PROCEEDINGS OF THE CONSTRUCTION BUSINESS & PROJECT MANAGEMENT CONFERENCE

THEME: Conceptualising challenges and opportunities in the construction industry

24 - 25 JUNE 2021

UCT GRADUATE SCHOOL OF BUSINESS, ACADEMIC CONFERENCE CENTRE
CAPE TOWN, SOUTH AFRICA

Proceedings of the Construction Business and Project Management Conference
Cape Town, South Africa, 24 – 25 June, 2021.

First published: June 2021, Cape Town, South Africa

Published by:
Department of Construction Economics and Management
University of Cape Town, Cape Town, South Africa
Rondebosch,
7701,
Cape Town, South Africa

ISBN - 978-0-620-91653-0

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Determinants of Smart Technology adoption in the Construction Phase of Projects: A Scoping Study of the United Kingdom

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Abstract:
The slow pace of adoption of smart technology in the construction industry poses a challenge to the industrial revolution. Within the United Kingdom (UK), there is limited understanding of the determinants to innovation in the construction phase of the project lifecycle. This has implications on industry performance. The current scoping study, fills this gap by identifying and assessing determinants to innovation in the construction phase of the project lifecycle. A methodology of unstructured, exploratory interviews followed by a structured survey of construction professionals in the UK was adopted. The study found that client demand heavily dictates the level of innovation and use of technology on a given project. However, industry structure consists of at least 99% small and medium sized enterprises (SMEs), many of whom undertake small-scale operations for clients who have neither the budget nor motivation for driving innovation on a project. SMEs therefore gain little to no exposure to smart technological advancements and as a result they lack the skillset to confidently influence client decisions on innovation. However, large construction companies, such as those who tender for government projects, are making vast advancements in the research and development of smart construction technologies and their implementation in projects. Although limited by the sample size, the implications of the findings include inequality being a key barrier to innovation in the construction phase and addresses the industry skills shortage. Consequently, it is recommended that the UK Government, in conjunction with large construction companies provide financial incentives and training via bodies such as Construction Industry Training Board (CITB) to support the upskilling of the workforce, including those employed by SMEs.

Keywords:
Construction 4.0, construction technology, digital technology, Industry 4.0, innovation, smart technology

1 Introduction

The current industrial revolution coined "Industry 4.0." is recognised as being brought about by the connectivity of current cyber-physical technologies and is already apparent in some industries such as manufacturing, automotive design, data management and communication (Feußner and Park, 2017). The performance of the construction industry remains a concern as covered in literature, for example, Farmer (2018), Rivera et al. (2017) and Pekuri et al. (2014). It there is evidence that Construction 4.0 would contribute to improvement of the poor performance of the industry (Bilal et al. 2016; Muller et al. 2018). Vast developments in construction technology such as the wide-spread adoption and evolution of BIM in the design phase (Bilal et al. 2016), and the development of smart buildings, enabling digitised and automated facilities management in the O&M phase demonstrate a revolution taking place. However, the lack of literature discussing the use of connective technologies available for the construction phase such as those illustrated by Feußner and Park (2017), indicates less technological progress in this area. The advancement of machinery used on site shows that the construction phase remains in the 3rd revolution, defined as automation by combining IT and electronics (Feußner and Park, 2017), however the cyber-physical connectivity, which is missing on site, gives the impression of the industry as a whole being slow to advance or resistant to change. Therefore, the focus of this investigation is specific to the construction phase of the project lifecycle, in particular, using the United Kingdom (UK) construction industry as a case study. The reported study (the undergraduate research project of the lead author (Dixon, 2020) assesses the drivers and barriers to the uptake of "smart technology", defined as Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI) and Robotics within the construction phase. Following this introduction is the literature review after which the methodology is presented. The findings, discussion, and conclusion with recommendations are then covered.

