provided. Regarding process review, and design of the DsDM, over the duration of the project these aspects were continually storyboarded and refined using online collaborative tools such as the Miro service. Figure 1 illustrates this 'design mapping', which ultimately identified 'what' needed to be done in the design and development tasks.

Figure 1: Extract of Design Manager User Journey from Design Mapping



Thereafter, 'how' the DsDM platform would be iteratively designed and developed was determined. Indicative system architecture for this is evidenced in Figure 2. The developed DsDM platform draws upon relevant project data to aid design coordination activity and facilitate DM task prioritisation and reporting functionality. It enables useful visual reporting capability that, in turn: allows focus to be retained on priority Technical Queries (TQs) / Requests for information (RFI), and enables design production to be monitored, and trends in designer performance to be assessed.

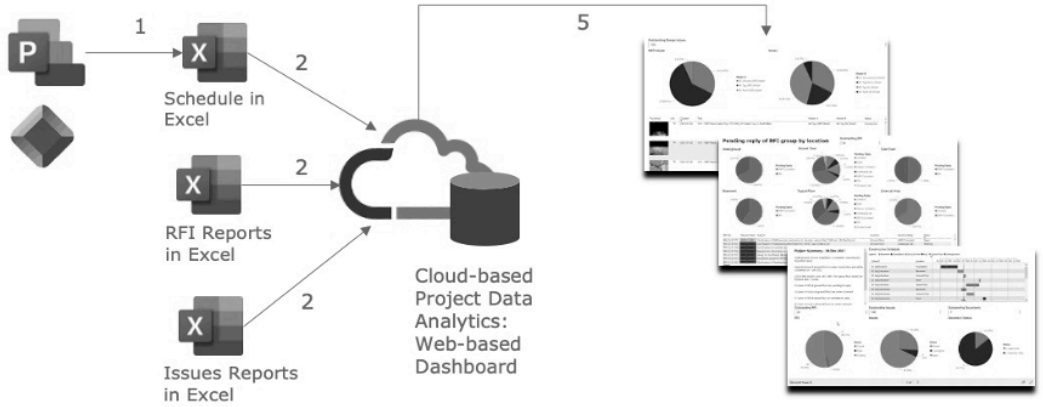


Figure 2: Indicative System Architecture

Addressing challenges of design coordination and information management through managed RFIs

Currently, individual RFI's (and/or TQs) are generated and issued in many different formats (e.g., by typed word docs, or handwritten memos etc). The key contents of these are then typically captured and aggregated via excel-based registers by DM personnel. The DsDM web-based dashboard allows for uploading of these summary reports to a project Common Data Environment (CDE), so as to host and visually present key information from these for review, onward routing and ultimately addressing. However, the web-based dashboard does not just host conventionally created TQs/RFIs. On this project the team also developed a new web-based form and associated cross-platform mobile app that allowed for electronic queries to be created 'on the go' (e.g., whilst on the jobsite), and uploaded to respective TQ / RFI schedules via ubiquitous computing tools such as a laptop computer or mobile cell phone device. Post issue, an autogenerated email is sent to advise the Design Manager of new queries, who in turn can route these on to the best placed project actor(s) to address the particulars. Using a programmed workflow to automate the task, total TQ/RFI data ultimately gets synthesised within respective schedules schedule overall so that better management and control of all project TQs and RFIs occur. Figure 3 gives an indication of this, showing how via analytics, Stage 5 RFI data is presented visually, and therefore more meaningfully in the web-based dashboard so to add value to the design management process.

Addressing challenges of design delivery programme

Presently, although design programmes are routinely prepared on projects, the accurate monitoring of designer performance in terms of if/how targeted design release dates are met by designers is unsatisfactory. Similarly, because of a long subsequent chain of activities following design release, project-decision makers are too often unaware of the impact upon the project of poor performance by designers in terms of the planned vs actual design release dates. This is because, after design

release is achieved there follows various: design approval(s); subcontract package procurement; subcontract award; and subcontractor lead-times; before trade contractors start their work packages on site.

Therefore, without being explicitly aware of these logical relationships it can be difficult to see how dates that are missed by designers, can impact upon planned start on site dates several months later.

