Optimisation of resource management in construction projects: A big data approach

Abstract

Resource management is one of the key factors for achieving project success, which includes the management of project teams, labour and plant and equipment needed to deliver the project. This study aims to identify challenges facing resource management in the UK construction industry and outline solutions proposed through focus group discussion with industrial experts. Based on a qualitative research methodology, fourteen (14) experts from the UK construction industry were chosen to be participants in the study. The participants were equally divided into two focus groups to discuss resource management using five projects as case studies. Thematic analysis of the discussion reveals seven key factors that affect resource management. The results show that most of the problems identified are due to poor data management processes and the practice of having data in silos. Overcoming this challenge requires the adoption of big data approaches for resource management to allow the integration of huge and different forms of data.

1 Introduction

A resource is anything that contributes to the completion of project tasks, and it includes the project manager, skilled labourers, and equipment such as plant and fleet. Resources are major contributors to project success because each project task must have sufficient and adequate resources allocated for the activity to finish to time and within budget (Nigaragu, 2012). The construction industry is riddled with problems such as increase in labour prices, shortage of skilled labour and stagnant productivity (Leeds, 2016). Besides, Fletcher (2017) argues that Brexit threatens the flux of skilled labour into the UK which adds pressure onto the already constrained labour market. These problems impact project performance by causing time delays, cost overrun and profit margin erosion. Additionally, Banaitiene and Banaitis (2012) reported that in recent years, project-based companies have found it more challenging to achieve the estimated profit margins on projects which are the core source of provision of cash flow. Consequently, these organisations do not have the cash flexibility to invest in huge, expensive digital innovations to solve the causes of margin erosion (Leeds, 2016). However, a solution to manage the limited resource effectively and efficiently is unavoidable.

There are two parts to resource management; resource allocation and resource levelling (Nagaraju *et al.,* 2012). Resource allocation is concerned with the supply of the demanded resource while resource levelling is concerned with reducing the fluctuations in peaks and troughs in a resource profile and how to minimise scenarios of under and over allocations. Both scenarios would have to consider the skillsets needed, the availability and the workload of the resources (Bautista-Arredondo et al. 2008). Resource allocation to a project is dependent on the nature of the project and some key attributes. Firstly, it is essential that the complexity of the project is understood and a robust methodology is developed for appropriate delivery. Then, a detailed project plan/schedule is developed outlining all the activities singularly with the duration each activity should take. Following the successful execution of these steps, a resource schedule is created that lists the details of the required resource per activity. Subsequently, the productivity of each resource type is used to calculate the quantities of human resource and equipment needed to safely deliver a project to the required standard. These schedules are then used to prepare an estimate that is sent to the client and serve as baseline data for allocating resource during the delivery phase (Nagaragu 2012).

Resource data is a fraction of the huge amount of data produced across a project's lifecycle which is from project development (estimate/tendering) to project delivery. In addition to historical data, there is an increase in the generation of real-time data with the adoption of emerging technologies such as Internet of Things (IoT) sensors, Building Information Modelling (BIM), blockchain and laser scanning (Mukherjee and Shaw, 2016) within the construction industry. The optimal solution to the challenges facing resource management would be a tool that can analyse relevant real-time and offline data from different domains. The tool must consider some key factors such as the skillsets needed, the resource available and resource workload (Bautista-Arredondo *et al.,* 2008). Therefore, efficient resource management requires the ability to produce insight from large amount of data. The credibility of the insight is dependent on the reliability of the data that underpins it. Fortunately, there is an improved level of data assurance during construction processes through the introduction of proper naming conventions and guides to the management of data maturity with the introduction of BIM (Bryde *et al.,* 2013).

Based on the identified gap in knowledge, this study seeks to bring to the fore challenges facing resource management in the UK construction industry and to propose solutions to address them. Understanding how to overcome current resource management challenges will open new doors to unlocking insights within the extensive resource-related data available in the construction industry. The specific objectives that are adopted to achieve the aim of the study are:

1) To understand the current resource management practices in regarding project teams, labour, plant, and equipment.
2) To identify challenges facing resource management in the UK construction industry
3) To propose appropriate solutions to the challenges

The study employs a qualitative research methodology to achieving the objectives. As such, two Focus Group Interviews (FGIs) were conducted with fourteen (14) expert from the UK construction industry who are directly involved in the management of project resources. The discussion of the FGIs focuses on five case study projects. The results of the thematic analysis reveal that there are seven fundamental problems confronting resource management in the UK construction industry. Most of these problems are due to poor data management processes and the fact that data are stored in silos. The discussion from the FGIs also reveals that overcoming these problems requires the adoption of big data approaches for resource management.

