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Potential benefits of Construction 4.0 in Aotearoa

The potential business and economic benefits of Construction 4.0 in New Zealand – a literature review

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Everything we do is to ensure we're a New Zealand that supports our metals based industry.

We want our members to be employers of choice, and to be optimising cost effectiveness through productivity and efficiency. Providing support so they follow global best practice, are evaluating and adopting new technologies for commercial success and are recognised for their outstanding commitment to quality.

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1 Abstract

Construction 4.0 is a manifestation of the broader Industry 4.0 revolution. It does not have a precise definition, and this is largely because it is an approach that combines a wide range of technologies, rather than being a technology in itself. Nonetheless, there are a few dominant technologies, with Building Information Modelling (BIM) being perhaps the most commonly discussed. The main purpose of this review is to examine the nature and magnitude of the business and economic benefits associated with the uptake of Construction 4.0. These benefits are potentially large, although there are a number of barriers to uptake that need to be overcome, if the benefits are to be realised.

2 Introduction

This review draws on the literature from around the world to consider the actual and potential benefits from applying Industry 4.0 technologies to construction in New Zealand. It starts by examining how Industry 4.0 is defined and how it relates to construction. It then discusses the principal technologies used in Construction 4.0. After this it explores what the business and economic benefits of widely adopting Construction 4.0 might be. Lastly, it highlights some of the barriers to the uptake of Construction 4.0 that need to be overcome, if its potential benefits are to be realised.

3 Industry 4.0 and its relationship to construction

What becomes clear from the outset is that Industry 4.0 is not a technology. Rather, it is an approach that combines different technologies in the rollout of an industrial revolution. In this respect, it is like its predecessors: Industry 1.0 (mechanisation); Industry 2.0 (electrification and mass production); and Industry 3.0 (computerisation). The notion of Industry 4.0 is generally recognised as having its origins in Germany in the 1990s.

The names given to these different revolutions tend to vary and so, too, does the definition of Industry 4.0. Deloitte (2020) notes that definitions for Industry 4.0 abound, and Forcael et al (2020) state that the concept is still diffuse and that there is no common definition. Focussing in particular on its application to construction, CanBIM (2020) comments that there is still no international consensus on what the concept Construction 4.0 really means. Nonetheless, it is evident that Construction 4.0 is simply about applying the principles of Industry 4.0 to construction.

Moving away from the question of its precise definition, Callaghan Innovation (2020) describes Industry 4.0 as a fusion of technologies. Deloitte (2020) describes it as the marriage of physical and digital technologies. Sniderman, Mahto and Cotteleer (2016) talk about Industry 4.0 connecting embedded system production technologies and smart production processes.

Again, focussing on construction, CanBIM (2020) records that some commentators talk about Construction 4.0 as the use of ubiquitous connectivity technologies for real-time decision-making. The same publication states that others see it as a means of finding a coherent complementarity between the main emerging technological approaches in the construction industry. Still others see it as a more encompassing approach that goes beyond the simple technology framework to best meet the industry's current challenges.

Rather more succinctly, Wang et al (2016) define it as end-to-end integration of systems in the value chain of construction. Maskuriy et al (2019) characterise the construction industry's version of Industry 4.0 as a move toward greater digitisation, whereby many new technologies (such as prefabrication, automation, 3D printing, virtual reality, drones, sensors and robots) are used to help the industry understand better the industry process almost in real time.

4 Principal technologies in Construction 4.0

Consistent with the idea that it is an amalgam of technologies, Chiarello et al (2020) describe Industry 4.0 as the aggregation point of more than 30 different fields of technology. In the same vein, in their review of the literature, Tabinda, Adafin and Wilkinson (2019) identify 32 digital technologies that could be used to improve productivity in the building industry.

Forcael et al (2020) argue that four technologies (i.e. 3D printing, big data, virtual reality, and Internet of Things) are essential to understand Construction 4.0 at present time. For their part, Sawhney, Riley and Irizarry (2020) characterise Construction 4.0 as encompassing three broad areas of technology: Industrial production (including prefabrication and 3D printing); Cyber-physical systems (including actuators, sensors and the Internet of Things); and Digital and computing technologies (including BIM and AI and big computing).

