Institute of Data Analytics and
Information Systems

THESIS BOOKLET

for the Ph.D. Dissertation by

ORSOLYA HEIDENWOLF

titled

Construction 4.0 Digital Maturity

Supervisor:
DR. ILDIKÓ BORBÁSNÉ SZABÓ

Budapest, 2025

Doctoral School of Economics and Business Informatics

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1. BACKGROUND AND RATIONALE

The construction industry (CI) is a cornerstone of the global economy, contributing approximately 13% of global gross domestic product (GDP). Despite its economic prominence, productivity within the sector has shown minimal improvement, rising by only 1% over the past two decades. This persistent stagnation has significant macroeconomic consequences, particularly in an increasing demand for sustainable and cost-effective infrastructure delivery. Recent data from the Royal Institution of Chartered Surveyors underscore this trend: in 2023, only 9% of surveyed stakeholders anticipated productivity growth over the following 12 months, compared to 21% the previous year, reflecting a pronounced deceleration in construction activity (RICS, 2023).

In response to these systemic challenges, the concept of *Construction 4.0* has emerged, drawing from the paradigmatic shift embodied in *Industry 4.0*. Construction 4.0 envisions reconfiguring construction ecosystems through integrating cyber-physical systems, intelligent automation, data-driven decision-making, and digital innovation. It is structured around three interdependent pillars: (1) integrated technologies and cyber-electronic systems, (2) redefined methods and processes, and (3) enhanced human resource competencies. These dimensions are underpinned by automation and data analytics, with sustainability framed as a central strategic objective (Heidenwolf and Szabó, 2024).

The academic discourse on Construction 4.0 has expanded in recent years, exploring diverse technologies and methods to improve operational efficiency and address sectoral issues such as labour shortages (Schönbeck et al., 2020; Sadeh et al., 2024). Nevertheless, organisations continue to encounter significant challenges when adopting these innovations. A recurring barrier is the industry's generally low level of digital maturity, which inhibits the systematic deployment and scaling of advanced technologies (Osunsanmi et al., 2020; Nagy et al., 2021). This dissertation addresses this critical barrier by developing and validating a Construction 4.0 Maturity Model (C4MM) to guide middle and senior management through the complexities of digital transformation.

The research is further justified by the sharp increase in academic attention to this topic. A review of the Scopus database reveals that until 2017, fewer than ten publications per year included the keyword or title "Construction 4.0". Since then, the field has grown exponentially, reaching over 150 publications by 2025. Similarly, scholarly work focusing on "Construction Digital Maturity" remained under 20 publications annually until 2019, when this research commenced, and rose to 71 by 2024.

While prior studies have explored the relationship between technological adoption and firm-level factors—such as strategic alignment, human capital, and organisational processes—these connections have rarely been formalised into integrated frameworks. This dissertation adopts an ontology engineering approach to construct a structured, machine-readable model that captures these interdependencies and supports automated maturity assessment.

By applying Design Science research methodology, the study advances theory and practice by developing the Construction 4.0 Maturity Model. This model offers construction firms a diagnostic and strategic tool to benchmark their digital maturity, identify performance gaps, and implement targeted transformation initiatives. The resulting framework contributes to the academic literature on digital transformation and responds directly to pressing industry needs for structured, evidence-based guidance.

2. METHODOLOGIES

The dissertation adopts the Design Science Research (DSR) methodology as its overarching framework, aiming to create a practical and scientifically grounded artefact: the Construction 4.0 Maturity Model (C4MM). Thus, served as a guideline for the dissertation (Figure 1).