The remaining sections of the paper are structured as follows: Following the introductory section is a review of the literature on current resource management. Lean Six Sigma, which combines Lean and Six Sigma theories were reviewed in-line with resource management. After that, Section 3 details the research methodology adopted in the study. Section 4 contains the discussion of the data analysis and the findings. Section 5 contains the discussion of the results of the qualitative data analysis. Section 6 concludes the paper with a summary of the results and areas of further study.

2 Resource management tools and practice

The industry is rife with several resource management software for project scheduling, resource scheduling and resource allocation. Microsoft Project leads the market with over 22 million users (Schwalbe, 2015). Besides, cloud-based project management tools (such as Asana, LiquidPlanner, JIRA, Zoho projects, Trello, Monday.com, Freshdesk, slack) are becoming popular. The goal of these project management tools is to make project management more efficient through accurate time, cost and resource scheduling. However, a major limitation of these tools is that they do not perform resource allocation and levelling across multiple projects with overlapping resources to know how resources correlate with each other and to show how resource might be in demand or waste (Biafore, 2013). Also, these tools do not have the potential to provide real-time updates on project progress. Therefore, live updates of information about resources are through manual input which leads to time wastage and subjects the process to error. Another limitation is that these tools do not use historical data from previous projects to optimise the delivery of projects and to proactively solve problems.

A common practice in the industry is the use of Microsoft Excel to keep track of all resource type, quantities, and current allocations. It is easier to see the resource demand per project and initial allocations for each demand. By using functions within excel, it is also possible to see the overall resource available at a given time. However, to enable these functionalities within excel, summarised versions of the original timeline are manually created within excel or the project plans are copied from Microsoft Project or Primavera into excel. The lack of integration between these systems mean that to get live resource information resource managers have an added task of updating the Excel version as well as other versions when a project schedule changes; which is often not done. Therefore, resource levelling analysis cannot be done with high accuracy and with minimal manual intervention. Besides, the manual admin works are at a cost to the company.

Optimising resource management has been trialled with different techniques such as integer programming (Easa, 1989), branch and bound, dynamic programming, genetic algorithm (Hegazy, 1999) and hybrid genetic algorithm (Valls, 2013). However, these approaches have several limitations. The techniques have only considered situations where there are resource constraints but the project duration is fixed or scenarios where there are unlimited resources but several changes to the project. They do not consider real-time changes to variables nor do they perform predictions based on previous data.

3 Methodology

To develop an initial understanding of resource management problems and to deduce some solutions, an interpretive study was carried out by collecting and analysing qualitative data. Adopting this approach allows the exploration of the experiences, perspectives and opinions of experts within the industry (Holloway and Wheeler, 1996). The methodological approach of the study is demonstrated in Figure 1. Methods for collecting qualitative data include individual interviews, Focus Groups Interviews (FGIs), archival analysis, and observations (Moustakas, 1994; Creswell 2014). Focus group interview was chosen to be the best fit for this study because the practice enables the researcher to gain deeper insights into the phenomenon under study within a short time. The use of FGIs also helps to confirm shared beliefs and group thinking. Additionally, the use of FGIs bring together otherwise siloed personnel to encourage diversity in the perspectives of the participants in the discussion.