2 Literature Review

2.1 Industry 4.0: Projections from the Manufacturing Industry

Projections on the future of the construction industry are often drawn from the past of the manufacturing industry. A review by Smith, (2019) of the American economists Jill and Frank Manzo highlights social impacts of automation on the manufacturing industry as a "warning" to the Construction industry, in regard to the industry becoming less reliant on human labour due to automation. According to a PWC (2018) report, 20% of all UK jobs are "at risk" of automation by the mid-2030s, opening opportunities as well as threats. Consultancy roles which remove repetitive tasks such as cost schedules and engineers' calculations result in creative tasks which require human input to rise in demand. It is possible more jobs could be created than destroyed albeit with the requirement of different skillsets. (Gardiner, 2018, p31). Modern methods of construction (MMC) is a growth area, attracting young people interested in 3D modelling and robotics to the industry (Farmer, 2018). Balfour Beatty (2017) predict that in 2050 "new jobs and industries will be created – and some will disappear, especially low or zero skill roles and those relying on repetition of tasks." Such reports are examples of the ways in which negative opinions about the use of technology in the construction industry are formed. These conclusions could be flawed, as according to the Smith's review, infrastructure is an economic growth driver, prompting a rise in demand for labour. Meanwhile, existing skills shortages in the labour market could actually be the driver to roles being filled by robots and drones (Manzo, et al, 2018).

2.2 Client Driven Demand for use of Technology

Evidence that client influence drives and hinders the adoption of construction technology is documented throughout the literature. For example, Aecom found that 36% of the respondents view the lack of client demand for technology use in construction projects as a barrier (Ray 2019). Lindblad & Guerrero (2020) agree that clients are key actors in driving construction innovation but question whether innovation should be supplier-driven as in practice few clients are willing or have the capacity to promote innovation.

2.3 Government Incentivisation

The "Construction sector deal" struck in 2008 (Department for Business, Energy & Industrial Strategy, 2018) brought about the "i3P" initiative, created to "work with construction clients to drive demand for innovative construction materials, technologies and techniques." However, Farmer in 2016 is still calling for tripartite leadership involving, clients, government and industry to spark progress. Lindblad & Guerrero (2020) discuss the dichotomy of government (the client) and the policy maker, as is the case in the largest and most complex infrastructure and development projects in the UK. Governmental power to drive innovation through policy and incentives is evident.

2.4 Education and training for skills in the workforce

Lack of education and training for new digital and automated processes is a topic frequently referred to as a barrier. Ray (2017) and Farmer (2016) demonstrate that development of new enhanced skills amongst the existing workforce is imperative to the industry moving forward. Farmer (2018) recommended reform of the Construction Industry Training Board (CITB) to include an outreach programme to schools, focussing on innovation and technology rather than only focussing on current standards.

2.5 Sustainability

The lack of discussion of sustainability in relation to construction 4.0 was noticeable in the literature. Ray (2017) shows that more communication of the environmental benefits [of BIM] is required, which also applies to the positive environmental impacts of smart technology as a whole, for it to become a driver in industry-wide adoption. Oesterreich and Teuteberg (2016) found that automation reduced labour and material costs. Construction waste minimisation and emissions reduction via strategic project management and digital design was presented as environmental benefits - however these methods are currently used by the industry to improve sustainability. "The high levels of energy required by increased data usage and storage will also begin to have a significant impact on resources within the next decade" (Balfour Beatty, 2017). The industry must mitigate against the projections of the impact of construction 4.0 on the climate.

2.6 Industry Real and Perceived Threats/Opportunities

The opportunities to improve on health and safety management are drivers. Health & safety risk is reduced by use of virtual environments, and wearable safety technology such as smart glasses and helmets (Oesterreich and Teuteberg 2016). Robotic exoskeletons assist in manual handling, reducing the risk of back injury (Theurel and Debrosses, 2018). The project and commercial risk raised in the literature are related to the complexity of revolutionising all stakeholders along the chain of construction processes. This is considered by some an overwhelming task, making avoidance a more convenient option than adoption and adaptation (Oesterreich and Teuteberg (2016). Cyber Security poses a risk to any digitised industry and the need for data security and data protection as discussed by Oesterreich and Teuteberg (2016) and Balfour Beatty (2017), stating national cyber defence programmes should be run by the government. The data acquired and produced must be secured and managed as conscientiously as all assets are.