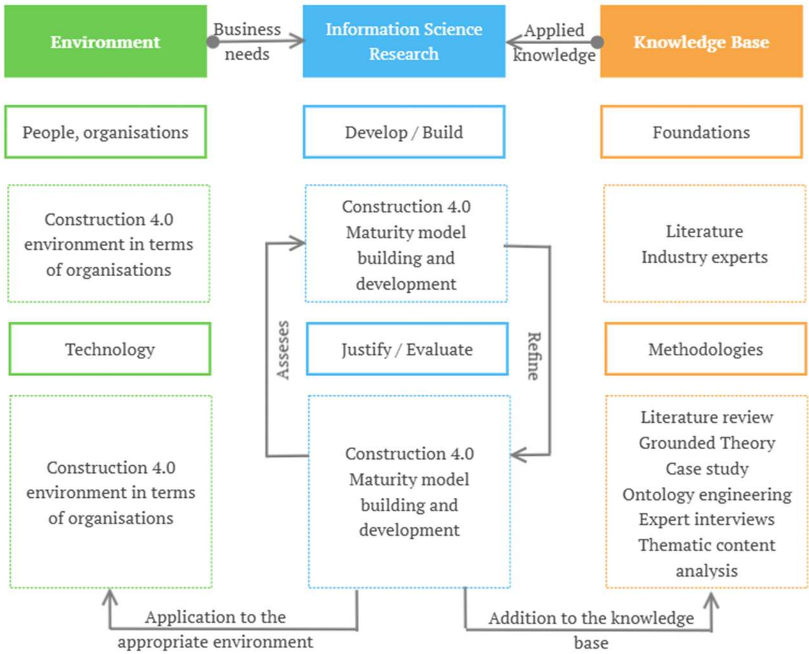

Figure 1 DSR framework based on Hevner et. al. (2004)

Design Science is well-suited to maturity model development, offering a systematic process for problem identification, requirement definition, artefact design, validation, and refinement. Thus, following the Design Science Research cycle outlined by Johannesson and Perjons (2014), the research unfolds in three first stages (Fig. 2) and is driven by the following research questions:

1. **Problem Identification**: Identifying the challenges related to digital transformation in Construction 4.0 through qualitative research and literature review.

- *RQ1:* What is Construction 4.0, and what are its challenges and solutions?
- *RQ2:* What solutions do innovations bring through the Construction industry value chain?

2. **Requirement Definition: Defining the developed model** requirements
3. **Artefact Design and Development**: Constructing and refining the C4MM across multiple iterations.
   - *RQ3: What factors influence the Construction 4.0 Maturity Model in the Construction industry? How to characterise and formalise construction companies' technology adaptation readiness?*
     - *RQ3.1: How to validate the Construction 4.0 Maturity Model by ontology?*
     - *RQ3.2: How can a case study validate the Construction 4.0 Maturity Model?*
   - *RQ4: What correlations and characterisation of the Construction 4.0 Maturity Model can be explored on the basis of input from industrial experts?*

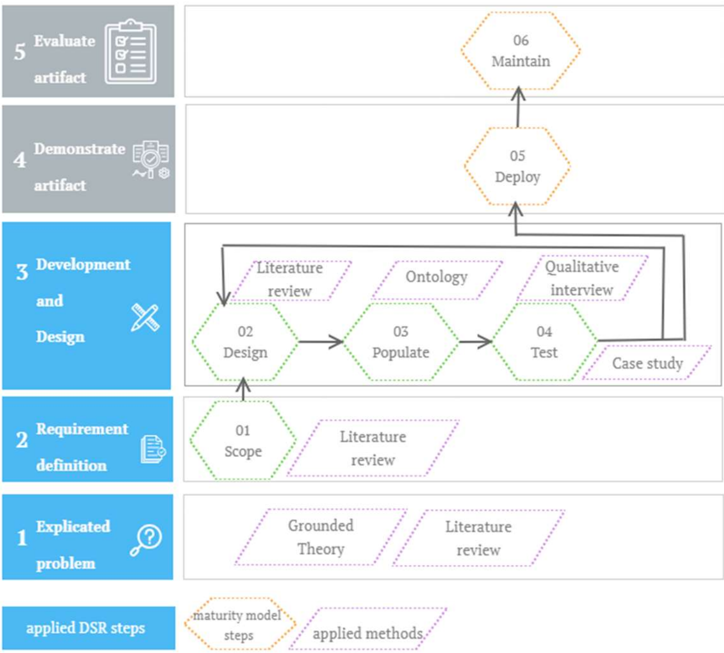

Figure 2 Research strategies application in the DSR framework

2.1. RQ1 What is C4, and what are its challenges and solutions?

Grounded Theory is a methodology-based strategy that was chosen to explain what Construction 4.0 is and the challenges and opportunities. Grounded Theory is a systematic method to explain a particular phenomenon with the information obtained during the research (Glaser and Strauss 1967).

