buildings

MDPI

Article

Industry 4.0 Maturity of General Contractors: An In-Depth Case Study Analysis

Priyadarshini Das *, Srinath Perera, Sepani Senaratne and Robert Osei-Kyei

Centre for Smart Modern Construction, Western Sydney University, Kingswood, NSW 2747, Australia
* Correspondence: priya.das@westernsydney.edu.au

Abstract: Industry 4.0 technologies have business process re-engineering capabilities that can radically improve process performance and increase the effectiveness of communication and collaboration between actors. Despite the significant emphasis on technology adoption, the slow uptake rate can be attributed to ignoring nontechnical aspects, such as systemic change concerning people and processes. There are ample Industry 4.0 maturity models in the literature; however, a common criticism of maturity models lies in their applicability. This paper attempts to address this criticism by presenting two case studies where maturity assessments for general contractors were conducted to understand how ready they were to adopt to Industry 4.0 and what they could do to improve their current readiness. This paper aims to answer the following research questions: (1) Can the Industry 4.0 maturity modelling literature be applied in an organisational context for a construction general contractor? (2) Do construction general contractors relate to such an assessment? To answer the research questions, a comprehensive assessment of the Industry 4.0 maturity of two general contractors was conducted, thereby intending to support their strategic planning and systematise their transformation in Industry 4.0. The richness of the findings lies in the detailed understanding of the organisation's current Industry 4.0 capabilities and future plans, thereby establishing the applicability of the maturity attributes identified from the literature and confirming whether the managers of a construction organisation can relate to them.

Keywords: Industry 4.0; maturity model; organisational case study; business transformation; strategy

Citation: Das, P.; Perera, S.; Senaratne, S.; Osei-Kyei, R. Industry 4.0 Maturity of General Contractors: An In-Depth Case Study Analysis. *Buildings* **2024**, *14*, 44. https://doi.org/10.3390/buildings14010044

Academic Editor: Carol K.H. Hon

Received: 31 October 2023
Revised: 4 December 2023
Accepted: 21 December 2023
Published: 22 December 2023

1. Introduction

Kautzsch, Kronenwett [1] and Pęciak [2] stated that a forthcoming industrial revolution can be analysed by studying the impact of ongoing megatrends on industries. Reports from global consultants dominate the literature about megatrends; in their report, "Megatrends of tomorrow's world", Klein, Bansal [3] from Deloitte elaborated on a range of megatrends that will impact the future of industries, the majority of which concern increasing digitalisation and the integration of technologies such as artificial intelligence, additive manufacturing, augmented reality and blockchain systems. They also highlighted globalisation as a megatrend along with climate change, environmental awareness and resource scarcity [3]. The megatrends considered by PricewaterhouseCoopers [4] were very similar; they listed the rise of technology, shift in global economic power, climate change and resource scarcity as megatrends and emphasised that the confluence of global megatrends can intensify challenges for industries. Kautzsch, Kronenwett [1] from the global management consulting firm Oliver Wyman presented views converging with both these reports, considering economic globalisation, the digital revolution and resource constraints as megatrends that will impact long-term opportunities for industries. Pęciak [2] presented an illustration of research in global megatrends, which was significantly dominated by globalisation, digitalisation, exhaustion of resources, growing pressures on ecosystems and climate change. The various sources concur that the impending industrial revolution will

be shaped by megatrends, primarily driven by digitalisation and technology integration, alongside globalisation, climate change and resource scarcity.

The convergence of these megatrends shaping the construction industry's future is often consolidated as Industry 4.0, an integrated concept that can be managed as a whole system [5–8]. The progression towards Industry 4.0, marked by adopting more cohesive, tailored and combined process–product business frameworks, is essential for construction enterprises to preserve their market competitiveness and capitalise on emerging opportunities [9,10]. It drives businesses to use digital channels to engage with their key stakeholders and maintain relevance [11–14]. In addition to this, it points towards platform-based, vertically integrated global supply chains [15,16]. Ultimately, construction firms are endeavouring to transcend their traditional roles as economic entities focused on wealth creation, aiming instead to address human and societal needs within the wider social framework [17–19]. To achieve such transformational change, construction businesses must evolve from "low costs and operational flexibility" as the only priorities to "value" creation and "value-based" competition [20]. However, there are several barriers to such radical transformation, the foremost being cashflow restrictions, lack of client demand and top management commitment, capacity deficit, the inherent fragmentation in the industry, resistance to change and onerously long payback periods [21–24]. Thus, although Industry 4.0, encapsulating the convergence of significant megatrends, is pivotal for the construction industry's shift towards integrated, customer-centric business models and digital engagement, it is challenged by financial, demand, managerial and systemic barriers.

Although extensive research has been conducted on the technological ramifications of Industry 4.0 for the construction sector, there remains a gap in understanding the conversion of these technological advancements into strategic business results [25–27]. Thus, even though organisations are using the prowess of Industry 4.0 technologies to improve the efficiency of their processes, they are yet to exploit the full potential of Industry 4.0 despite being aware that it will be a game-changer [28]. A lack of skills in the workforce, the pace of technology evolution, struggles with transformational change and an absence of strategy are the principal reasons businesses are not ready for Industry 4.0 [29]. Another school of thought claims that the adoption of Industry 4.0-driven changes is low because they are still treated as standalone operations; for instance, industrialised house building has been around for a long time, but the uptake is slow because companies are not aware of its impact on the business model of the entire firm [30]. This creates the need to consider the phenomena of Industry 4.0 holistically and not as standalone improvements. Thus, Industry 4.0 transformation needs step-by-step guidance, such as assessment frameworks that can be used to evaluate the status quo for construction businesses in navigating Industry 4.0 business scenarios and recommend improvements [12,31,32].

There are several Industry 4.0 maturity assessments in the literature: Industry 4.0 readiness and maturity of manufacturing enterprises [33], the connected enterprise maturity model [34], IMPULS Industrie 4.0 readiness model [35], INDUSTRIE 4.0 migration model [36], PricewaterhouseCoopers (PwC) model of Industry 4.0 [37] and the KPMG Fourth Industrial Revolution Benchmark [38] are some popular examples. The Smart Modern Enterprise Construction Maturity Model (SMCeMM) presented by Das, Perera [39] is one such model developed specifically for construction general contractors. These models present an evolutionary path that increases an organisation's process maturity in stages where improvements at each stage provide the foundation upon which improvements can be built in the next stage [40]. However, there has always been a polarising debate on maturity models. They are often criticised for the unit of analysis being blurry or the maturity characteristics not being distinct from each other, thereby confusing a user regarding which level aligns most with her or his organisation [41,42]; this limits their applicability. Therefore, whether construction organisations can genuinely relate to and apply the Industry 4.0 maturity models in the literature is still untested [43] and establishes the research gap for this study.

This paper aims to answer the following research questions: (1) Can the Industry 4.0 maturity modelling literature be applied in an organisational context for a construction general contractor? (2) Do construction general contractors relate to such an assessment? The research questions are mutually supportive. The usefulness of the Industry 4.0 maturity models in the literature is subject to their perceived relevance; if the maturity models are applicable but general contractors are found not to relate to the results and recommendations, the models might need to be fine-tuned, indicating a gap between theory and practice. The first question examines whether the abstract maturity models developed in the literature suit general contractors' operational context. This speaks to the adaptability and scalability of Industry 4.0 concepts. The second question assesses whether general contractors, as significant stakeholders of the construction industry and fitting subjects for these evaluations, find the evaluation worth undertaking. Together, they offer a comprehensive view of the Industry 4.0 maturity level by combining theoretical readiness with practical applicability. This could lead to more tailored models that can guide general contractors in benchmarking their current practices and identifying areas for process improvements.