3 Research Methodology

The literature review informed the development of the data collection instrument which was then validated by pilot interviews of two industry professionals in an unstructured format of open-ended questions. The interviews lasted 40 minutes and explored the barriers and drivers of innovation in the construction phase of construction projects. Following this, the questionnaire survey; the main method of the study, was conducted. The survey was conducted electronically through Google Forms. The survey comprised 4 sections addressing the 4 objectives and a total of 7 questions, a mixture of open and closed format. Closed, multiple choice style questions allow for the clearer categorisation of responses, allowing grouping and quantification. There was the need to gather information about the construction process from construction professionals. Hence, respondents must either work on the construction site, or be privy to the management of construction site activities. Certain criteria such as service department within the organisation were considered critical to qualify as a suitable participant within the sample frame, others, such as company size or sector, hierarchical level within an organisation, gender or educational background were not grounds for exclusion. Using random sampling technique, single stage sampling design was used. To the knowledge of the authors, there is no list of construction professionals working only in the construction phase. Consequently, the list of contacts was drawn up from two of the following accessible populations and sent a survey request: 1) construction professionals on LinkedIn, and 2) apprenticeship degree Kingston University Students, working part-time in the construction industry. Being an undergraduate research project, there was limited time to conduct the research. Of the questionnaires distributed, 30 usable ones were returned. Figure 1 shows the response sample characteristics.

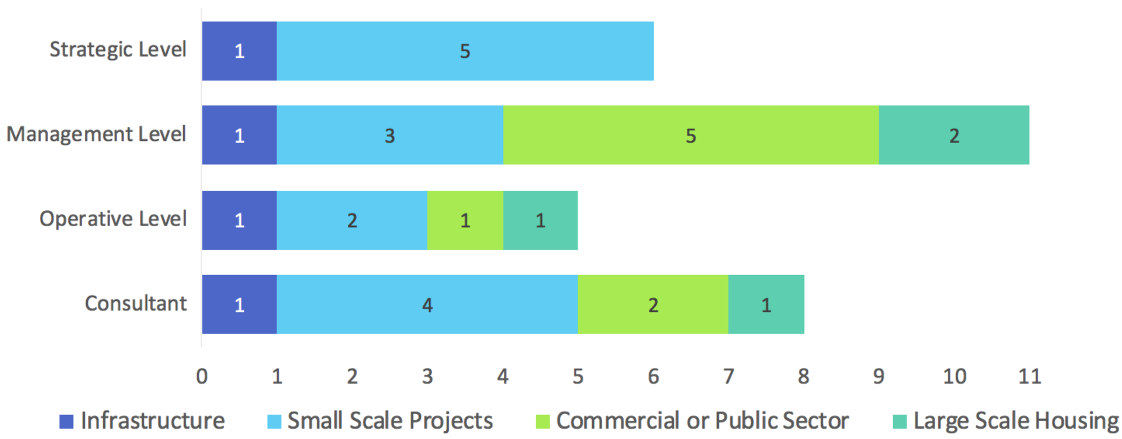

Figure 1: Organisational level profile of the respondents (Dixon, 2020)

4 Findings and Discussion

4.1 Profile of the respondents and discussion

Of the 30 respondents, as seen in Figure 1, over one third, the largest group are of managerial level. This may be explained by the accessible population being LinkedIn members and Kingston University Part-time Students. In construction, employees on this level are likely to have a LinkedIn account and to be supported by their companies to gain a degree via apprenticeship to complement their managerial role. Of the subgroups, the two majorities were 1) Managers of the Commercial and public sector at and 2) Strategic Level of the Small Projects sector, both with 5/30 participants each. Almost half, 14/30 of respondents are from the Small Projects sector, the majority of whom, as stated above selected the "Strategic Level" company position. This also correlates with the accessible population and translates to this group being the owners and directors of SMEs (Small/Medium Enterprises). Taking national statistics into consideration, SMEs make up over 99% of the construction industry. Of those SME's over 138,000 (ONS, 2018) are sole traders or only have 1 director. That translates to 42% of the total of companies in the industry, this is reflected as the largest single sector in the sample. The implication of the small data set is that the findings are indicative hence the interpretation of the data should be with caution. The limitations of the data do not allow for a direct proportionate comparison to the industry to test accuracy. However, sample characteristics are close enough to industry structure to enable theories to be tested for the sake of this study. Scoping studies with small data set is consistent with other research, for example Umeokafor (2016) uses 37 respondents and Yong and Mustaffa (2012), 14 respondents. Both are published in high-ranking journals.