To explore the Construction 4.0 environment, semi-structured interviews were conducted with 29 industry experts from diverse sectors—including construction, IT, automotive, and real estate—selected via LinkedIn and snowball sampling. The interviews, recorded using Microsoft Teams and transcribed through Office 365, followed a guide developed using Kvale's (1996) qualitative research principles. Expert selection considered company size, sector, and experience, reflecting the broad paradigm shift that Construction 4.0 represents. Data were managed through OneDrive and analysed using NVivo software through open, axial, and selective coding (Miles & Huberman, 1984), supported by concept mapping to build and refine theory. Iterative validation and theoretical sampling were complemented by a literature review (Bandara et al., 2011), contributing to a grounded understanding of the challenges and solutions where the maturity model would later be applied. (Nagy et al., 2021) (Fig. 3).

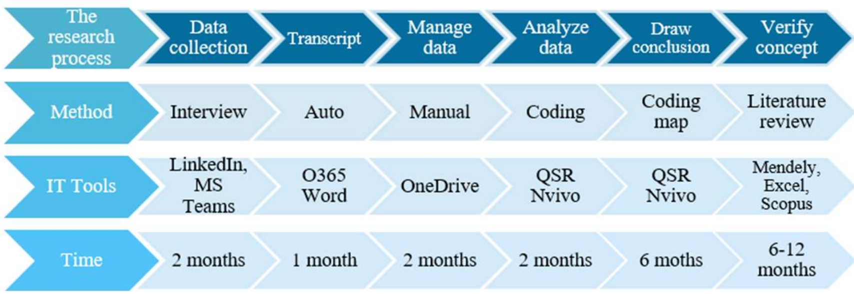

Figure 3 The Grounded Theory research process

2.2. RQ2 What solutions do innovations bring through the CI value chain? (RQ2)

During the pre-empirical stage of the research, literature was explored in the field of innovations through the Construction industry value chain. A systematic literature review guided this phase, and a structured approach was used to identify, evaluate, and synthesise research (vom Brocke et al. 2015). As a first step, the Year One Report Towards a Digital Built Britain (2018) was used to define keywords that guided the research literature review.

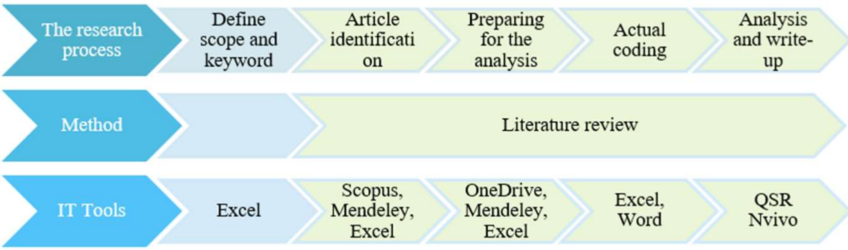

Figure 4 Research Process for RQ1

The **literature review** was conducted in 2021 in four phases. Phase I involved the identification and extraction of articles and case studies in leading journals in the CI field (Q1 or Q2) from 2019 to 2021. The defined keywords were applied to search for those in the article's abstract or title for the search strategy. Phase 2 involved analysing the project's objectives based on the initial scope and keywords. In Phase 3, a concept matrix was created to code the literature**.** Finally, the research ended in analysis and writing up the findings. (Fig. 4)

The answer to the research question indicated that the emerging technologies, innovations, and processes in the context of Construction 4.0 represent a fundamental point of origin for subsequent model construction.

2.3. RQ3 What factors influence the C4MM in the CI? How to characterise and formalise construction companies' technology adaptation readiness?

The Construction 4.0 Maturity Model (C4MM) was developed over three iterative cycles (Fig. 5).

- Version 0: Conceptualised from existing Industry 4.0 Maturity Models.

- Version 1: Refined through literature review and tested via a case study.
- Version 2: Systematically developed using a PRISMA-based literature review and validated through ontology.
- Version 3: Developed further and refined using qualitative research,