To answer the research questions, a comprehensive assessment of the Industry 4.0 maturity of two general contractors was conducted, thereby intending to support their strategic planning and systematise their transformation in Industry 4.0. This paper does not emphasise the impact of specific Industry 4.0 technologies; instead, it provides coherence and direction to the strategic transformation of construction enterprises in Industry 4.0. Moreover, the case studies detailed in this paper are derived from data gathered from Australian firms; while informative, they do not encompass the full spectrum of global industry practices. Consequently, the findings should be interpreted as a systematic aggregation of data appropriate for a cross-sectional analysis that offers a snapshot view rather than a comprehensive global perspective.

2. Preceding Work

Maturity assessments are instrumental in gauging business transformation by delineating the attributes that facilitate a progressive shift from an elementary to an advanced state of maturity [40,44,45]. Maturity assessments often describe the key process areas or KPAs: processes that are key to achieving a maturity level. As organisations accomplish the characteristics of a certain KPA continuingly, it is said to have institutionalised process capability relevant to that KPA at a given maturity level. Related key process areas are often grouped under process categories to easily structure the maturity model [40,46]. As mentioned earlier, there is no dearth of Industry 4.0 maturity models in the literature. Hajoary [47] systematically reviewed Industry 4.0 maturity models; 53 articles were thematically analysed to identify process categories of Industry 4.0 maturity that included strategy, people, culture, information technology and customer. Hizam-Hanafiah, Soomro [32] carried out a similar systematic review but extended it by including industry reports; 97 articles and industry reports were analysed to obtain the process categories of Industry 4.0 maturity that included technology, people, strategy, leadership and innovation. The aforementioned process categories also appear in the systematic review conducted by Mittal, Khan [48]. While there is clear consensus in the literature about the process categories critical for Industry 4.0 maturity, whether these can align with the construction context was questionable until recently.

Even though several maturity assessments have been published in the construction management literature—project controls maturity [49], BIM maturity [50], risk management maturity [51], safety management maturity [52], offsite construction maturity [53] and lean construction maturity [54]—the literature on Industry 4.0 maturity in construction is very recent. Das, Perera [55] presented a systematic review of 56 Industry 4.0 maturity models and then evaluated if the process categories of Industry 4.0 maturity identified would be appropriate in the context of a construction general contractor. The seven process categories identified were data management, people and culture, leadership and strategy, automation, collaboration and communication, change management, and innovation. In a subsequent

work, Das, Perera [39] presented an Industry 4.0 maturity model and assessment framework explicitly developed for construction general contractors. The structural aspects of the framework, including the five levels of maturity, were adopted from Paulk, Curtis [40]; the levels were named suitably as ad-hoc (L1), driven (L2), transforming (L3), integrated (L5) and innovative (L5). Table 1 illustrates a high-level overview of the maturity model presented by Das, Perera [39] with an example of the maturity characteristics of one of the KPAs—data integration.

Table 1. A high-level overview of the maturity model presented by Das, Perera [39].

Maturity Level	Characteristics	Example Process in Which Data Integration Happens
Level 1—Ad-hoc	Enterprises that consider Industry 4.0 attributes an overhead, and their change initiatives are infrequent.	Standalone and solid systems that do not interact and rely on human intervention (different departments submit forms and data).
Level 2—Driven	Operations are "driven" by Industry 4.0 attributes, and enterprises are transitioning to a level where they actively search for opportunities of Industry 4.0 transformation, but traditional habits persist.	Third-party cloud-based solutions such as Procore and Hammertech help to collect and integrate data.
Level 3—Transforming	Enterprises are at the turning point of Industry 4.0, and they are "transforming" to assimilate their attributes into the business, which means it usually has parity with other considerations, but at times it is left behind in favour of other higher priorities.	Extract, load and transform (ELT) processes exist to define the structure, nature and storage of data.
Level 4—Integrated	Industry 4.0 transformation is well "integrated" into the business, and enterprises start considering it as a key business strategy, a competitive advantage and a key driver of top and bottom-line growth.	Seamless integration of systems using APIs.
Level 5—Innovative	Enterprises start undertaking Industry 4.0 business model innovation initiatives, integrate them into all aspects of the business and continually improve them.	A digital ecosystem based on a universally accepted standard data structure such as the ISO 27,001 exists, enabling plug and play.

Further, the framework comprised 63 assessment attributes translated into assessment questions (refer to Appendix A) encompassing the seven process categories mentioned above and corresponding maturity characteristics across the five maturity levels. Given its complete alignment with this research, the work carried out by Das, Perera [55] and Das, Perera [39] was considered the theoretical foundation for this paper.

3. Research Approach

Two case study organisations were selected to conduct the maturity assessment presented by Das, Perera [39] and evaluate whether it can be applied to a real-world construction organisation. A significant criticism of maturity models is that there is a misconceived linearity that oversimplifies reality and does not consider multiple paths to maturity [42,56–58]. Therefore, it was necessary to consider more than one case study to demonstrate different approaches to adopting Industry 4.0. There was potential for each case to provide unique insights into the application of Industry 4.0 maturity characteristics within different operational environments or organisational cultures. It was considered that two case studies might reveal nuances that a single case study would not, thereby enriching the understanding of the central theme. However, it is to be noted that the intent of the paper was to understand the maturity characteristics of both organisations and not to analyse them against each other comparatively.

Organisations whose primary service proposition was general contracting were selected. The selection criteria for the organisations involved in this research were twofold. Firstly, the organisations needed to have managed contracts exceeding one million AUD, ensuring that the study focused on entities with substantial operations and influence in the

construction sector. Secondly, the organisations must have demonstrated a willingness to engage with our research team, providing access to their employees and data. This is vital for accurately assessing their current maturity levels and identifying the specific challenges and opportunities that Industry 4.0 presents to them. As seen earlier, the assessment framework comprised 63 questions (Q1–Q63) and corresponding characteristics across different maturity levels. Exemplary qualities of maturity models include software tool support [42] to enhance the utilisation and applicability of the research outputs [59]. Therefore, the theoretical assessment was converted into a web-based format to ease data collection. The web-based assessment was developed by translating the assessment attributes into assessment questions and the maturity level characteristics into answer options to generate an Industry 4.0 maturity assessment for construction enterprises [39]. This paper used the cloud-based solution Typeform (https://www.typeform.com/) to develop the web-based maturity assessment. It is to be noted that this does not represent a survey; the essence of the case studies lies in the in-depth interviews that followed the data collection through the web-based assessment. The web-based assessment provided a high-level overview, while the in-depth interviews aided in a more profound understanding; both complemented each other.

Organisation 1 was a family-owned construction company primarily providing retail, commercial and residential building and construction services across Australia. They employ a workforce of approximately 700 employees with an annual revenue of around 1.6 million AUD. They had a designated role called "General Manager of Design and Innovation" through which any pilot innovation initiative goes. The digital design manager reported directly to the general manager of design and innovation. He was tasked with completing the web-based maturity assessment and taking part in in-depth interviews to provide supporting evidence on behalf of the organisation, as it was considered an innovation initiative for the organisation. Organisation 2 operated as a privately held, local entity, generating income through the delivery of construction management services for retail, commercial and industrial projects. They operate in Australia and employ a workforce of approximately 200 employees with an annual revenue of around 0.34 million AUD. Organisation 2 did not have a designated role for innovation; the head of data, technology and systems was in charge of spearheading innovation in the company; he completed the web-based maturity assessment and participated in the in-depth interviews on behalf of the organisation. Over and above their designations, the interviewees were knowledgeable about the ongoing industry trends and were experienced in transformational initiatives in their organisations. The process flow for conducting the organisational case studies is illustrated in Figure 1.

