



ASSESSING DIGITAL MATURITY IN CONSTRUCTION DESIGN PROJECTS ACROSS EUROPE

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Abstract

Digital technologies significantly enhance efficiency and integration across industries. In construction, Building Information Modeling (BIM) is a key driver of digital transformation. Despite its growing adoption, traditional methods still dominate, and the sector lags behind others in digitalization. This underscores the importance of measuring digital maturity to identify barriers and guide improvements. This paper presents findings from a digital maturity assessment applied to 256 European construction design projects across nine offices using Exploratory Data Analysis (EDA). It also analyzes the indicators used to calculate digital maturity scores and explores variations across different European countries.

Introduction

Digital technologies provide consistent solutions to integrate people, processes, business systems and information in a more efficient way as well as creating an information-based process life cycle (Shen et al., 2010). Utilization of digital technologies has been increasing and there is a significant potential for transforming the construction industry as well (Sezer & Bröchner, 2019). Building Information Modeling (BIM) has become a key enabler of digital transformation. According to the European Construction Industry Federation (FIEC), BIM is one of the key factors in digital transformation in the construction industry (FIEC, 2017). In the past years, various BIM capability, maturity and assessment models have been developed in the literature (Yilmaz et al., 2019; Kassem et al., 2013; Wernicke et al., 2023). Although, these models have been proposed to facilitate the adoption of digital technology in construction (Willis & Rankin, 2012), their main focus was limited to BIM and its adoption behaviors at the company level (Kassem et al., 2013; Wernicke et al., 2023). On the other hand, BIM is not the only way of digitalization in the construction industry. Digitalization of various processes are needed even for the companies that adopted BIM (Boluk & Ergen, 2023). Under these circumstances, measuring digital maturity measurement is crucial to identify lagging behind in digitalization.

Digital maturity measurement is particularly relevant in today's rapidly evolving digital environment, where

organizations seek to harness the potential of technology for innovation, competitiveness, and efficiency. Although previous researchers have shown results on digital process benefits and BIM maturity measurements, studies on digital maturity measurement in the construction industry remain limited. Moreover, comparative studies on BIM or digital maturity across different geographies have rarely researched (Azzouz et al., 2018). This research aims to address these gaps by analyzing the results of a digital maturity measurement tool developed by an international design, engineering and consultancy company and applied to 256 construction design projects across nine offices in eight European countries. It aims to provide an in-depth analysis of the indicators used to calculate the digital maturity score and examines how digital capabilities vary across different European countries.

Literature Review

The literature highlights various models designed to measure the digital maturity and performance of companies and countries. For example, a digital maturity tool that assessed the digital maturity in five business dimensions (i.e., customer, strategy, technology, operations, organizations and culture) were developed and highly endorsed by telecommunication companies (Deloitte & TM forum, 2018). De Carolis et al. (2017) used four basic dimensions and five disciplines (e.g., design & engineering, production management, quality) in their work to evaluate the digital status of manufacturing companies. On the other hand, DiGiX is a country level index which summarizes relevant indicators on 100 countries' digital performance (Cámara & Tuesta, 2017).

While digital maturity measurement has received significant attention across various industries, its utilization within the construction sector remains relatively limited. However, the increasing utilization of BIM in recent years has underscored the necessity of maturity measurement for construction organizations. Consequently, multiple studies addressing BIM maturity are found within the existing body of literature.

BIM QuickScan is one of the tools which was developed in order to measure the BIM performance of Dutch companies (Van Berlo & Hendriks, 2012). BIM Quick Scan measures the companies with a 50 multiple choice

questionnaire. This tool is used for benchmarking BIM performance at the company level and provides insight into current BIM activities. Kam et al., (2013) utilized the VDC Scorecard across 108 projects in 13 countries to validate and refine evaluation measures, showcasing the scalability and repeatability of the scorecard framework. Their work emphasized the significance of a global knowledge base in BIM and VDC maturity, establishing benchmarks for project performance. Kassem and Succar (2015) (2017), conducted a comprehensive study on BIM adoption at a macro level. BIM adoption levels of countries have been analyzed through five models, which were validated with input from 99 experts across 21 countries.