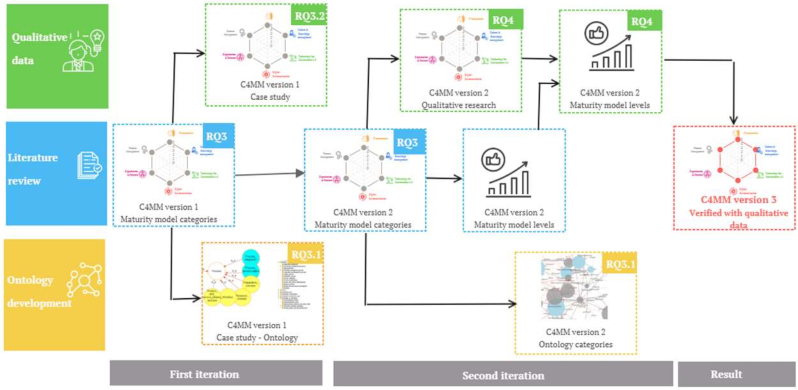

Figure 5 The Construction 4.0 Maturity Model (C4MM) development and validation process

The C4MM version 0 was conceptualised during the first iteration phase from existing Industry 4.0 Maturity Models. This model guided the development of the first model version with a **literature review** and was tested by a **case study**. The C4MM version 1 was influenced by subjectivism, as the validation of the model relied solely on a simple case study, thus a new model was developed. This model then was used as a guide – the coding structure of the literature review - to redesign the artefact and develop the C4MM version 2 using **PRISMA-**and validated through **ontology**. Finally, the model was further refined and evolved to the C4MM version 3 using **qualitative research**.

Literature review – Phase I

In developing the initial model, relatively limited literature was available. Therefore, to construct the zeroth version of the model, I relied on the three most frequently cited I4 maturity models, which I supplemented with the definition of

C4. This zeroth version served as a preliminary conceptual framework and guided the subsequent literature review that informed the development of the first model version.

A literature review was conducted in 2022 during the development process using the following keywords to identify relevant literature: ‘Industry 4.0 maturity model”, “Industry 4.0 readiness”, “Construction maturity model”, “Construction 4.0 readiness”, and “Construction 4.0 business model”. The literature review identified 22 relevant articles in the field of Industry 4.0 and only three in the Construction industry. A matrix was created during the review to establish the main categories of the C4MM. These categories supported the next development phase, where further literature was identified using the following keywords: category name (technology, culture, change management, innovation, IT), and/or maturity model/readiness model, and construction (Heidenwolf and Szabó, 2024a).

Systematic literature review – Phase II

In the second iterative phase, a **systematic literature review** was conducted. The process followed the **PRISMA** method (Page et al. 2021). We integrated various research databases, pre-screening tools, manual searches, and coding techniques to ensure a comprehensive and refined set of relevant literature.

The literature review examined Industry 4.0 and Construction 4.0 maturity models, using the C4MM version 1 as a benchmark to guide the development. An initial keyword search across Scopus and Web of Science yielded 944 results, which were refined to 564 unique articles. We identified relevant papers, reducing the pool to 230, and then screened to 84, prioritising Q1-Q2 journals. A backwards and forward citation search added 28 articles and three reports, totalling 85 publications—52 on Industry 4.0 and 33 on Construction 4.0. Using NVivo, a codification tree was created following Gökalp et al. (2017), enabling the identification and classification of model elements across three levels: categories, subcategories, and elements. The initial version of the Construction

4.0 Maturity Model (C4MM v1) informed the coding structure, which was iteratively refined. This dual-phase review produced an Industry 4.0-based model adapted to the specificities of Construction 4.0, forming the foundation of the second version of the C4MM. (Fig. 6)

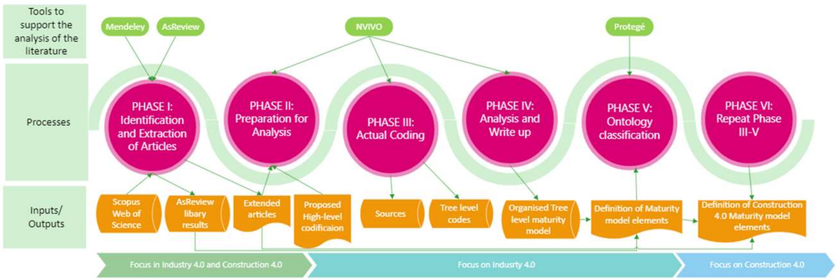

Figure 6 Overview of the literature review approach based on (Bandara et al. 2011)

2.4. RQ3.1: How can the C4MM be validated by ontology?

Ontology development was employed in this research as a formal method to validate the conceptual integrity and structural coherence of the Construction 4.0 Maturity Model (C4MM v2). Ontology, defined as a *"formal and explicit specification of a shared conceptualisation"* (Thomas R.Gruber 1993, pp. 199), provides a precise, machine-interpretable representation of concepts, their attributes, relationships, and logical rules.