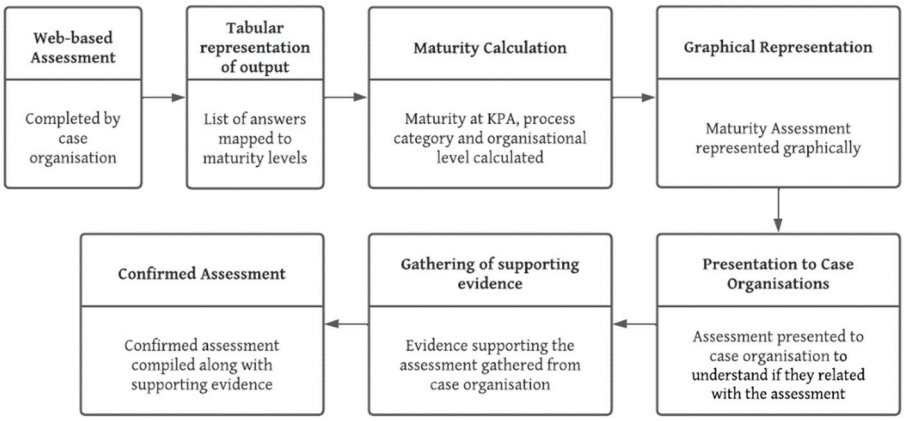

Figure 1. Process flow for conducting the two organisational case studies.

The case organisations selected the maturity characteristics that aligned with their organisation using the web-based maturity assessment. The assessment generated maturity of the organisations at three levels: key process area (KPA), process category (PC) and

overall organisational maturity. Initially, the response to each assessment item was used to assign a corresponding maturity level. Subsequently, responses to a set of items within each key process area (KPA) produced a series of maturity levels (e.g., L5, L5, L3, L4, L4, L3). If discernible, the mode of these levels was designated as the KPA's maturity level; otherwise, the average, rounded up to the nearest whole number, was adopted. This methodology was consistently applied to determine the maturity for each process category, culminating in an aggregated organisational maturity level. The maturity assessment was then represented graphically. As mentioned earlier, the purpose of the web-based assessment and graphical representation was to provide a high-level representation of the organisation's maturity and initiate the in-depth interviews as is usually performed in case of maturity assessments. This does not represent a survey and subsequent quantitative analysis of results. The assessment generated was then presented to the case organisations in the in-depth interview to understand if they related to the assessment and believed it was an accurate representation of the status of their organisation. Subsequently, evidence supporting the selected maturity characteristics was gathered from the case organisation. The structure of the in-depth interviews was kept semi-structured to allow for further investigations wherever required. The questions were fine-tuned to their maturity assessment and differed for each organisation.

A qualitative data analysis technique is adopted for this paper. The qualitative methodology employed in this paper is chosen to align with the research's intent to deeply understand the dynamic and subjective nature of Industry 4.0 maturity characteristics within construction enterprises—a field where established quantitative benchmarks are yet to be defined [47]. This approach allows for an in-depth exploration of context-specific maturity processes through a subjectivist lens [60], capturing the nuanced interpretations essential in a nascent domain where social constructs significantly influence technological adoption and practices. By integrating web-based assessments with rich, qualitative interviews, this research avoids the rigidity of quantitative measures [61] in favour of a more flexible, interpretive analysis that is both inductive and value-laden [62], thus providing a profound understanding of the evolving phenomenon under investigation.

The answers extracted from the interview transcripts were labelled uniquely and referred to using the labels while compiling the confirmed assessment (maturity characteristics and supporting evidence), as explained in the subsequent sections. The label was used to uniquely identify each statement and comprised the organisation (O1/O2), the process category the statement is related to (DM for data management and so on), followed by a statement number. Each statement was used as the unit of analysis. For ease of understanding, an example is illustrated in Table 2, below.

Table 2. Example of questions and corresponding answers (Organisation 1).

Question Based on the Assessment	Answer Obtained from Case Organisation	Unique Label
What tools do you use for data acquisition and integration in your company?	Hammertech mandated on our projects, models and metadata for digital assets—we acquire from the content creator or the digital supply chain going up and then it is Q/Aed by one of our digital engineers to make sure it has maintained the requirement. Integration is just with Hammertech now, but we are talking with Mulesoft, a company that builds APIs for SaaS platforms. Revitzo, LIDAR scan.	O1/DM/1 (Organisation 1/Data Management/Statement 1)
Describe your criteria or metrics to decide what data to acquire.	Construction program—the status, cost data—understand the actual cost (Synchro Pro), in terms of information delivery—the number of clashes, trends in clashes, how does that communicate back to the sub-contractor (Revitzo), what happens on site with the digital engineering side of things and how does that stack up with the commercial side of the business (ROI).	O1/DM/2

Table 2. *Cont.*

Question Based on the Assessment	Answer Obtained from Case Organisation	Unique Label
What are your primary data analytics and visualisation tools/dashboard?	Revitzo for collaboration. Issue tracking. Design, preinstall and post-install. Customisable dashboard. Working on Power BI to get a dashboard across our projects as well. Power BI is very good at live capture of information that can be customised. Executive level information, project director information and then the design and delivery team (construction management) dashboard. However, it will depend on the API integration.	O1/DM/3

4. Results and Discussion

This section presents the findings of this paper. The input obtained from the web-based assessment of Organisation 1 is presented in Appendix A. Following this, a comprehensive assessment of Organisation 1's maturity corresponding to the seven process categories consolidated from the detailed interviews is presented. A similar analysis was carried out for both case studies but is not presented for Organisation 2 to avoid redundancy issues. The outputs from the maturity assessments pertaining to both organisations are graphically illustrated in Figure 2. The richness of the findings lies in the granular analysis of the organisations' current Industry 4.0 capabilities and future plans, thereby establishing the applicability of the maturity attributes identified in Das, Perera [39] and confirming whether the managers of a construction organisation can relate to them.

4.1. Sample Assessment

4.1.1. Data Management

For data collection, Organisation 1 relies on Hammertech (https://hammertechglobal.com/en-au/) and utilises light detection and ranging (LIDAR) for progress tracking (O1/DM/1). Integration remains compartmentalised, but the interest in MuleSoft's (https://www.mulesoft.com/) APIs (O1/DM/1) hints at future seamless integration aspirations. Analytics focus on profitability using static methods. Revitzo (https://revizto.com/en/) is employed for design collaboration, with plans to transition to Microsoft Power BI (https://powerbi.microsoft.com/en-au/) for broader analytics (O1/DM/3). The drive towards role-based access suggests a move towards inclusive data visualisation strategies. Organisation 1 adopts hybrid storage, using local servers and third-party clouds. They are contemplating a data hub for government projects, with protocols like the Citrix (https://www.citrix.com/en-au/products/citrix-web-app-firewall/) firewall (O1/DM/10) ensuring security. Validation methods, such as BIM auditing within REVIT (https://www.autodesk.com.au/products/revit/overview) (O1/DM/11), guarantee data accuracy. Organisation 1's machine-readable data exists sporadically. However, they are exploring BuildAI (https://www.buildai.construction/) and Openspace.ai (https://www.openspace.ai/), exemplifying advanced machine-readable datasets. Their strategy to embed transformation initiatives in bids (O1/DM/12) underscores a commitment to digital evolution. Given the above, Organisation 1 was assessed at level 2, which is "driven", as per the assessment attributes for each KPA under data management. The breakdown of data management maturity at the KPA level is illustrated in Figure 2a. Before this assessment, Organisation 1 had conducted an internal assessment to evaluate its data management capabilities and achieved a score of 25%, which revealed the organisation has not gone beyond knee-jerk reactions such as digital coordination (O1/OC/1). This aligned with the assessment derived from the current framework; however, this framework clearly articulated that the organisation is progressing in the right direction.