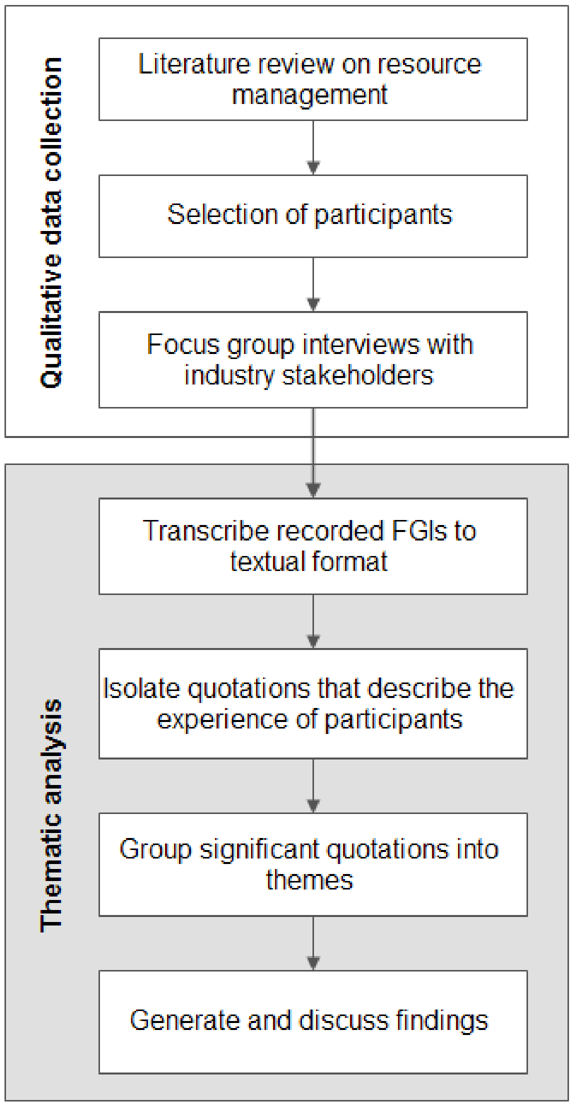

Figure 1: Methodological approach of the study

Krueger (2014) suggested that the size of a focus group should not exceed 10 participants because it may be difficult to control large groups and members may not have the opportunity to share their experience and insights. Furthermore, in large groups, dominating personalities within the group can overshadow quiet participants. Therefore, two focus groups were conducted with seven members in each group. All the participants are involved in resource management either at the development or delivery stage. The participants of the FGIs include resource managers, project managers, project engineers, quantity surveyors, estimators, planners and plant and equipment managers. An overview of the focus group interviews and participants is provided in Table 1. The idea behind this distribution is to create a platform where participants who are front-end office workers (who manages resource demands and supplies) can interact with participants that utilise the resource on-site and have the experience of how resource allocation affect on-site activities. This combination led to discussions about lessons learned from individual experience, challenges encountered and opinions about possible collaborative solutions to the challenges.

Table 1: An overview of the focus group interviews and participants

Focus group	Job role of participant	Years of experience
FGI1	Resource manager	20 years
	Project manager	8 years
	Project engineer	9 years
	Quantity surveyor	14 years
	Estimator	11 years
	Planner	15 years
	Plant and equipment manager	21 years
FGI2	Resource manager	16 years
	Project manager	15 years
	Project engineer	10 years
	Quantity surveyor	13 years
	Estimator	18 years
	Planner	8 years
	Plant and equipment manager	9 years

The discussion during the FGIs was informal, and an open conversation style was adopted. The FG discussion were based on an interventionist approach which meant using five carefully selected power transmission and distribution projects to guide the focus of the groups. It is also worth noting that the members of the two FGIs were all involved in at least one of the five case study projects. A summary of the five case studies is shown in Table 2.

Table 2: An overview of the five case studies used in the study

Case study project	1	2	3	4	5
Work stream	Cabling	Overhead line	Overhead line	Overhead line	Offshore
Region in UK	Scotland	Scotland	North	North	North
Project type	New build	Refurbishment	Upgrade	Refurbishment	New build
Route voltage (kV)	132	275	400	132	66
Duration of the project	259 days	245 days	589 days	136 days	434 days
Sale value (m)	£9,069,981	£5,151,787.51	£5,261,875	1,485,000	6,741,372
Profit margin (%)	-12.2	11.56	-0.18	19.91	1.32

4 Data analysis and findings

Data analysis in a descriptive interpretive research requires a structured method, which involves a textual and structural description of participants' experiences (Creswell, 2013). According to Moustakas (1994), descriptive interpretive research follows six steps, which are: (i) description of researcher's personal experience with phenomenon, (ii) transcription of voice data to written statements and identification of quotations that explain participants' experiences, (iii) identification of units of meaning using thematic analysis and grouping significant statements into themes, (iv) textual description of participants' experiences with verbatim quotations, (v) structural description of the setting and context in which phenomenon was experienced, and (vi) composite description that contains the textual and structural descriptions.