BIM is Building Information Modelling, and it is the technology that is probably the most commonly talked about in the context of Construction 4.0. Allison and Hartley (2020) define BIM as an intelligent 3D model-based process that gives architecture, engineering and construction professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure. CanBIM (2020) describe BIMs as complete numerical models of a construction project. New Zealand Government Procurement (2019) describe them as digital representations of the complete physical and functional characteristics of a built asset.

In more detail, New Zealand Government Procurement (2019) explains that using BIM involves building better processes using a model with real life attributes within a computer and sharing that information to optimise the design, construction and operation of that asset. Further, BIM processes apply to all types of assets, including buildings, industrial facilities, and civil infrastructure. While it provides an efficient way to design and plan, it goes beyond initial conception and construction. BIM typically includes information on design, construction, logistics, operation, maintenance, budgets, schedules, and much more, providing a far richer analysis than traditional approaches. Information created in one phase can be passed to the next phase for further development and use.

CanBIM (2020) emphasises, however, that BIM models are complemented by other technologies to automate their connection to the reality of the construction site. These technologies are mainly Cyber-Physical Production Systems (CPPS), including sensors, drones, embedded robotics and monitoring systems. In the operational phase, the BIM and the Internet of Things, together with other CPS sensors, make it possible to monitor the performance of the facility and to set up an effective system for preventive maintenance management.

5 Business and economic benefits of adopting Construction 4.0

As a prelude to summarising what the literature says about the business and economic benefits of Construction 4.0, it is worthwhile summarising what it says about the problems that Construction 4.0 can help to ameliorate.

The World Economic Forum (2017) regards poor productivity in construction as a global problem, with zero productivity growth in some countries, including the United States of America. Furthermore, the Forum laments the fact that the available technologies, like BIM have still not been widely adopted. Based on their experience as consultants with McKinsey in Singapore and India, Agarwal, Chandrasekaran & Sridhar (2016) characterise construction as an industry where R&D spending is low and where shortages of skilled labour and supervisory staff are common. The result of these things is that productivity generally grows slowly. Hossan and Nadeem (2019) point to similar problems in Kazakhstan, i.e. low productivity and slow adoption of new technologies. From a New Zealand perspective, Allison and Hartley (2020) also point to poor productivity in the industry.

Focussing on residential construction, Bealing and Leroy de Morel (2020) highlight the impact of quality defects, arising from poor workmanship, design and materials. These lead to the need for rework, avoidable demand for materials, and incentives to price-in rework.

On the other hand, the benefits of obviating these problems are potentially great. Looking first at the benefits described qualitatively, New Zealand Government Procurement (2019) claims that the application of BIM promises a step-change in construction productivity, instead of the incremental progress that the industry in New Zealand has been experiencing. More specifically, the collaborative approach promoted by BIM in the design phase has a flow-on effect to the construction phase, leading to, amongst other things: fewer unexpected design changes during construction; improved constructability and quality; improved construction quality; and shorter construction programmes, resulting from better planning of site activities and construction sequencing. Overall, the benefit to the constructors is increased productivity and lower costs because of reduced waste and rework as the result of better trade coordination, task conflict avoidance, easier design interpretation and greater accuracy. For the client, the construction phase benefits are reduced errors, lower costs and improved quality. In the operational phase, the client benefits are lower environmental impact, greater user comfort and safety and lower running costs.

Tabinda, Adafin & Wilkinson (2019) associate BIM and other digital technologies in Construction 4.0 with the key function of cost reduction engineering (CRE). When the cost of constructed facilities is reduced through CRE, the facilities themselves become more affordable, and, therefore, more accessible to a greater proportion of the population. With reference to residential building, Bealing and Leroy de Morel (2020) also point to productivity gains and cost savings. In addition, they claim benefits in the form of labour and capital becoming available for other uses, increased housing supply, and increased wellbeing for the industry consumers and society as a whole.