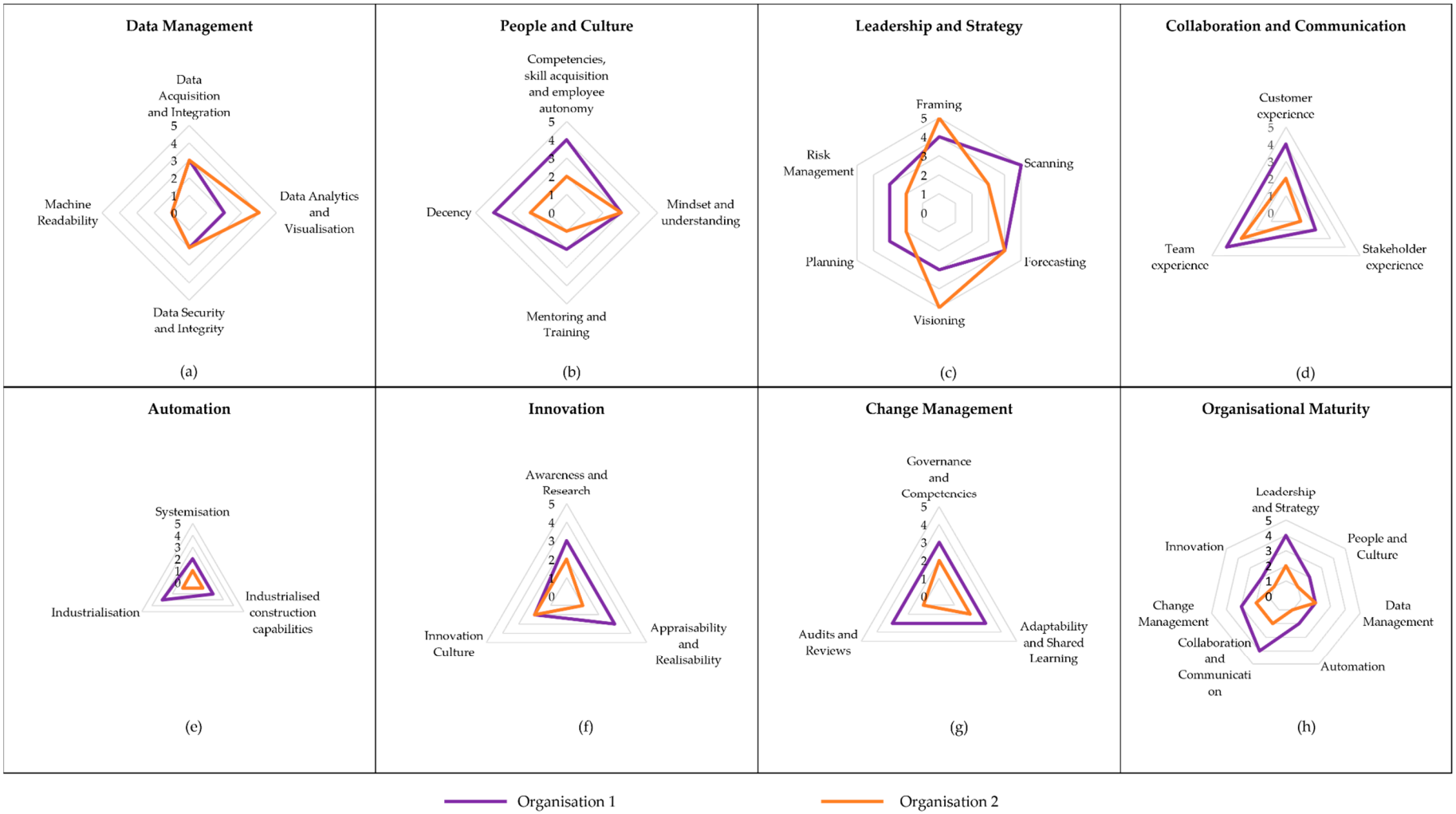

Figure 2. Maturity assessment output—graphical representation of the maturity characteristics of Organisation 1 and 2. (**a**–**h**) Represent the maturity of each of the process catergories at a granular level.

4.1.2. People and Culture

Organisation 1 presently maps specific role competencies via its intranet (Q16-17). A forthcoming integrated platform linked to LinkedIn Learning (https://www.linkedin.com/learning/) emphasises digital skills (O1/PC/1). QR codes aid in capturing training codes through Hammertech (O1/PC/2). The promotion of hybrid roles is notable, like the transformation of a services manager to a digital services manager (O1/PC/3). Scalable capacity-building features the definition of "super users" (O1/PC/4). Role-specific, outcome-based controls are consistently refined, including monitoring metrics on Revitzo and other cost-based outcomes (O1/PC/5, O1/PC/6). Employees partake in the transformation process, with their feedback vital for success (Q20-21). Visual communications, like mock-ups, facilitate this understanding, ensuring that new digital tools resonate with tasks and do not intimidate users (O1/PC/7). While a buddy system exists, it is largely unstructured. Notably, the digital design manager personally mentors new recruits. A significant training program for digital engineering is on the horizon, aiming to train over 400 employees tailored to specific roles (O1/PC/8, O1/PC/9). Earning a recommendation as a top workplace in Australia in 2019, Organisation 1 prioritises decency and wellbeing, as reflected in their induction processes and mental health programs (O1/PC/10). An established ethics framework further underpins their commitment (Q26). Given the above, Organisation 1 was assessed at Level 2 in the process category of people and culture, as per the assessment attributes for each KPA under it (Q16-26). Refer to Figure 2b for the illustration.

4.1.3. Leadership and Strategy

Organisation 1′s executive leadership team (ELT) is deeply attuned to the feedback they receive from their ground-level employees. Their comprehensive understanding of the market and its trends is further solidified through rigorous market research. Moreover, they utilise tools like Microsoft Power BI for visualising data (O1/LS/3). This strategic vision is not just theoretical; it is meticulously translated into actionable metrics, with planning efficiently executed through platforms like Microsoft Teams (https://www.microsoft.com/en-au/microsoft-teams/group-chat-software) (Q31, O1/LS/4). As a testament to their dedication to digital transformation, Organisation 1 also presented an in-house strategic digital transformation report (O1/LS/1), which delves deep into industry analysis, assessing the organisation's digital capabilities and setting forth digital design strategies and plans. Given the above, Organisation 1 was assessed at Level 4 for their leadership and strategy as per the assessment attributes for each KPA under it, indicating that their ELT has started to view the Industry 4.0 transformation as an integral component for business growth and as a competitive advantage. Refer to Figure 2c for the illustration.

4.1.4. Collaboration and Communication

Organisation 1 employs three specialised common data environments: Autodesk BIM 360 (https://www.autodesk.com/bim-360/) for design interactions, Aconex (https://www.oracle.com/construction-engineering/aconex/) for client engagements and Revitzo for issue management (O1/CC/3). Their proactive customer engagement approach is digital-centric, with consistent metrics-driven feedback loops (Q35-38, O1/CC/1). For client presentations, platforms like Enscape (https://enscape3d.com/), Revitzo and Autodesk 3Dsmax (https://www.autodesk.com.au/products/3ds-max) are pivotal, and the sharing of project details is judiciously managed (O1/CC/3). Stakeholder engagement is enhanced by integrating the extended supply chain into their common data environment (Q39). While some champions within the organisation drive stakeholder relationships (Q41), a unified integration strategy remains a future goal (Q40). Their supply chain operations are orchestrated through an in-house enterprise resource planning system (O1/CC/4). Team experiences are characterised by an emphasis on inclusivity, wellbeing, and effective communication facilitated by the common data environments (Q42, Q43). However, alignment of team objectives and individual interests is ongoing (Q44). Given the above,

Organisation 1 was evaluated at Level 4 for collaboration and communication as per the assessment attributes for each KPA under it; the breakdown is illustrated in Figure 2d.

4.1.5. Automation

In the realm of systemisation, Organisation 1 has implemented standard operating procedures (SOPs) to address specific improvements, resulting in discernible enhancements in productivity (Q45-47). They have introduced training modules such as Revitzo and Synchro 4D (https://www.bentley.com/en/products/brands/synchro) (O1/AT/1), and they maintain ISO 9001 quality assurance, notably via the Aconex platform. Regarding industrialisation, Organisation 1′s engagement with the industrialised construction (IC) model is foundational. Their projects lack standardisation and predominantly opt for unique approaches (Q48-51). While there is a tendency towards design for manufacturing and assembly (DfMA) for specific components, a holistic adoption of the IC model is limited due to various project-specific variables (O1/AT/2). Therefore, Organisation 1 was assessed at a "driven" Level 2 concerning its automation capabilities per the assessment attributes for each KPA under it, as depicted in Figure 2e.