The ontology for the C4MM was developed using a **middle-out strategy**, which balances abstract high-level concepts with detailed, application-driven definitions (Vas, 2007). This approach allowed the model to capture categories (e.g., Technology, Organisation, Process) and specific subcategories while remaining flexible and extensible. The widely used methodology of Noy and McGuinness (2001) guided the process. (Fig. 7)

Figure 7 The Ontology building steps by (Noy and McGuiness 2001)

Protégé software was used with the OWL2 Web Ontology Language for the model development, later exported into RDF (Resource Description Framework). OWL was chosen for its expressiveness in defining classes, relationships, and constraints, while RDF ensures machine-readability through its subject–predicate–object triple structure, supporting Linked Data principles.

Although no prior ontology existed for Construction 4.0 maturity models, this research established a new ontology grounded in a systematic literature review and C4MM definitions. The ontology development ensured that the C4MM was logically consistent, semantically robust, and computationally usable, providing a rigorous foundation for validation and future integration into AI-driven assessment platform or recommender system.

2.5. RQ3.2 How can the C4MM be validated by a case study?

A **qualitative case** study was conducted in four phases—design, data collection, analysis, and conclusion—to validate the Construction 4.0 Maturity Model version 1 (C4MM v1) within a real-world context. A digitally mature company was purposefully selected to ensure coverage of all model dimensions across planning, design, construction, and production phases (Heidenwolf and Szabó, 2024a). Two interviews were held: the CEO outlined the firm's digital transformation journey and evaluated C4MM elements, while the CTO provided further technical insights. Transcripts were analysed using a matrix in Excel, aligning C4MM elements with responses to identify key transformation drivers and inter-element relationships. This analysis resulted in verifying the C4MM v1 and creating a schematic digital transformation process model, which was formalised into a BPMN 2.0 model using Aris Express, to visualise and validate the firm's Construction 4.0 transformation pathway. (Heidenwolf and Szabó 2024a)

2.6. RQ4 - What correlations and characterisation of the C4MM can be explored on the basis of input from industrial experts?

The empirical phase of my research was conducted under the Virginia Tech

Institutional Research Protocol (IRB #24-984), ensuring compliance with U.S. standards for human subject research. Its primary aim was to refine and validate the Construction 4.0 Maturity Model (C4MM v2) by assessing its practical applicability to construction companies' digital transformation efforts. The study focused on identifying best practices for implementing short- and long-term technology, measuring their success, and exploring interrelationships between technology adoption and the model's categories and subcategories. To achieve this, semi-structured interviews with 33 industry experts provided insights into challenges, use cases, and company-level impacts of technology adoption. These interviews also informed the refinement of maturity model elements, particularly within the *Technology for Construction 4.0* category, and contributed to defining digital maturity levels.

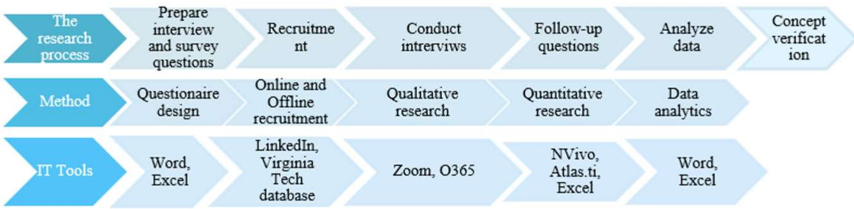

Figure 8 Qualitative research process

The interviews were recorded via Zoom, transcribed with Microsoft Word, and manually verified for accuracy. A qualitative analysis followed, using coding (initial, focused, and theoretical) to identify and categorise emerging themes. Case classifications captured demographic data, technologies, and use cases, forming the basis of a thematic content matrix. Digital maturity levels were developed iteratively through a literature review, and 20 companies were assigned to specific levels based on the maturity levels developed by the literature review.

3. RESULTS

I divided the dissertation results into four sections. The first two sections describe the findings from the qualitative research, while the third introduces the ontology developed from the systematic literature review.