Thematic analysis of the FGI transcript was done using an appropriate coding scheme. The schemes identify units of meaning from the transcript and classify them into themes. Four tags were used for the coding of the transcript quotations, which are discipline, context, keywords, and theme category. Discipline tag represents the job role of the participant that provided the quotation. Context tag represents the circumstance that informs a quotation, which are: (i) "*new*" for the start of a new direction of discussion; (ii) "*response*" for a response to a question; (iii) "*build-up*" for a contribution to an ongoing discussion; and (iv) "*moderator*" for a control segment provided by the moderator. Keyword tag provides a summary of the main issue raised in the quotation. The theme category tag shows the principal theme under which the quotation falls. Adopting this coding scheme helps to isolate prevalent issues and recurring themes across the FGI transcript. Example of how the coding scheme was used during thematic analysis is shown in Table 3. The keyword segment of the quotation is underlined.

The data analysis reveals seven key challenges to resource management which are: (1) poor understanding of project complexity at the tender stage, (2) incomplete survey of the project site, (3) little visibility of resource profile at the tender stage, (4) changes to project schedule, (5) running multiple projects in parallel, (6) shortage of specialised resources, and (7) poor management of client specific authorisations and certifications.

Table 3: Example of how the coding scheme was used during thematic analysis

No	Quotation	Source	Discipline	Context	Theme Category
1.	"*we did not understand the complexity at the tender stage and neither were there any input from the operations to develop the estimate; hence, we underestimated some resource, materials and completely omitted some items*"	FGI1	Estimator	Build-up	Poor understanding of project complexity
2.	*"we had been supplied with a number of resources to perform an activity but half way through the activity, half of the resource was pulled off the project because they were needed to carry out a specialised task which they had attended training for in Japan. It was too expensive to send new workers for training on such a short notice"*	FGI2	Resource manager	Response	Shortage of specialised resources

5 Discussion

This section presents a discussion of the seven key challenges identified from the thematic analysis. Solutions suggested to these challenges are also discussed in this section.

5.1 Poor understanding of project complexity at the tender stage

One of the most crucial stage to a project is project estimation where the contractor has been invited to compete with others by submitting a tender. Most of the time, clients use this stage to their advantage and drive the contractors' price down as much as possible. The adverse effect is that contractors tend to underestimate; to remain competitive especially if the contractor is new in the market. As such, due to client pressure or top management pressure to break into a new market, contractors do not fully grasp the complexity involved in the delivery of the project which leads to a poorly developed methodology. Consequently, the initial estimate of the resources needed throughout the project is not precise enough. This compromise leads to underestimation and cost over-run during the project (Akintoye, 2000). An estimator from FGI1 stresses the importance of understanding the complexity of a project and its entire scope:

> *"we did not understand the complexity at the tender stage and neither were there any input from the operations to develop the estimate hence we underestimated some resource, materials and completely omitted some items"*

A project engineer in FGI1 narrates his experience of when the complexity of the project was not adequately understood at the estimate stage to buttress the point that when project complexity is not understood very well, it leads to subpar resource allocation:

> *"My experience for a long time has been working with cabling projects...I am a cabling expert. I was allocated to manage a heavily sided substations project by default. I had no technical experience of delivering substation projects and therefore did not understand the process of substations nor the designs involved. At the end of the project the cabling aspect of the project went very smoothly but the PCA (pre-construction agreement) that has to do with the substation projects and the whole aspect of the substation continued to suffer".*

A unanimously agreed solution is that the tender stage needs to involve the right operational resources so that the difficulty of the opportunity is understood correctly. The comprehensive knowledge is used to develop the right methodology which leads to the design of a more precise project plan. As such, the estimate includes the right resources, skills and equipment to deliver the project (Pinto and Slevin 1998).

5.2 Incomplete survey of the project site

One of the vital processes discussed during the FGIs was 'line-walk'. Line walk is when a person physically walks the entire proposed area of the project. The observations from the line walk informs an appropriate methodology for the project. The FGI participants agreed that this process is a necessity for all projects. Though the significance of line-walk is common knowledge, the participants express dismay that walking a project route is not a compulsory process during tender. Physical observation of a project's route is only done when the client explicitly asks for it and is willing to cover the cost. The participants agreed that the effectiveness of the line walk lies in the expertise of the person that conducts it. The participants go on to suggest that a member that will eventually be part of the management team should be included in the process because their familiarity with the line is an asset during project delivery. Accordingly, a quantity surveyor from FGI2 mentions:

> *"it is necessary to have operational experts, preferably one amongst the team that will be delivering the project, to walk the route line of the project. It will familiarise them with the line and point out any issues that needs to be factored in at the tender stage".*

The above excerpt shows that failure to carry out appropriate project site survey will lead to incorrect estimation of resources. As such, delays and high repair costs are inevitable because of damages to equipment, damages to the environment, plant exchanges. A project manager from FGI1 stressed that:

> *"… there were a lot of damages to environment and grounds due to heavy tracks from heavy machinery operations. The project incurred more cost from repairs to environment and reinstatement of land to usable conditions".*

This statement shows clearly that thorough site surveys should be carried out by operational experts to determine ground condition and previous knowledge of the route should be used to determine the resource needed (Akintoye, 2000). Another project manager from FGI2 mentioned that:

> *"... the senior manager allocated to the job had previous experience of working on the route and the general foreman himself had worked on the route before numerous times. It helped to steer the tender prices in a better direction"*

5.3 Little knowledge of resource profile at the tender stage

Another barrier to efficient resource management is that at the tender stage, there is no clear visibility of the quality and quantity of resource available to projects at the expected delivery time. There is currently no system that supports estimators in the decision-making about resources that will be available at a given time. Often the resource needed is known, but there is no guarantee that they will be available during project delivery. Surprisingly, this is common knowledge in the construction industry due to the unpredictable nature of projects. The participants pointed out that having a good idea of what resource would be available to deliver a project ahead of when they are needed would increase the likelihood of project success. A project manager pointed out that:

> *"It is usually the case that at the tender stage we do not know what particular resource will be available at the period the projects need them. Therefore, when it comes to delivery any resource that is available and competent is supplied to the project."*

It was argued during the FGIs that there is a growing need for a robust database that contains information about all resources employable on a project and all projects in the pipeline. Emerging technologies such as big data analytics should be utilised to draw insights from such extensive data. As such, upon a resource request, details of matched resources are listed along with their current commitments, relevant information like distance to work site and their availability. For this process to be successful, it demands that these details are updated by all projects as they progress. This approach will enable the proper optimisation of resources. Resource allocation and levelling can be quick and efficient.

5.4 Changes to project schedule

Project schedules usually contain key activities, start dates, end date, and dependencies. Many requirements are then calculated using these schedule parameters. However, these task end date may change due to internal factors such as client descoping or increasing the scope. The project schedule may also change due to external factors such as weather and bird nesting season. These changes have a direct effect on the resource demand and hence on resource allocation and levelling. The changes will also impact on other ongoing projects (Belassi 1996). A resource manager from FGI2 says:

> *"We could not start work on the project because we were waiting for the planned resource to arrive. They had not arrived due they were delayed on a previous project that could not be completed to time".*

Therefore, it is essential to monitor changes to project plan dates using software such as Primavera or Microsoft projects. However, a robust system must also be developed to track these changes and perform impact analysis on resource demands across other tasks and projects. Achieving good resource analysis will allow resources to be efficiently used on projects. For example, it will support decisions about when plant equipment must be hired or off-hired to minimise costs.

5.5 Running multiple projects in parallel

Most medium-sized or all large-sized construction companies run more than one project at the same time. In this case, resource availability is dependent on other projects being delivered to their project plan like achieving project completion at the indicated. The lack of transparency between projects about their activities and milestone dates tend to create a low supply-to-demand ratio in terms of the number of resource available against the number of projects/activities/tasks to be completed. The result of such practice is that resources allocated to projects, such as the project managers arrive late and thereby have less time to get acquainted with the projects. A project manager from FGI1 recalls that:

> *"I had three days between operational completion of a project and mobilising another project"*

The effect of this situation is that companies invest in selective projects. Examples of the criteria that influence the interest of companies include the value of the project (e.g. project above 500,000 sale value), the client (e.g. best clients), the innovative capacity of the project.. After this prioritisation is applied, projects that are deemed more important are allocated the best resource in terms of skills and quantity (Patanakul & Milosevic 2008 and Jaselskis & Ashley 1991). As suggested during the FGIs, a way of addressing this challenge is to adopt a project management system that can establish links amongst multiple projects and their resource demands. As such, the system provides a platform that will enable impact analysis of how changes of resources on one project affect the other projects. Another approach could be to separate strong resources and weak resources using performance criteria such as delivering to time, delivering to budget, zero health and safety issues (Belassi and Tukel 1996). This exercise will help to pair up resources and to encourage a learning environment whilstimproving competencies of resources by complementing individual skills for better outcomes. For example, pairing up a PM that consistently delivers projects to time but performs poor on commercial aspectswith a commercially sound quantity surveyor. This process will also reduce the stigma around hogging the best resources as pointed out by plant and equipment manager in FGI1:

> *"I encourage devolution and allow people to do their job. For example I leave all things commercially related in terms of CEs and client meetings to the quantity surveyor which allows me to be out on the field and get more involved to make sure things are done right and to time".*

5.6 Shortage of specialised resources

Some tasks on a project require specific resources due to the speciality of the job. To save training cost, companies often only sponsor a few individuals to be trained instead of training all resources. The problem arises when these resources are held on too long on a project. A project engineer commented that:

> *"we had been supplied with a number of resources to perform an activity but half way through the activity, half of the resource was pulled off the project because they were needed to carry out a specialised task which they had*

attended training for in Japan. It was too expensive to send new workers for training on such a short notice".

It was argued that resources with special skills need to be managed separately from other resource to tackle this challenge and that an indication into what these resources are and their allocations are needed to manage them properly.

5.7 Poor management of client specific authorisations and certifications

As a profit-making scheme, some clients require specific certifications to be held by resources that work on their projects. Projects are often allocated less resource because some resources do not have the right authorisation required by the client. A lot of these certifications expire and are not renewed; thus, leading to resources being rejected (Belassi and Tukel, 1996). A resource manager from FGI1 argued that:

"I tend to spend huge amount of my time sorting out the certificates and authorisations for gang members instead of concentrating on the job at hand. I have had to complete activities with resource numbers lower than the safe limit because members have been sent off for authorisation training or rejected completely by the client due to no authorisations".

The above excerpt shows that project teams often use fewer resources than required, which could lead to health and safety issues and hazards. A way of overcoming this challenge is adopting a system that could manage client's specific authorisations and their expiry dates. The system would also highlight the resource that need to undergo training and show details about projects that need resources with those type of authorisations.

Also, training to renew these certifications can be scheduled and approved such that their impact on projects is reduced. A project engineer from FGI2 described a process that worked very well at his previous job:

"... authorisations and certification processes had a dedicated staff. The staff created a database within Microsoft excel of resource, authorisations and clients".

6 Conclusion

Resource management is a difficult but important process in construction projects. However, there are several factors that prevent effective resource allocation on projects. Generally, effective resource management requires sophisticated data collection and storage, integration of separate departments' databases and robust optimisation models with high-tech user interfaces. This study, therefore, identifies challenges facing resource management in the UK construction industry and proposes solutions to them. Based on a qualitative research methodology, fourteen (14) experts were drawn from the UK construction industry and equally divided into two focus groups to discuss resource management using five case study projects. After this, thematic analysis of the FGI transcript reveals seven key factors that affect resource management, which are: (1) poor understanding of project complexity at the tender stage, (2) incomplete survey of the project site, (3) little visibility of resource profile at the tender stage, (4) changes to project schedule, (5) running multiple projects in parallel, (6) shortage of specialised resources, and (7) poor management of client specific authorisations and certifications. A critical factor that contributes to these problems is the poor data management practice of keeping data in silos. As such, big data approaches must be adopted for resource management to allow the integration of huge and diverse data.

The results of this study have two important implications: first, the proposed solution will improve project management practices in the aspect of minimising resource management problems; thus, reducing margin erosions. Second, the study contributes to industry practices by promoting the awareness of collecting big data for resource management and the importance of effective data integration to avoid data residing in silos. This study promotes the idea that resource management can harness the capabilities of big data analytics to perform efficiently. Big data analytics allows for large amount of unstructured and structured data generated real-time or offline from a wide range of sources to be stored and analysed to gain insights from the data (Assuncao et al 2014). Big data analytics has evidently proven its worth in using its model characteristics; 5Vs (volume, variety, velocity, veracity & value) and its analytical methods (descriptive, prescriptive, predictive). Big data analytics has provided companies with a competitive edge in their respective industries (Drus et al 2017; Bilal et al 2016) and will be key to optimising resource management (Ram, 2015). Also, big data analytics will help to identify past trends and forecast a resource profile.

Despite the contributions of the study to existing knowledge, it has some limitations. The first limitation is that the study only considers human and equipment aspects of resource management. The second limitation is that the study was carried out using qualitative methods to explore depth rather than breadth. As such, further studies must generalise the findings from this study to a larger sample using a quantitative questionnaire survey. The third limitation is that only the study only considers problems affecting the UK construction (power transmission and distribution) industry; and the participants of the FGIs from this industry accordingly. Therefore, future studies could explore transferability of findings from this study to other sectors and countries.

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