4.1.6. Innovation

Organisation 1 is crafting an innovation strategy aligned with its growth objectives (Q52-54). Despite methodical innovation drives, their innovation processes lack standardisation (O1/IN/1). A pivotal role, "Head of Design and Innovation", has been established (O1/IN/2). The ELT values innovation pilots. Typically favouring safer ventures, they occasionally embrace calculated risks (Q55-56). Their approach involves a rigorous evaluation of operational roles before implementing suitable software. A recent pilot using Revitzo achieved significant cost and time efficiencies (O1/IN/3–O1/IN/5), though exact ROI determination remains a challenge (O1/IN/6). A budding innovation culture is evident, but it is limited to specific teams. Despite the intent, resource constraints occasionally hinder scalable innovation (Q57). Given the above, Organisation 1′s innovation capabilities were assessed at "driven" Level 2 based on the assessment attributes for each KPA under it, as detailed in Figure 2f.

4.1.7. Change Management

Organisation 1 applies informal change procedures without rigid governance (Q58). While replicating prior achievements is preferred, its consistent application varies (Q59). New software additions are treated as change catalysts, evaluated using success metrics like time, cost and reskilling requirements (O1/CM/1, O1/CM/2). The organisation is change-responsive (Q60) and promotes inter-team knowledge sharing (Q61), though its transformative potential may be limited. Audits and reviews are annual, sometimes involving third-party consultants (Q62, Q63), with insights guiding future change actions. Given this, Organisation 1, assessed at Level 3 for change management, emphasises "metamorphosis" in its digital design strategy, denoting a shift towards Industry 4.0 change attributes, as illustrated in Figure 2g.

4.1.8. Overall Organisational Maturity

Figure 2h illustrates the overall maturity assessment for Organisation 1. Organisation 1 was assessed as Level 4 for both *leadership and strategy* and *collaboration and communication* process categories, signifying the Industry 4.0 transformation is well integrated into these process categories, and the executive leadership team is starting to consider it a key business strategy, competitive advantage and key driver of top- and bottom-line growth. *Change management* was assessed as Level 3, signifying that Organisation 1 is at the turning point of Industry 4.0 and they are transforming to assimilate change management attributes into the business. Aligning with the above, Organisation 1 was assessed as Level 2 for maturity in the majority of the process categories, including *data management*, *people and culture*, *automation*, and *innovation*, justifying why they are, overall, at Level 2. Organisation

1 completely related to the assessment and said it was helpful, as every business needs a reality check but not everyone wants to hear it. They added that the assessment helps to crystallise the organisation's strategic objectives and start managing their efforts efficiently (O1/OC/2). Organisation 2 was also at an overall maturity of Level 2, which makes it a "driven" organisation. This signifies Industry 4.0 attributes drive them, and they are transitioning to a level where they actively search for opportunities for Industry 4.0 transformation. Figure 2 illustrates the overall maturity assessment for Organisation 2 in contrast with Organisation 1. Organisation 2 was assessed as Level 2 for *data management*, *leadership and strategy*, *collaboration and communication*, *and change management* process categories, justifying why they are, overall, at Level 2. The process categories that lagged at Level 1 included *people and culture*, *automation*, and *innovation*, signifying that relevant to these process categories, Industry 4.0 attributes are considered an overhead and change initiatives are infrequent and ad-hoc. Organisation 2 completely related to the assessment and said it was very comprehensive and would prove an educational piece for them (O2/OC/1).

The case studies effectively addressed the research questions concerning the relevance of Industry 4.0 maturity models in real-world settings and the degree to which organisations aligned with the evaluations. Both the case organisations believed the assessment was an effective way of understanding the status of their organisations when navigating Industry 4.0 business scenarios and prioritising their process improvements. They defined it as a "reality check" that helps organisations initiate conversations that otherwise would have remained tacit. They confirmed the assessment was easy to use and the maturity level characteristics distinctly represented step changes in an organisation's journey towards Industry 4.0 maturity, thereby not confusing users while selecting a particular stage of maturity with respect to their organisation. This aligns with Maier, Moultrie [63], who stated that the assessment criteria of a maturity model should exhibit a high level of intersubjective verifiability; i.e., the corresponding descriptions must be precise, concise and clear when discriminating between levels. It was evident from the case studies that even though both Organisations 1 and 2 were assessed as "driven" organisations, on a granular level, there were differences. These are explained in detail in the following section.

4.2. Granularity of Assessment

The assessment provided for granular analysis and helped to distinguish the two organisations even when both were assessed as "Driven (Level 2)" enterprises. The assessment deconstructed organisational maturity into an array of key process areas (KPAs), which effectively narrowed down the improvement areas. When the maturity characteristics of Organisations 1 and 2 were compared, it was observed that 33 per cent of the characteristics for Organisation 2 matched an ad-hoc (Level 1) enterprise, while for Organisation 1, only 6 per cent of the characteristics were at an ad-hoc level. Moreover, while only 10 per cent of Organisation 2′s maturity characteristics were aligned with a "Transforming (Level 3)" enterprise, Organisation 1 had 27 per cent of their maturity characteristics matching "Transforming (Level 3)" enterprises. Figure 3 illustrates the distinctions between the two organisations according to their maturity characteristics.

Figure 3 signified that even when both organisations were assessed as "Driven (Level 2)" enterprises, Organisation 2 had just managed to cross into Level 2, while Organisation 1 was comfortably cruising towards becoming a "Transforming (Level 3)" enterprise. The assessment clearly identified that Organisation 2 lagged Organisation 1 with respect to people and culture, collaboration and communication and change management to name a few. Figure 2d illustrates how the assessment was able to distinguish between both organisations with respect to their collaboration and communication capabilities. Organisation 1 is measurably more mature than Organisation 2 as they use three different common data environments for collaboration and communication, each with a different purpose. As discussed in Section 4.1.4, the first one is for design and subcontractor interaction (design management), the second one for client interaction (contract management) and the third one for issue management and reality capture. The existence of such common data environ-

ments was one of the key differences between the two test organisations that was accurately identified through the assessment. It is expected that this granular analysis will lead to precise recommendations fine-tuned to the status of the organisation being assessed. The following subsection explains how the assessment aids in generating recommendations to prioritise process improvement of the organisations being assessed.

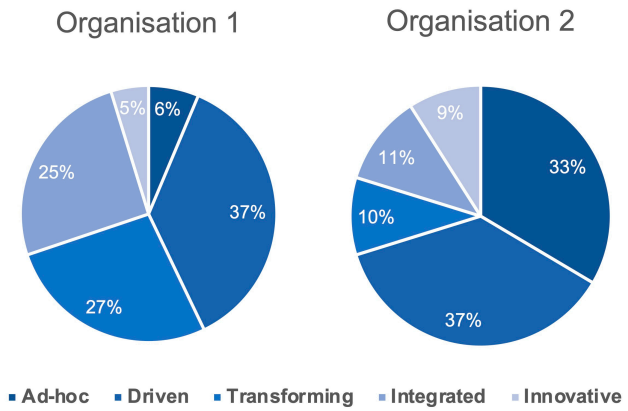

Figure 3. Comparison of maturity characteristics for Organisation 1 and 2.

The comprehensive assessment facilitated the classification of the Industry 4.0 capabilities into dynamic capabilities and benchmark capabilities. Dynamic capabilities are proponents of change and aid an enterprise to integrate, build and reconfigure internal and external competencies to address a rapidly changing environment [64]. Benchmark capabilities are tools, state-of-the-art software or technology products that are in use today but that might be replaced in the future. The benchmark capabilities are a means of achieving a dynamic capability. The assessment was able to distinguish between the dynamic and benchmark capabilities of the organisations being assessed. For example, both Organisations 1 and 2 were assessed as "Driven (Level 2)" enterprises for their data management capabilities, and the granular assessment was also very similar, as illustrated in Figure 2a; however, the software or tools they used to achieve the same dynamic capability were vastly different, and the assessment was able to remain agnostic to the software or tools, as illustrated in Table 2.