3.1. Construction 4.0, challenges and opportunities and technologies

The first research question established that Construction 4.0 is a novel ecosystem built on three pillars—integrated technologies, methods and processes, and human resource competencies—underpinned by automation and data analytics, with sustainability as a core objective (Heidenwolf and Szabó, 2024b). The study identified key challenges and solutions, emphasising the importance of attracting younger talent, improving knowledge transfer, adopting effective data management, and aligning leadership mindsets and business strategies with innovation.

The second research question examined innovations across the construction value chain, highlighting technologies such as BIM, 3D libraries, robotics, mobile applications, and real-time monitoring, which enhance efficiency, collaboration, safety, and sustainability. Six technology groups emerged—BIM and Digital Twin, IoT and sensors, Robotics and Automation, Data Analytics, and XR—forming the basis for use cases and maturity level assessment.

3.2. Maturity Model Dimensions

The initial Construction 4.0 Maturity Model (C4MM v0) was developed by combining earlier models with the definition of Construction 4.0, leading to seven dimensions: strategic governance, IT and innovative tools, digital process transformation and BIM, supply chain, workforce management, sustainability, and security. A refined version (C4MM v1) emerged from a literature review, resulting in six categories—Technology Management and Business Applications, Culture and People Management, Collaboration and Communication, Technology for Automation, Innovation, and Change and Process Management—comprising ten subcategories and 57 elements.

The **case study** validated the applicability of C4MM v1, and most of the model categories were verified. However, some elements could not be validated or were recommended for removal. At the same time, specific categories required more precise definitions and refinement, particularly Technology for Automation. Consequently, the validation based on a single company introduced subjectivity (Peshkin, 1988), underscoring the need for further refinement and broader validation through systematic review and additional empirical studies.

The Construction 4.0 Maturity Model (C4MM) underwent further refinement through a PRISMA-based literature review, leading to C4MM version 2 with six main categories and precise subdimensions. **Culture and Knowledge Management** emphasises collective intelligence, corporate culture, and knowledge management, while **Digital Synchronisation** integrates governance, regulatory compliance, standards, and human–machine collaboration. **IT Management** addresses cybersecurity, data-centric IT management, digital infrastructure management, and system integration, highlighting interoperability challenges in BIM and IoT. The **Organisation and Structure** category focuses on structural agility and flexibility, strategic collaboration and coordination the strategic leadership required to align the organisation's vision and goals, while **Process Management** focuses on organisational change management, process development, core and operational processes, and supporting processes. Finally, **Technology for Construction 4.0** captures key technological use cases—AI, BIM, robotics, IoT, XR, data analytics, digital twins, GIS, and ERP and project management platforms—that collectively drive transformation in the construction industry.

The six maturity model categories listed above were examined based on qualitative interviews. A seventh category, namely Digital Investment and Performance Metrics, evolved from qualitative findings. The qualitative research included 33 expert interviews conducted online between 2020 and 2023. Most participants worked in large enterprises, with over 60% in executive roles. Spanning 15 U.S. states, the sample captured diverse contexts of organisational structure, technology adoption, and digital maturity.

The qualitative research validated and refined the C4MM version 2 categories, subcategories and evolved to C4MM version 3, revealing both opportunities and barriers to digital transformation.

The results revealed that in **Culture and Knowledge Management**, firms urgently need to reskill their workforce, mitigate knowledge loss from turnover, and foster technology-oriented cultures, where innovation and culture influence each other. **Digital Synchronisation** findings emphasised the need for stronger data governance, interoperable standards for digital twins, and strategies to address resistance to human–machine collaboration. In **IT Management**, cybersecurity emerged as a central concern, alongside challenges in managing vast amounts of data and achieving syntactic, semantic, and organisational interoperability. Within **Organisation and Structure**, experts stressed the importance of leadership education, employee training, and horizontal and vertical collaboration, while legacy systems and the lack of clear strategies hinder integration. **Process Management** results showed that technology adoption is inseparable from process development, requiring updated procedures and contractual innovations (e.g., Integrated Project Delivery). *Risk management* was identified as a new maturity element. Finally, the research introduced **Digital Investment and Performance Metrics** as a new category, highlighting the need for evaluation frameworks that move beyond short-term Return on Investment to capture long-term adaptability and operational efficiency.