4.2 Findings of Interviews and Survey

4.2.1 – Findings of the exploratory interviews

The exploratory, unstructured interview validated the findings of the literature review which was used to develop the questionnaires. The barriers in literature included lack of awareness of the benefits of the technologies and the high cost of investments in digital technology. Both of which were validated by the interviewees. The interviews confirmed and revealed other barriers such as 'lack of client demand', 'inability to adapt to change', 'inability to procure technology' and 'fear over job security'.The same is applicable to the drivers where 'improvement of processes' and 'client demand' were consistent with literature and the following emerging from literature: 'legislative demands', 'solving real problems', 'available funds to invest', and 'return on investment'. The themes emerging from the 'effects of industry structure' are 'company structure', 'company size' and 'male dominated industry'. The implication of validating the questionnaires is evident as issues explored are not detached from reality. The exploratory interviews, although limited in number, improved the data collection instrument to be as reflective as possible, of what occurs in practice in the industry.

4.2.2 – Findings of the Survey

The survey assessed the smart technologies the respondents had witnessed in use in the construction phase. The answers were multiple choice and allowed a participant to answer "no" if not, or "in another phase" if they had witnessed smart technology in pre/post construction but not within the construction phase. Figure 2 illustrates, more than one third of the respondents answered "yes". These were asked to confirm in what percentage of projects over the last year, they had witnessed any of the named smart technologies in use. Four of the 11 respondents report witnessing smart technology in use in more than half of the projects assessed. The remaining three, stated they could not answer, or did not know the answer.

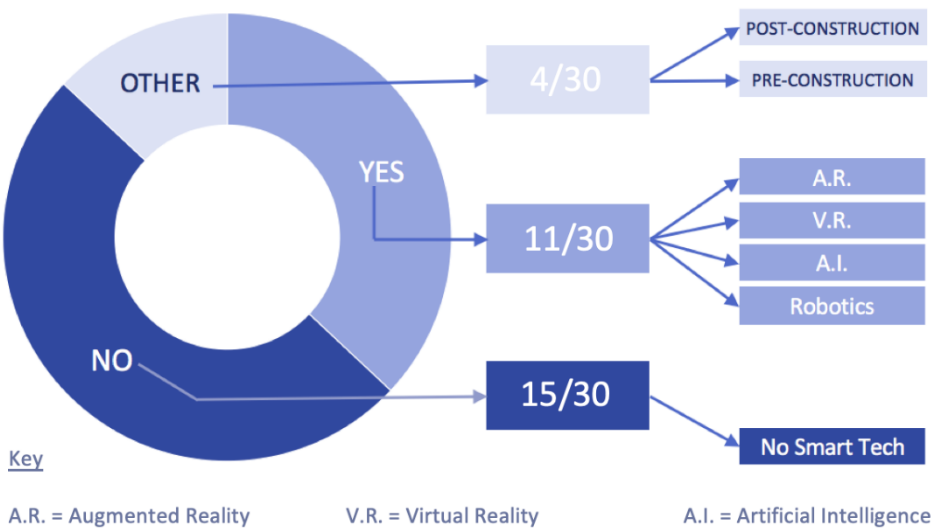

Figure 2: Observation of use of Smart Technology in the Construction Phase (Dixon, 2020)

To better understand the responses in Figure 2, the implications of industry structure on the adoption of smart technology was assessed. Figure 3 suggests that the characteristics of the industry determine whether smart technology will be adopted. In particular, the size of companies and the scope of operation are assessed. The implication is that the smaller the project, the less likely smart technologies will be adopted. However, this should be interpreted with caution due to the scoping nature of the study.

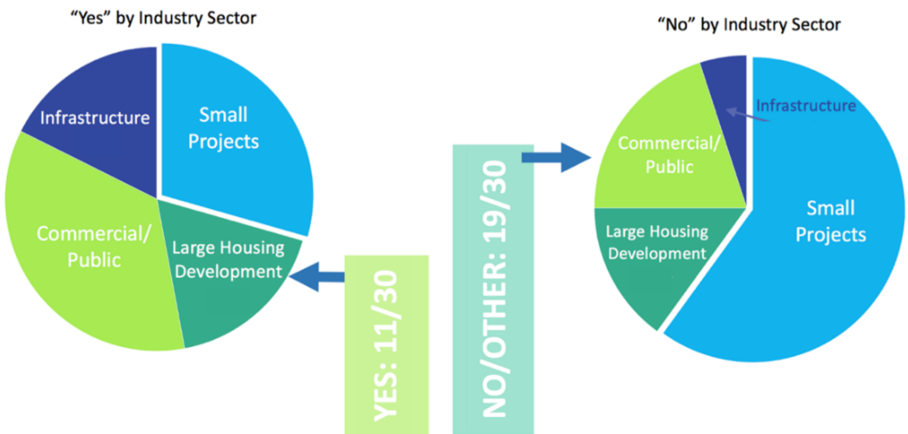

Figure 3. Adoption of smart technology based on industry characteristics (Dixon, 2020)