Table 3 illustrates how Organisation 1 and 2 achieved similar dynamic capabilities using a vastly different set of software and tools yet the assessment remained agnostic to those and accurately identified them. This shows how dynamic capabilities can be achieved by whatever technology product is suitable for an organisation; technology products are a means to achievement and not the criteria for attaining maturity.

Table 3. Comparison of dynamic and benchmark capabilities.

Sl. No.	Dynamic Capability	Benchmark Capability	
		Organisation 1	Organisation 2
1	Acquiring and integrating data	Hammertech™; MuleSoft™ integration in the pipeline	Technology stack comprising multiple tools: Dynamics 365™, CostX™, Microsoft Excel™, Jobpac™ and a paid market data provider BCI™ Central. Integration using Calumo™.
2	Analysing and visualising data	Revitzo™; Microsoft Power BI™	Calumo™; Procore™ is in the pipeline.
3	Validating data	Interoperability tools within REVIT™; LIDAR scanner input is overlayed with Navisworks™	For cost modelling, there are human resource gatekeepers for validating the metrics monthly.

Table 3. *Cont.*

Sl. No.	Dynamic Capability	Benchmark Capability	
		Organisation 1	**Organisation 2**
4	Generating insights from learning systems	BuildAI™ and Openspace.ai™ for reality capture and construction programme update	Calumo for twelve-month projection of the pipeline of projects and cost modelling.

5. Future Work

While the assessment helped to ascertain the maturity of the organisations with respect to the KPAs, the assessment criteria and maturity characteristics, to some extent, aided in generating recommendations for the organisations. Recommendations were derived from the maturity characteristics of the subsequent level; for example, if the organisation was assessed as "Driven (Level 2)" with respect to data acquisition, the recommendation was extracted from the maturity characteristics defined for "Transforming (Level 3)". The recommendations for Organisation 1, as obtained from the model, aligned with the organisation's planned initiatives, which strongly validates the maturity characteristics identified in this research. However, these recommendations are very high-level, as it is not a fully developed comparative or prescriptive model, since the domain of application is still evolving. Comparative or prescriptive maturity models need significant historical data, which are unavailable for Industry 4.0 business scenarios. Nonetheless, the framework proposed in this study promises to establish benchmarks for Industry 4.0 within the construction sector. This can be achieved through the execution of a comprehensive assessment survey across a substantial cohort of construction firms, coupled with the application of quantitative analytical methods to interpret the data. The test organisations were keen to compare themselves against industry standards and mentioned that understanding where they stand in comparison to their competitor would be an influential driving force to improve.

6. Conclusions

The theoretical contribution of this paper lies in the confirmation that the Industry 4.0 maturity models in the literature can be applied in the real-world context of a construction organisation including the demonstration of a method of conducting the assessment. Furthermore, the paper also established the relatability of such an assessment to the managers of a construction organisation through two in-depth case studies. Practically, the results indicated that the organisations were able to successfully complete the web-based assessment. They associated with the process categories, KPAs, their definitions and maturity level characteristics and were able to choose the characteristics that aligned most with their organisation. The assessment provided for granular analysis and helped to measurably distinguish the two organisations even when both were assessed as "Driven (Level 2)" enterprises. The assessment deconstructed organisational maturity into an array of key process areas (KPAs), which effectively narrowed down the improvement areas. This granular analysis also led to high-level recommendations fine-tuned to the status of each organisation. The assessment was able to distinguish between the dynamic and benchmark capabilities of the organisations being assessed and hence identify multiple paths to maturity. The assessment was successful in its attempt to give coherence to the strategic planning of general contractors by assessing their capabilities across process categories of data management, people and culture, leadership and strategy, collaboration and communication, automation, innovation and change management.

Despite the relevance of the findings of this research, there are a few limitations worth acknowledging. The assessment framework devised in this research employs a qualitative approach, primarily focused on evaluating existing capabilities against given criteria while providing suggestions for improvement. Currently, it does not function as a comparative tool, nor is it suitable for benchmarking purposes without analysing extensive historical data collected from numerous evaluations through quantitative methods. The assessment

provides high-level recommendations for improvement; however, it is not a fully developed prescriptive model, as the domain of application is still evolving.

Considering the diverse range of stakeholders within the construction industry, forthcoming research endeavours should extend their focus to include entities such as subcontractors, consultants and clients. The maturity assessment demonstrated in this paper could be refined to reflect the specific dimensions and capacities of various enterprise sizes and types. Future scholars are encouraged to determine which enterprise categories would benefit from such tailored maturity models and explore their differential attributes. Additionally, there is an opportunity to convert this maturity assessment into a practical tool within an enterprise setting, implementing it periodically to evaluate whether the proposed improvements effectively elevate the organisation's maturity level.

Author Contributions: Conceptualization, S.P., S.S., R.O.-K. and P.D.; methodology, S.P., S.S., R.O.-K. and P.D.; validation, P.D.; formal analysis, P.D.; writing—P.D.; writing—review and editing, S.P., S.S. and R.O.-K.; supervision, S.P., S.S. and R.O.-K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Centre for Smart Modern Construction and the School of Engineering, Design and Built Environment, Western Sydney University, Australia.

Data Availability Statement: Data presented in this study are available in the article.

Acknowledgments: The authors acknowledge the contributors of the Centre for Smart Modern Construction, Western Sydney University, Australia, and the case study organisations that participated in the web-based maturity assessment.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Inputs from the web-based assessment for Organisation 1.

	Assessment Questions	Maturity Levels				
		1	2	3	4	5
Data Management						
Q1	How would you describe the data that you are acquiring?				■	
Q2	How are you acquiring this data?			■		
Q3	What is the extent of your data acquisition?					
Q4	How do you decide what data to acquire?		■			
Q5	To what extent do your systems talk to each other?	■				
Q6	What is the extent of your data integration?					
Q7	What kind of data analytics are you using for decision-making within your enterprise?				■	
Q8	What kind of tools are used for data analytics and visualisation?		■			
Q9	How would you describe data analytics and visualisation in your enterprise?					
Q10	What is the extent of visibility of your analytics and visualisation?					
Q11	Do you have an understanding of where your data is stored?					
Q12	How would you describe your data security standard?			■		
Q13	Who maintains your data security protocols?				■	
Q14	How do you ensure the integrity of your data?	■				
Q15	How would you describe the extent of machine readability in your enterprise?					

Table A1. *Cont.*

	Assessment Questions	Maturity Levels				
		1	2	3	4	5
People and Culture						
Q16	How do you map competencies in your organisation?					
Q17	What is your approach to competency building?					
Q18	What is your approach to skill acquisition?					
Q19	What is your approach to employee autonomy?					
Q20	What is the mindset of your employees towards change?					
Q21	What is the mindset of your ELT towards business transformation?					
Q22	What is your approach to mentoring?					
Q23	How do you monitor the mentoring process?					
Q24	Which of these would best describe the learning culture in your organisation?					
Q25	Which of these would best describe the Learning Management System (LMS) in your organisation?					
Q26	What is your approach towards ensuring decency of decision making within your organisation?					
Leadership and Strategy						
Q27	Which of these best describes how you identify and create strategic focus towards key challenges?					
Q28	How do you understand what is going around in both the immediate and extended environments?					
Q29	How do you consider a range of future possibilities?					
Q30	How do you decide what the organisation wants in the future?					
Q31	How do you translate foresight into action?					
Q32	Which of these best describe your risk culture?					
Q33	What are your risk protocols?					
Q34	Who is in charge of risk management?					
Collaboration and Communication						
Q35	Which of the following would best describe customer engagement in your organisation?					
Q36	Does your organisation ensure customer involvement? If yes, how?					
Q37	Which of the following best describes your customer relationship management?					
Q38	Which of these best describe how you communicate with your customer?					
Q39	How would you describe your relationship with your extended supply chain?					
Q40	Which of the following best describes your approach to managing your extended supply chain?					
Q41	Who drives supply chain relationship management in your organisation?					
Q42	Which one of the following describes how committed teams in your organisation are?					
Q43	What is the level of cooperation amongst teams and team members in your organisation?					
Q44	What is the level of communication amongst teams and team members in your organisation?					