3.3. Maturity Levels

The literature review revealed five maturity levels. At **Level 1**, firms lack digital culture and strategy, rely on isolated tools such as ERP and CAD, and prioritise traditional processes while neglecting IT security and ROI measurement (Das et al., 2024; Han et al., 2024; Perera et al., 2023; Razkenari and Kibert, 2022; Wernicke et al., 2023). **Level 2** companies begin recognising the strategic importance of digitalisation, experimenting with ERP, BIM, and cloud systems, though adoption remains fragmented and collaboration underdeveloped (Das et al., 2023; Jäkel et al., 2024; Razkenari and Kibert, 2022). At **Level 3**, firms transition to enterprise-wide transformation, introducing structured training, integrated ERP, interoperability frameworks, and performance dashboards, while experimenting with IoT, big data, and robotics, though coordination challenges persist (Razkenari and Kibert, 2022; Perera et al., 2023; Han et al., 2024; Wernicke et al., 2023). **Level 4** is defined by a mature digital culture, cross-company collaboration, cloud-integrated ERP, automation, and measurable ROI through advanced tools such as digital twins and blockchain, supported by R&D investment above 5% of turnover (Han et al., 2024; Perera et al., 2023; Razkenari and Kibert, 2022). Finally, at **Level 5**, companies achieve full-scale business model innovation, continuous adaptability, seamless interoperability, and alignment of digital and business strategies, creating fully digitised ecosystems that maximise operational efficiency and sustainability (Das et al., 2023, 2024; Han et al., 2024; Jäkel et al., 2024).

The qualitative research revealed a clear progression of organisational capabilities across the five maturity levels based on 33 expert interviews. **At Level 1**, companies resist digital transformation, lack leadership support and training, and rely on paper-based or basic digital tools, with technologies like BIM reduced to 2D drafting. **Level 2** firms begin recognising the need for digital skills and knowledge bases but remain culturally resistant, relying on fragmented tools such as Procore and Google Sheets without performance tracking or integrated strategies. **Level 3** marks a turning point, with growing training initiatives, early standard-setting, and experimentation with technologies such as drones, 3D scanning, and project management platforms. However, reliance on spreadsheets persists, and innovation is not yet embedded. **Level 4** organisations develop robust IT policies, dedicated innovation teams, and systematic integration plans, fostering a culture of knowledge sharing, human–machine collaboration, and process-centric governance while expanding their technology portfolios with measurable ROI. Finally, **Level 5** companies achieve complete digital fluency, advanced training, and continuous innovation driven by leadership, with fully integrated systems, AI-supported analytics, high-level cybersecurity, and widespread adoption of IoT, BIM, robotics, Virtual Design Construction, and digital twins, enabling seamless collaboration, process optimisation, and industry-leading transformation.

3.4. Ontology results

The ontology development for C4MM v2 served as a modelling activity and a validation method, transforming narrative definitions into formalised logical constructs. Building on the categories and subcategories of the maturity model, core elements were formalised as ontology classes, arranged hierarchically in Protégé, and connected through object properties expressed as subject–predicate–object triples. This structure ensured semantic precision, eliminated overlaps, and enabled inferential reasoning, allowing relationships such as links between *DataCentricITManagement* and *IoT* to be logically deduced. Exported into RDF and visualised using RDFLib, the ontology revealed three major relational clusters—Technology for Construction 4.0, Process Development, and Organisational Change Management—highlighting their integrative role in digital transformation. Automated reasoners such as Pellet and Hermit verified logical consistency by identifying unsatisfiable classes and redundancies, confirming the structural robustness of the model. Ultimately, the ontology validated C4MM v2 as a coherent, semantically rich, and machine-readable framework, reinforcing its reliability as both an academic construct and a practical tool for assessing digital maturity in construction.

4. CONCLUSIONS AND PRACTICAL IMPLICATIONS

This dissertation has presented the design, development, and validation of the Construction 4.0 Maturity Model**.** Through an iterative process grounded in Design Science Research**,** the model evolved from a conceptual structure (C4MM v0) into a detailed model (C4MM v3). Design science methodology provided a framework for the development of this model. Several methodologies were applied during the iteration cycles, including case study, grounded theory, qualitative research, and systematic literature review. Through the combined application of these methodologies, I could answer the research questions. The final model integrates the results from the systematic literature review, ontology development (developed from C4MM version 2), and qualitative research with 33 experts, resulting in seven categories—Culture and Knowledge Management, Digital Synchronisation, IT Management, Organisation and Structure, Process Management, Digital Investment and Performance Metrics, and Technology for Construction 4.0—mapped across five maturity levels from Initial to Transformative. (Fig. 9)