In terms of quantified gains and potential gains, Allison & Hartley (2020) note that the value of the construction industry's economic output in New Zealand in 2018 was $64 billion, or 11.5 percent of total economic output. They also cited research by the McKinsey Global Institute that indicated digital transformation in the construction industry globally could result in productivity gains of 14 -15 percent and cost reductions of 4 – 6 percent.

On the specific issue of building defects and quality issues, Bealing & Leroy de Morel (2020) estimate that their elimination would improve the productivity and performance of residential construction in New Zealand. This would release opportunities for additional consumption and economic growth. Residential construction output would increase by $112 million annually, and capital investment across the economy would increase by 1 percent annually. The productivity improvement in residential construction would lead to a 1.3 percent increase in wages throughout the economy. The economy-wide effects of an increase in productivity would see New Zealand's GDP rise by $2.5 billion, as the industry's overall costs of production decrease. Households would have $1.9 billion additional income available to spend on goods and services, which would increase aggregate living standards.

Tabinda, Adafin & Wilkinson (2019) cite PWC research showing that, in New Zealand, a one percent increase in sector productivity, through the advanced use of digital technologies, would generate an increase in GDP of around $139m annually. The same authors cite research by the International Centre for Complex Project Management (ICCPM) in Australia, indicating that a 10 percent efficiency increase in the construction industry productivity would in turn increase the economy's gross domestic product (GDP) by more than 2.5 percent.

What is not clear, however, is how achievable the productivity gains and cost savings mentioned in the literature, actually are. Hence, the aim of the UK's "Construction 2025" initiative to complete construction projects 50 percent faster and with a 33 percent cost saving, referred to by Turner et al (2020), seems highly ambitious, but is difficult to completely dismiss it as being fanciful.

6 Barriers to the uptake of Construction 4.0

The potential benefits of the widespread application of Construction 4.0 are obviously great, but the barriers to its uptake are also significant. The barriers are of three broad types: technical, structural and human.

Dealing first with some of the technical barriers, BIM, in particular, depends on interoperability of the IT applications used by the various actors in the value chain, including: architect; structural engineer; quantity surveyor; construction manager, amongst others. Yet, as HERA (2021) notes, decision points in the process are done in linear silos with little inter-connection or data-derived decision support.

Nowotarski & Paslawski (2017) also point to problems such as lack of standards for many technologies, higher requirements for the equipment and increasing need for communication networks. These problems are more common amongst small and medium sized enterprises (SMEs), which tend to dominate construction, especially in the residential sub-sector. Hence, they arise as much from the structure (i.e. its enterprise size composition) of the sector, as much as they are technical. Perhaps related to the structure of the sector, Tabinda, Adafin & Wilkinson (2019) cite evidence from Statistics New Zealand, showing that the New Zealand construction sector appears to be a low-technology performer, with an insignificant contribution (5 percent of total expenditure) to Research and Development (R&D) expenditure when compared to all-industry averages.

Maskuriy et al (2019) highlight a separate structural issue that challenges the sector; namely, the prevalence of bespoke projects and one-off designs. This lack of standardisation inhibits productivity gains and cost savings. Construction 4.0 will help to overcome, but not eliminate, this challenge.

Although not specific to New Zealand, Chan (2020) points to human factors that could slow the take up of Construction 4.0. These include a lack of social will to change that could result in Construction 4.0 failing to deliver its transformative power. The same author argues that, rather than focus on technology, questions are raised around systemic change by considering people and process issues. More broadly, but in a similar vein, Thuy Dong & Teuteberg (2016) consider, why, despite its potential benefits in terms of improvements in productivity and quality, the 4.0 concept has not gained much attention in the construction industry. They point out the political, economic, social, technological, environmental and legal implications of its adoption that need to be addressed.

7 Conclusions

From this review, there is obvious potential for Construction 4.0 to deliver productivity improvements and cost reductions, with the benefits thereof being shared by constructors, clients and occupiers. There is also some evidence, albeit not empirical, that Construction 4.0 will have significant economic impacts.