Table A1. *Cont.*

	Assessment Questions	Maturity Levels				
		1	2	3	4	5
Automation						
Q45	Which of the following would describe the standard operating procedures (SOPs) in your organisation?					
Q46	Who drives systemisation in your organisation?					
Q47	What kind of gains are you observing from your systemisation initiatives?					
Q48	How would you describe your cognition of IC mode and your willingness to adopt the IC mode?					
Q49	Are your organisational capabilities, such as design capability, supply chains etc., suited to meet IC requirements?					
Q50	How would you describe your experience in selecting technologies and process schemas to deal with IC mode in components design, production, transportation and assembly?					
Q51	Which of these would best describe your delivery?					
Innovation						
Q52	What is your approach to growth through innovation?					
Q53	What is the focus of innovation in your organisation?					
Q54	Which of the following best describes how you obtain new knowledge that you might use to innovate?					
Q55	How do you review, select and invest in innovation for potential growth and expansion?					
Q56	Which of the following best describes the benefits or return on investment for your innovation initiatives?					
Q57	Which of the following best describes the innovation culture in your organisation?					
Change Management						
Q58	Which one of the following best describes the change governance in your organisation?					
Q59	How do you roll out change at scale in a repeatable standardised format?					
Q60	How does your organisation react to changes?					
Q61	Do you share learning from a change management process across teams?					
Q62	Do you perform audits on a change management process?					
Q63	Do you review changes implemented and outcomes achieved?					

References

1. Kautzsch, T.; Kronenwett, D.; Thibault, G. *Megatrends and the Future of Industry*; Oliver Wyman: New York, NY, USA, 2017.
2. Pęciak, R. Megatrends and their implications in the globalised world. *Horyzonty Polityki* **2016**, *7*, 167–184.
3. Klein, F.; Bansal, M.; Wohlers, J. *Beyond the Noise: The Megatrends of Tomorrow's World*; Deloitte Centre for Long View: München, Germany, 2017.
4. PricewaterhouseCoopers. *Five Megatrends and Their Implications for Global Defense & Security*; PricewaterhouseCoopers: London, UK, 2016.
5. World Economic Forum. *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*; World Economic Forum: Colony, Switzerland, 2016.
6. World Economic Forum. *Future Scenarios and Implications for the Industry*; Prepared in Collaboration with The Boston Consulting Group; World Economic Forum: Colony, Switzerland, 2018.
7. Ribeirinho, M.J.; Mischke, J.; Strube, G.; Sjödin, E.; Blanco, J.L.; Palter, R.; Biörckas, J.; Rockhill, D.; Andersson, T. *The Next Normal in Construction: How Disruption Is Reshaping the World's Largest Ecosystem*; McKinsey & Company: Chicago, IL, USA, 2020.
8. Swaddle, P. Megatrends—What Are the Global, Long-Term Impacts on the Future of the Built Environment? This Article Will Form Part of a Wider Series on These Subjects, in Association with CIMCIG. 2020. Available online: https://www.thenbs.com/knowledge/megatrends (accessed on 10 December 2021).
9. Weking, J.; Stöcker, M.; Kowalkiewicz, M.; Böhm, M.; Krcmar, H. Leveraging industry 4.0—A business model pattern framework. *Int. J. Prod. Econ.* **2020**, *225*, 107588. [CrossRef]

10. Culot, G.; Nassimbeni, G.; Orzes, G.; Sartor, M. Behind the definition of Industry 4.0: Analysis and open questions. *Int. J. Prod. Econ.* **2020**, *226*, 107617. [CrossRef]
11. Ernst & Young. *The Digitisation of Everything: How Organisations Must Adapt to Changing Consumer Behaviour*; Ernst & Young: London, UK, 2011.
12. Dowd, T.; Marsh, D. The Future of BIM: Digital Transformation in the UK Construction and Infrastructure Sector. RICS Insight Paper 2020. Available online: https://www.rics.org/oceania/news-insight/research/insights/the-future-of-bim-digital-transformation-in-the-uk-construction-and-infrastructure-sector/ (accessed on 21 December 2022).
13. Newman, C.; Edwards, D.; Martek, I.; Lai, J.; Thwala, W.D.; Rillie, I. Industry 4.0 deployment in the construction industry: A bibliometric literature review and UK-based case study. *Smart Sustain. Built Environ.* **2021**, *10*, 557–580. [CrossRef]
14. Rivera, F.M.L.; Mora-Serrano, J.; Valero, I.; Oñate, E. Methodological-Technological Framework for Construction 4.0. *Arch. Comput. Methods Eng.* **2021**, *28*, 689–711. [CrossRef]
15. Zabidin, N.S.; Belayutham, S.; Ibrahim, C.K.I.C. A bibliometric and scientometric mapping of industry 4.0 in construction. *J. Inf. Technol. Constr.* **2020**, *25*, 287–307.
16. Farmer, M. Digital Dexterity. 2018. Available online: https://www.building.co.uk/communities/digital-dexterity/5094574.article (accessed on 25 July 2018).
17. Schwab, K. Davos Manifesto 2020: The Universal Purpose of a Company in the Fourth Industrial Revolution. 2019. Available online: https://www.weforum.org/agenda/2019/12/davos-manifesto-2020-the-universal-purpose-of-a-company-in-the-fourth-industrial-revolution/ (accessed on 21 December 2022).
18. El Baz, J.; Tiwari, S.; Akenroye, T.; Cherrafi, A.; Derrouiche, R. A framework of sustainability drivers and externalities for Industry 4.0 technologies using the Best-Worst Method. *J. Clean. Prod.* **2022**, *344*, 130909. [CrossRef]
19. Piccarozzi, M.; Silvestri, C.; Aquilani, B.; Silvestri, L. Is this a new story of the 'Two Giants'? A systematic literature review of the relationship between industry 4.0, sustainability and its pillars. *Technol. Forecast. Soc. Chang.* **2022**, *177*, 121511. [CrossRef]
20. Pekuri, A.; Suvanto, M.; Haapasalo, H.; Pekuri, L. Managing value creation: The business model approach in construction. *Int. J. Bus. Innov. Res.* **2014**, *8*, 36–51. [CrossRef]
21. Blismas, N.; Wakefield, R. Drivers, constraints and the future of offsite manufacture in Australia. *Constr. Innov.* **2009**, *9*, 72–83. [CrossRef]
22. Wang, K.; Guo, F.; Zhang, C.; Schaefer, D. From Industry 4.0 to Construction 4.0: Barriers to the digital transformation of engineering and construction sectors. *Eng. Constr. Archit. Manag.* **2022**. *ahead-of-print*. [CrossRef]
23. Olawumi, T.O.; Chan, D.W.; Wong, J.K.; Chan, A.P. Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts. *J. Build. Eng.* **2018**, *20*, 60–71. [CrossRef]
24. Vasista, T.; Abone, A. Benefits, barriers and applications of information communication technology in construction industry: A contemporary study. *Int. J. Eng. Technol.* **2018**, *7*, 492–499. [CrossRef]
25. Trotta, D.; Garengo, P. Industry 4.0 key research topics: A bibliometric review. In Proceedings of the 7th International Conference on Industrial Technology and Management (ICITM), Oxford, UK, 7–9 March 2018; pp. 113–117.
26. Alaloul, W.S.; Liew, M.S.; Zawawi, N.A.W.A.; Kennedy, I.B. Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders. *Ain Shams Eng. J.* **2020**, *11*, 225–230. [CrossRef]
27. Oztemel, E.; Gursev, S. Literature review of Industry 4.0 and related technologies. *J. Intell. Manuf.* **2018**, *31*, 127–182. [CrossRef]
28. Deloitte Review. *Industry 4.0: Are You Ready?* Deloitte: München, Germany, 2018.
29. KPMG. *The 2021 KPMG Fourth Industrial Revolution Benchmark*; KPMG: Amstelveen, Netherlands, 2021.
30. Brege, S.; Stehn, L.; Nord, T. Business models in industrialized building of multi-storey houses. *Constr. Manag. Econ.* **2014**, *32*, 208–226. [CrossRef]
31. Oesterreich, T.D.; Teuteberg, F. 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. *Comput. Ind.* **2016**, *83*, 121–139. [CrossRef]
32. Hizam-Hanafiah, M.; Soomro, M.A.; Abdullah, N.L. Industry 4.0 Readiness Models: A Systematic Literature Review of Model Dimensions. *Information* **2020**, *11*, 364. [CrossRef]
33. Schumacher, A.; Erol, S.; Sihn, W. A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP* **2016**, *52*, 161–166. [CrossRef]
34. Rockwell Automation. *The Connected Enterprise Maturity Model*; Rockwell Automation: Milwaukee, WI, USA, 2014.
35. Lichtblau, K.; Stich, V.; Bertenrath, R.; Blum, M.; Bleider, M.; Millack, A.; Schmitt, K.; Schmitz, E.; Schröter, M. *Industrie 4.0 Readiness*; VDMA's IMPULS-Stiftung: Aachen, Cologne, 2015.
36. Leineweber, S.; Wienbruch, T.; Lins, D.; Kreimeier, D.; Kuhlenkötter, B. Concept for an evolutionary maturity based Industrie 4.0 migration model. *Procedia CIRP* **2018**, *72*, 404–409.
37. Geissbauer, R.; Vedso, J.; Schrauf, S. *Industry 4.0: Building the Digital Enterprise*; PricewaterhouseCoopers (PwC): London, UK, 2016.
38. KPMG. The 2020 Fourth Industrial Revolution Benchmark.Digital and Disruption 2020. Available online: https://assets.kpmg/content/dam/kpmg/au/pdf/2020/fourth-industrial-revolution-benchmark.pdf (accessed on 21 December 2022).
39. Das, P.; Perera, S.; Senaratne, S.; Osei-Kyei, R. A smart modern construction enterprise maturity model for business scenarios leading to Industry 4.0. *Smart Sustain. Built Environ.* **2023**. *ahead-of-print*. [CrossRef]