Yilmaz et al. (2019) developed a reference tool named as BIM-CAREM to assess the BIM capabilities of construction processes. This tool had two dimensions, namely capabilities and process to assess. BIM capability dimension was composed of a set of BIM capability levels such as incomplete, performed, integrated and optimized where BIM process dimension was composed of a set of process elements related to BIM. The tool was validated through five case projects.

Although fewer in number, studies on measuring digital maturity in construction industry can also be found in the literature. Sezer et al. (2021) developed a digitalization index to assess digitalization level of construction site operations based on the questionnaire responses. They first examined how the technology was used in a construction site activity. Then, data management processes that were involved and the degree of digitalization of each of them was analyzed. Arrhenius & Linell (2022) performed a literature review to establish a theoretical framework and understand the basics of implementing digital tools for performing construction activities. They also employed a qualitative abductive method in the construction industry, primarily relying on semi-structured eleven interviews to gather empirical data. Their study highlighted cultural transformation and user-aligned vision development for the digital tools must be prioritized.

This study distinguishes itself from existing literature by extending the focus beyond BIM-specific maturity assessments to a comprehensive evaluation of digital maturity in the construction industry. Unlike prior research, which typically relies on qualitative methods, such as surveys or interviews and is often limited to single case studies or specific geographies, this study employs a data-driven approach, analyzing a large dataset of 256 projects across eight European countries. By leveraging an established digital maturity assessment tool developed by a global design, engineering and consultancy firm, this research provides an empirical, project-level analysis of digital capabilities, offering comparative insights across different national contexts. The study fills a critical gap in the literature by providing a large-scale, cross-country evaluation of digital maturity in construction, moving

beyond theoretical models to generate practical and generalizable findings.

The main objective of this study is to 1) examine the indicators employed in calculation of digital maturity scores and reveal central tendency across diverse projects, 2) assess the digital maturity of design projects that were performed across Europe and compare the performance of the countries.

Research Methodology

In this study, digital maturity score of 256 design projects were analyzed. They were retrieved from a digital maturity assessment tool that was developed by a global design, engineering and consultancy company. These projects ranged from medium to large-scale developments. The distribution of project types was as follows: approximately 30% were property projects (e.g., commercial, residential, retail), 20% were industrial, 20% were transportation (i.e., highway and railway), and the remaining 30% covered various other project types (e.g., hotel & leisure, sport, aviation, water, art & culture). Exploratory Data Analysis (EDA) was used to examine project-wide indicators and evaluate country-specific digital performance. EDA is the process of analyzing datasets to summarize their main characteristics (Unwin, 2020). It was commonly utilized to understand the structure of data, identify patterns and detect anomalies (Beyer, 1981; James et al., 2013).

The digital maturity scores have been obtained based on set of indicators. In the first step, these indicators have been analyzed in detail to determine the tendency, patterns and anomalies. Descriptive statistics was applied, such as central tendency measures (i.e., mean, median, mode), measures of dispersion (i.e., standard deviation, variance), and graphical representations (histograms, box plots). In the second step, the digital maturity of countries was assessed individually and compared, considering the number of projects assessed within each country. This analysis offered a comprehensive overview of digital maturity across eight countries and nine groups included in the study. It highlighted communalities, differences, and trends in digital maturity across the countries. It was also used to summarize how the digital indicators and overall scores varies in different countries.

Google Colab was employed to run the EDA analysis and the following Python packages used to perform EDA: pandas, seaborn, matplotlib and numpy.

Dataset Overview

This section 1) explains the digital maturity measurement tool, detailing its purpose, structure, and key indicators, 2) provides an overview of the dataset content used in this study, including the project distribution, geographical coverage, and the specific indicators analyzed.

Introduction of Digital Maturity Measurement Tool

A global design, engineering and consultancy firm of designers, planners, engineers, consultants, and technical

specialists was chosen to investigate the digital maturity tool that has been in use for over three years. This tool was originally released as a BIM maturity measurement tool in 2014 to assess and compare the maturity of BIM implementation within projects. It is based on the Organizational BIM Assessment Profile (CIC, 2013) under the Creative Commons 3.0 license (Azzouz et al., 2016). This tool was initially launched to be used as an internal self-assessment tool in different offices and started using globally.