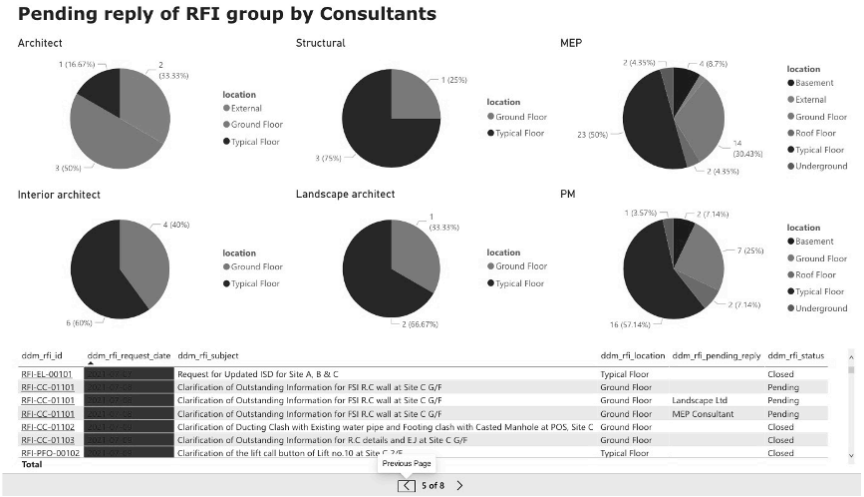


Figure 3: Indicative constructions stage RFI analytics

Current approaches to tracking performance against Design Programme do not clearly reveal this impact, or indeed longer-term highlight trends of continually missing dates. These often involve tracking via excel based 'Information Release Schedule' (IRS) forms. The DsDM web-based dashboard corrects this by using such excel based data to better visually presenting such information for trend analysis and uses programmed workflow to semi-automate this activity. Figure 4 gives an indication of how via analytics, such data is presented visually, and therefore more meaningfully in the web-based dashboard so to add further value to the design management process.

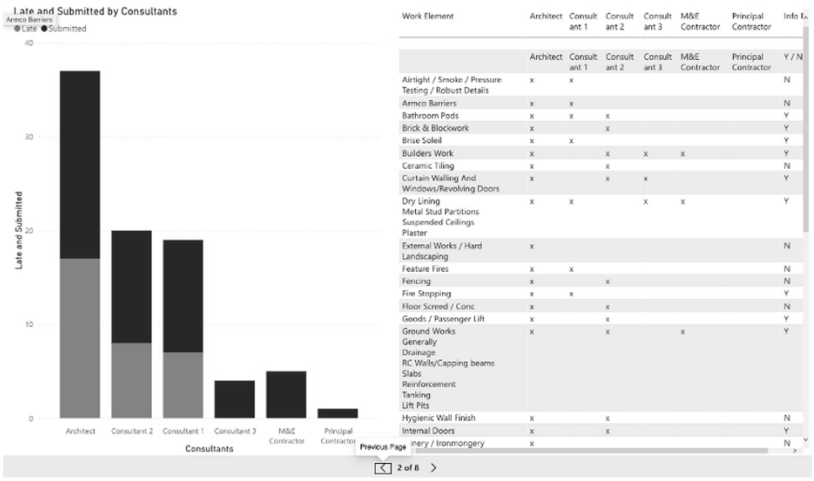


Figure 4: Indicative design programme monitoring analytics

Plans to enhance these functions via the web-based platform were shared back with various participants (amongst other targeted users), who acknowledged the value these would add to the DM role: "A monitoring system like that is really good […] that's really powerful, because that's the sort of thing that as a design manager I would have

loved to have had." (Participant 9), and: "I think, having something like that is a huge benefit. You just get a better view, and the design team manage it a lot better, and they're being overseen. From a [project] control perspective, that's quite important." (Participant 8).

CONCLUSIONS

This work has reported on the development of a web-based platform, produced as part of the current progress of a collaborative industry-academia Knowledge Transfer Project (KTP) with a Case Study Organisation (CSO) designed to tackle some of the challenges of the DM role. Across the work, mixed research strategies were employed. Purposively selected design managers were interviewed to further uncover real world DM concerns against those found in the knowledge base. These revealed how problems of design coordination, and designer performance monitoring remain key challenges worth addressing.

Then, in digitalizing selected design management processes, a web based DsDM prototype platform was developed to uses project data to aid design coordination activity and facilitate DM task prioritisation and reporting functionality. Specifically, it enabled dashboard analytics to provide visual reporting capabilities enabling monitoring of design production, assessment of designer performance, and better management of design stage technical queries and construction stage RFIs. This work therefore reinforces how better integration and use of project data can be used for analytics in digital platforms and tools to address real concerns in construction practice. The final steps of the KTP project are now being enacted that involve final 'Solution Implementation' (#4) and 'Commercial Launch (#5) stages. Further knowledge contributions via additional academic output discussing a fuller range of DM functions addressed within the dashboard will follow this interim work.

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