What is less clear, however, is whether there is potential to apply Construction 4.0 to all parts of the construction sector, or whether it is more suited to commercial and industrial construction than it is to residential building. Regardless, it is also evident that the barriers to its take up, including non-technical barriers, are significant. The barriers will need to be removed or reduced, if the full benefits of Construction 4.0 are to be realised. The construction industry is already subject to a whole raft of standards and regulations, so more would probably not be welcomed. But some changes to standards and regulations might be needed to ensure that the industry is more open to adopting Construction 4.0.

8 References

Agarwal, R., Chandrasekaran, S., & Sridhar, M. (2016). The digital future of construction. Voices.

Allison, N., & Hartley, G. (2020). Digital Product Data for Lifting Productivity, BRANZ, ER56 2020.

Bealing, N. & Leroy de Morel, L. (2020) "The Economic Cost of Quality Defects", BRANZ, ER49 2020.

CanBIM. (2020). Construction 4.0. Retrieved from https://www.canbim.com/articles/construction-4-0.

Callaghan Innovation, C. (2020). Industry 4.0 Infosheet. Retrieved from https://www.callaghaninnovation.govt.nz/sites/all/files/industry-40-infosheet.pdf

Chan, P. W. (2020). Briefing: Industry 4.0 in construction: radical transformation or restricted agenda? Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, 173(4), 141-144.

Chiarello, F., Trivelli, L., Bonaccorsi, A., & Fantoni, G. (2018). Extracting and mapping industry 4.0 technologies using Wikipedia. Computers in Industry, 100, 244-257.

Deloitte. (2020). The Fourth Industrial Revolution is here-are you ready?

Forcael, E., Ferrari, I., Opazo-Vega, A., & Pulido-Arcas, J. A. (2020). Construction 4.0: A Literature Review. Sustainability, 12(22), 9755.

HERA (2021) Notice – exploring Industry 4.0 opportunity for construction. Retrieved from https://www.hera.org.nz/construction-industry4-0/

Hossan, A., & Nadeem, A. (2019). Towards digitizing the construction industry: State of the art of construction 4.0. Structural Engineering and Construction Management, 1-6.

Maskuriy, R., Selamat, A., Maresova, P., Krejcar, O., & David, O. O. (2019). Industry 4.0 for the construction industry: review of management perspective. Economies, 7(3), 68.

New Zealand Government Procurement (2019) Building Information Modelling (BIM) – Construction Procurement Guidelines v2.0. Retrieved from: https://www.procurement.govt.nz/assets/procurement-property/documents/building-information-modelling-construction-procurement.pdf

Nowotarski, P., & Paslawski, J. (2017). Industry 4.0 concept introduction into construction SMEs. Paper presented at the IOP Conference Series: Materials Science and Engineering.

Sawhney, A., Riley, M., & Irizarry, J. (2020). Construction 4.0: An innovation platform for the built environment: Routledge, Taylor & Francis Group.

Sniderman, B., Mahto, M., & Cotteleer, M. J. (2016). Industry 4.0 and manufacturing ecosystems: Exploring the world of connected enterprises. Deloitte Consulting, 1, 3-14.

Tabinda C., Adafin J., and Wilkinson, S. (2019) "Review of digital technologies to improve productivity of New Zealand construction industry".

Thuy Duong, O. and Teuteberg, F. (2016). "Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry." Computers in industry 83: 121-139.

Turner, C. J., Oyekan, J., Stergioulas, L., & Griffin, D. (2020). Utilizing Industry 4.0 on the Construction Site: Challenges and Opportunities. IEEE Transactions on Industrial Informatics, 17(2), 746-756.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industrie 4.0: an outlook. International journal of distributed sensor networks, 12(1), 3159805.

World Economic Forum (2017). Shaping the Future of Construction Inspiring innovators redefine the industry Retrieved from http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_Inspiring_Innovators_redefine_the_industry_2017.pdf

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