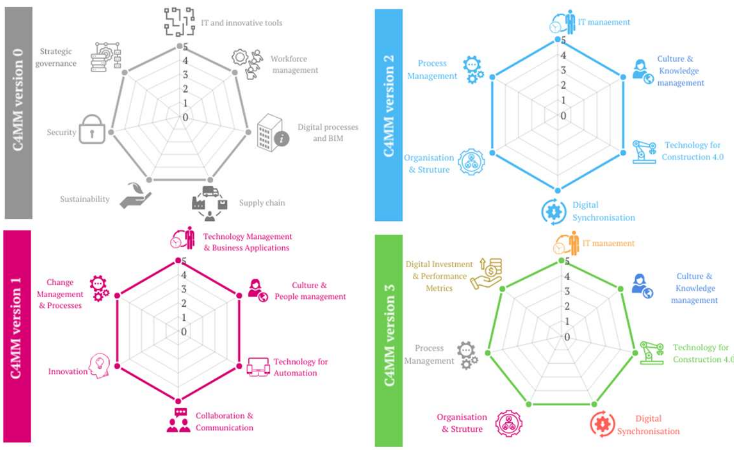

Figure 9 The evolution of the C4MM

The results of my dissertation revealed that digital maturity is not achieved through technology adoption alone but through a combination of factors: developing knowledge-sharing cultures, fostering strong leadership, implementing governance and data strategies, and aligning business models with innovation. Firms must overcome barriers such as fragmented digital strategies, outdated processes, and limited interoperability to realise the benefits of Construction 4.0.

Practical implications are significant: the C4MM can be applied by companies as a diagnostic tool to benchmark their maturity, identify gaps, and define targeted actions for improvement. The ontology-driven structure lays the foundation for future AI-based applications, including interactive self-assessment platforms or recommender systems for technology adoption. This research bridges the gap between academic theory and industry application by providing a machine-readable, logically validated model.

While the model is robust, limitations remain. The study sample was concentrated on U.S.-based firms, and further testing is needed to develop it further for global applicability. Ontology validation was restricted to structural testing rather than operational deployment, and longitudinal studies are needed to assess how firms evolve across maturity levels over time. Therefore, future research focuses on quantitative validation, developing a performance-indexed maturity model that links levels to business outcomes, and testing across diverse cultural and regulatory environments. In conclusion, this dissertation advances academic understanding of digital maturity in construction, delivers a practical roadmap for industry leaders, and lays the foundation of an AI-based recommender system by developing an ontology, affirming that Construction 4.0 transformation is a continuous journey of innovation, adaptability, and strategic alignment that requires vision, adaptability, and an integrated understanding of the technological and human systems at its core.

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6. PUBLICATIONS RELATED TO DISSERTATION

6.1. Journal paper

Orsolya, H., & Roland Zs., S. (2024). Paradigmaváltás az építőiparban / Paradigm shift in the Construction industry. Tér-Gazdaság-Ember , I–II, 85–102. https://tge.sze.hu/images/dokumentumok/Foly%C3%B3irat/TGE_2024_12_evfolyam_1-2_szam_K%C3%89SZ.pdf

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6.2. Conference paper

Heidenwolf, O., Antal, K., Szabó, Dr. I. (2024). Applying BPMN and Ontology to Measure Digital Maturity in Construction 4.0 - A Case Study. Proceedings of the 58th International Conference of System Science, Hawaii, United States of America https://hdl.handle.net/10125/109555

Heidenwolf, O., & Szabó, Dr. I. (2024). Justification of Construction 4.0 maturity model with a case study of a data-driven façade company. Proceedings of the 41st International Symposium on Automation and Robotics in Construction, Lille, France, 1272–1279. https://doi.org/10.22260/ISARC2024/0164

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6.3. Book chapter paper

Heidenwolf, O., & Szabó, R. Z. (2023). Construction 4.0. In Sándor Gyula Nagy & Tamás Stukovszky (Eds.), Smart Business and Digital Transformation (1st., pp. 165–170). Routledge. https://doi.org/10.4324/9781003390312-17

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