Figure 4 presents the drivers of smart technology adoption in the construction phase of the project. An open question asked the 11 respondents who answered "yes" to provide views on what the drivers were. The answers totalled 17 (some respondents gave multiple answers) and covered several categories. Indications from Figure 4 are that the main driver is time related, followed by cost related factors.

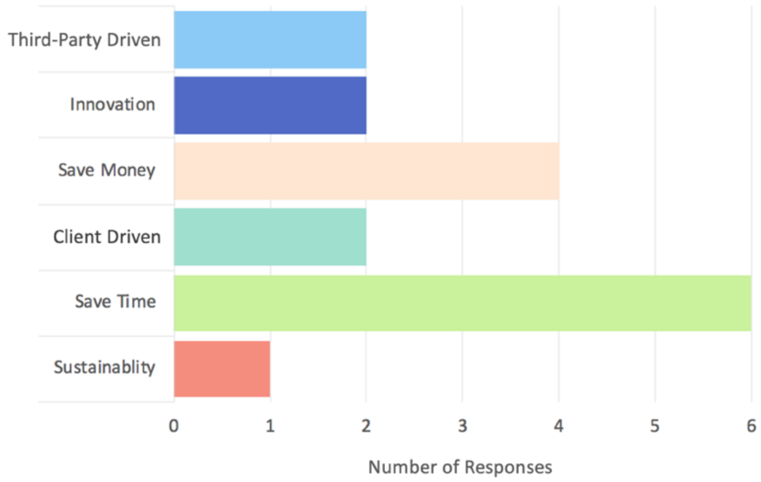

Figure 4: Drivers of smart technology adoption in the construction phase (Dixon, 2020)

Respondents who answered "no" or "other" (nearly two thirds) were subjected to further analysis and asked why those named technologies were not used in the construction phase. Some gave multiple reasons. By implication, the barriers to the adoption of smart technologies were identified and assessed. Figure 5 shows that in the view of the respondents, clients not requiring use of smart technology is the main barrier. Again, cost-related factors in procuring smart technology ranks second, followed by the lack of skills and knowledge required.

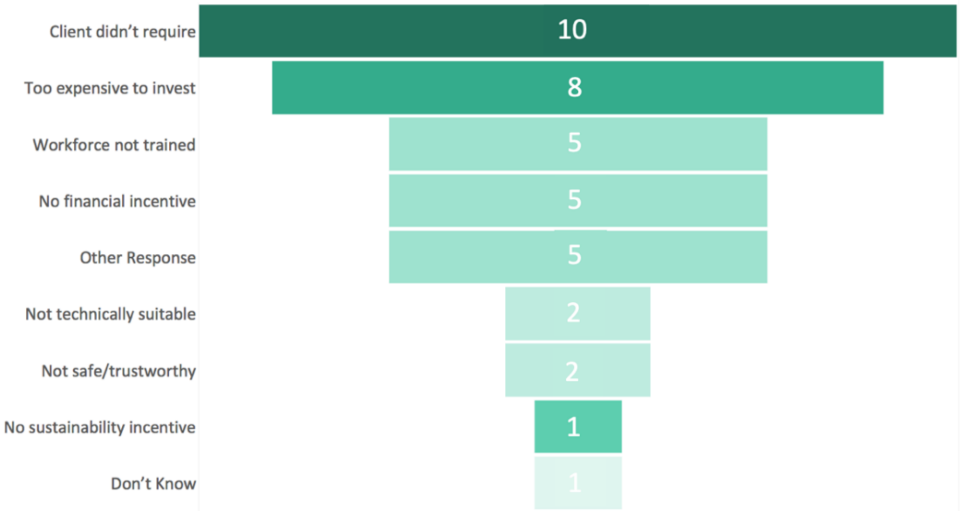

Figure 5: Barriers to smart technology adoption in the construction phase (Dixon, 2020)