40. Paulk, M.C.; Curtis, B.; Chrissis, M.B.; Weber, C.V. Capability Maturity Model for Software, Version 1.1. 1993. Available online: https://resources.sei.cmu.edu/asset_files/technicalreport/1993_005_001_16211.pdf (accessed on 21 December 2022).
41. Normann Andersen, K.; Lee, J.; Mettler, T.; Moon, M.J. Ten misunderstandings about maturity models. In Proceedings of the 21st Annual International Conference on Digital Government Research, Seoul, Republic of Korea, 15–19 June 2020; pp. 261–266.
42. Pöppelbuß, J.; Röglinger, M. What makes a useful maturity model? Framework of general design principles for maturity models and its demonstration in business process management. In Proceedings of the European Conference of Information Systems, Helsinki, Finland, 9–11 June 2011.
43. Dikhanbayeva, D.; Shaikholla, S.; Suleiman, Z.; Turkyilmaz, A. Assessment of industry 4.0 maturity models by design principles. *Sustainability* **2020**, *12*, 9927. [CrossRef]
44. Becker, J.; Knackstedt, R.; Pöppelbuß, J. Developing Maturity Models for IT Management—A Procedure Model and its Application. *Bus. Inf. Syst. Eng.* **2009**, *1*, 213–222. [CrossRef]
45. Jesus, C.d.; Lima, R.M. Literature Search of Key Factors for the Development of Generic and Specific Maturity Models for Industry 4.0. *Appl. Sci.* **2020**, *10*, 5825. [CrossRef]
46. SEI. *Capability Maturity Model Integration (CMMI): Version 1:1*; Software Engineering Institute, Carnegie Mellon University: Pittsburgh, PA, USA, 2002.
47. Hajoary, P.K. Industry 4.0 Maturity and Readiness Models: A Systematic Literature Review and Future Framework. *Int. J. Innov. Technol. Manag.* **2020**, *17*, 2030005. [CrossRef]
48. Mittal, S.; Khan, M.A.; Romero, D.; Wuest, T. A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *J. Manuf. Syst.* **2018**, *49*, 194–214.
49. Jawad, S.; Ledwith, A. A measurement model of project control systems success for engineering and construction projects case study: Contractor companies in Saudi's petroleum and chemical industry. *Eng. Constr. Archit. Manag.* **2021**, *29*, 1218–1240. [CrossRef]
50. Yilmaz, G.; Akcamete, A.; Demirors, O. A reference model for BIM capability assessments. *Autom. Constr.* **2019**, *101*, 245–263. [CrossRef]
51. Hartono, B.; Wijaya, D.F.; Arini, H.M. The impact of project risk management maturity on performance: Complexity as a moderating variable. *Int. J. Eng. Bus. Manag.* **2019**, *11*, 1847979019855504. [CrossRef]
52. Musonda, I.; Lusenga, E.; Okoro, C. Rating and characterization of an organization's safety culture to improve performance. *Int. J. Constr. Manag.* **2021**, *21*, 181–193. [CrossRef]
53. Dang, P.; Niu, Z.; Zhang, G.; Gao, S.; Hou, L. Developing a fuzzy multi-criteria evaluation model for prefabrication development maturity of construction firms. *IEEE Access* **2020**, *8*, 222397–222409. [CrossRef]
54. Rodegheri, P.M.; Serra, S.M.B. Maturity models to evaluate lean construction in Brazilian projects. *Braz. J. Oper. Prod. Manag.* **2020**, *17*, 1–21. [CrossRef]
55. Das, P.; Perera, S.; Senaratne, S.; Osei-Kyei, R. Paving the way for industry 4.0 maturity of construction enterprises: A state of the art review. *Eng. Constr. Archit. Manag.* **2022**. *ahead-of-print*. [CrossRef]
56. King, J.L.; Kraemer, K.L. Evolution and organizational information systems: An assessment of Nolan's stage model. *Commun. ACM* **1984**, *27*, 466–475. [CrossRef]
57. DeBruin, T.; Freeze, R.; Kulkarni, U.; Rosemann, M. Understanding the Main Phases of Developing a Maturity Assessment Model. In Proceedings of the 16th Australasian Conference on Information Systems, Sydney, Australia, 29 November–2 December 2005.
58. Teo, T.S.; King, W.R. Integration between business planning and information systems planning: An evolutionary-contingency perspective. *J. Manag. Inf. Syst.* **1997**, *14*, 185–214. [CrossRef]
59. Miles, M.B.; Huberman, A.M. *Qualitative Data Analysis: An Expanded Sourcebook*; Sage Publications: Southend Oaks, CA, USA, 1994.
60. Hickey, P.J.; Erfani, A.; Cui, Q. Use of LinkedIn Data and Machine Learning to Analyze Gender Differences in Construction Career Paths. *J. Manag. Eng.* **2022**, *38*, 04022060. [CrossRef]
61. Bryman, A. *Social Research Methods*; Oxford University Press: Oxford, UK, 2016.
62. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 5th ed.; Pearson Education Limited: London, UK, 2009.
63. Maier, A.; Moultrie, J.; Clarkson, P.J. Developing maturity grids for assessing organisational capabilities: Practitioner guidance. In Proceedings of the 4th International Conference on Management Consulting: Academy of Management, Vienna, Austria, 11–13 June 2009.
64. Teece, D.J. *Dynamic Capabilities and Strategic Management: Organizing for Innovation and Growth*; Oxford University Press on Demand: Oxford, UK, 2009.