4.3 Discussion of Findings

Client demand or lack there-of as a driver and barrier is one major finding of the study. The construction industry is driven to deliver to client demand, which correlates with the 2016 survey by Aecom (Ray, 2019). Akin to Lindblad & Guerrero (2020), the survey also reveals suppliers can be catalysts in the adoption of new, innovative techniques. Respondents revealed that drone technology is used as a survey method due to encouragement by the surveyor engaged on the project. This highlights the nature of the client/contractor/supplier relationship as recommended by Farmer (2016). Subcontractors are the experts in their specialism and qualified to provide guidance on best-practice and techniques.

The survey reveals those contactors operating small projects don't have clients who encourage innovation. A large infrastructure company may absorb the cost of applying a new technology due economy of scale. Costs are more visible on smaller projects therefore the client, who leads on allocation of funds would require encouragement by a confident contractor, to adopt an alternative, disruptive technological method, over a traditional method. There is evidence to suggest that education and training for skills in the workforce is necessary for advancement in the construction phase. Some respondents are concerned the workforce are unfamiliar with the technologies. Both interviewees agreed that there is an unawareness of the existence of beneficial existing technology amongst the workforce. Farmer (2016) suggests addressing through the CITB, the largest education and training provider to the workforce, including SME's. This, in correlation to the last paragraph could lead to SME's being proactive in the use of innovative technologies on projects.

Education and training may improve confidence in connective technology, but for SME's, procurement requires finance. Cost-related factors emerge from the study as barriers and drivers, with over one fifth of the surveyed population claiming cost is the main barrier and reason why they have not used or seen these technologies being used. The expense of investment is strongly connected to innovation in the experience of SME's, hence the need for government incentivisation. As stated by the Farmer Review, government bursaries for innovation, aimed at SME's were largely going untouched. Communication blockages between the government and SME's regarding available incentives must be queried, as more than 99% of the construction industry are classed as SME. Bursaries should not remain untouched.

The survey reveals concerns over risks of technical suitability or safety/security ranked low as a barrier. Logically, these risks would only be of concern to companies in the financial position and with the necessary skills to procure these technologies. In terms of sustainability, there is not enough conversation about the impacts of connected construction technology on global environmental sustainability. The industry urgently require data comparable to that by Balfour Beatty, to communicate and address the benefits or threats to sustainability targets. The lack of conversation in this specific area was proportionally reflected in the survey, where only one participant uses the word "sustainable".

5 Conclusion and Further Research

This scoping study assesses the barriers and drivers to the adoption of smart technology in the construction phase of the project lifecycle. This stems from the limited attention in literature to the implications of barriers and drivers in this specific area. The findings indicate that up to two thirds of respondents claim that smart technology is not adopted in their projects. On further analysis, it was found that the smaller the project, the less likely smart technology will not be adopted in the construction phase, with commercial/public projects most commonly reported to have witnessed the use of smart technology. While major barriers are the lack of client requirement and the high cost involved in acquiring the technologies, the main drivers include the quest to save time and money and the encouragement of third-party construction professionals involved on the project. The implication of the findings include that the SMEs therefore gain little to no exposure to smart technological advancements and as a result they lack the skillset to confidently influence client decisions on innovation. However, large construction companies, such as those who tender for government projects, are making vast advancements in the research and development of smart construction technologies and their implementation in projects. Therefore, inequality is a key barrier to innovation in the construction phase. The vast proportion of the industry are SME's continuing with trusted, traditional methods, albeit whilst improving the specification of their machinery. Hence, there is a requirement for the diversification of (affordable or funded) methods of procuring advanced, connected technology and the training required for these, to SME's. Consequently, it is recommended that the UK Government in conjunction with large construction companies provide financial incentives and training via bodies such as CITB to support the upskilling of the workforce, including SMEs. The interpretation of the data should be with caution given the small data set. However, the study offers insight into discourse and can be used as a framework for further studies. Further study of a larger sample is recommended.

6 Acknowledgement

The research and data presented in this study was carried out as part of another body of work, the lead author's undergraduate dissertation (Dixon, 2020).

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