In 2021, the tool upgraded as a digital maturity measurement tool to measure the digital capabilities of all fee-earning projects. It was built on the existing BIM maturity tool and moved beyond assessing BIM to encompassing the full range of company's digital delivery of buildings, infrastructure and consulting projects, and the growing types of digital services and tools that were used in projects and develop for the clients (Hill, 2023).

To date, the company has assessed over 5,000 projects, with more than 3,000 projects evaluated using the Digital Maturity Measurement Tool and 2,000 projects were assessed with the earlier BIM Maturity Tool. Each project has been assessed based on the "project wide" and "discipline specific" indicators. 18 project wide indicators are given in Table 1 and explained as follows:

01. Digital inception emphasizes the importance of data-centric tools and ways of working. Project bid and inception are key opportunities to improve the way how projects are delivered.

02. Common ways of working focus on a common understanding of project objectives, standards and expectations, and consistent data management (e.g., well-structured BIM execution plan).

03. Digital leadership looks for a digital champion / integrator helps teams improve their delivery by communicating digital possibilities, connecting them to people and services, and supporting the projects digital delivery.

04. Document Controlling explains collaboratively working such as model and data referencing, version control and status to help recipients when exchanging data.

05. Knowledge Sharing expects data transfer at the company level through digital case studies and lessons learned.

06. Client Digital Requirements is understanding of the Client's goals, needs and uses for digital services and data.

07. Digital Contracts aims to review the contract in terms of intellectual property, liabilities for digital issues, scope of work, model and digital delivery.

08. Data is an important asset and how it is managed and secured in the projects.

09. Project Environment / CDE requires a secure, managed, common and collaborative working environment.

10. Digital Tool Use aims to select and use the right data-centric tool for the job.

11. Workflow and Automation relates to using & configuring) internal or external automation.

12. Digital Communication is needed to support client, contractor or public understanding of the project and its potential impact.

13. Deliverables & Reporting expects integrated sets of project output that are delivered in formats that allows coordination, interrogation, re-use, integration and reporting.

14. Adapt looks for improvement of existing scripts, workflows and processes, or extending frameworks.

15. Virtual Design Reviews aims to conduct a collaborative or virtual design reviews prior to issuing model to client.

16. Open Standard Deliverables is being able to issue deliverables verified by open standard specifications (e.g., IFC, COBie)

17. 4D Construction Sequencing is construction sequence analysis based on a 4D model.

18. 5D Quantity, Cost and Carbon is the ability to reliably extract and use cost, quantity and carbon information.

Table 1: Project wide indicators

#	Indicators
1	Digital Inception
2	Common ways of working
3	Digital Leadership
4	Document Controlling
5	Knowledge Sharing
6	Client Digital Requirements
7	Digital Contracts
8	Data
9	Project Environment / CDE
10	Digital Tool Use
11	Workflow and Automation
12	Digital Communication
13	Deliverables & Reporting
14	Adapt
15	Virtual Design Reviews (VDR)
16	Open Standard Deliverables
17	4D Construction Sequencing
18	5D Quantity, Cost and Carbon

A scoring between 0-5 was used to assess these indicators and each indicator has its own weight which was determined by company experts. N/A is also an option while scoring if the indicator is not relevant to some types of projects. The calculation involves multiplying the adjusted score of each indicator by its respective weight.

W = weighted average (project digital maturity score)

n = number of indicators

W_i = weights applied to x values

X_i = scores to be averaged

The overall score was calculated with the weighted average as a percentage.

$$W(\text{project digital maturity score}) = \frac{\sum_{i=1}^{n=18} w_i X_i}{\sum_{i=1}^{n=18} w_i}$$

Data Sample Selected

The dataset analyzed in this study included 414 projects distributed across nine offices in eight European countries. A total of 18 project-wide indicators are included (Table 1), offering a comprehensive view of digital maturity. These indicators were specifically chosen to exclude discipline-specific metrics, ensuring that the analysis remains focused on general project-wide attributes.

To enhance the dataset's quality and ensure an effective analysis, a systematic data cleanup process was implemented. The following categories were removed:

- Projects containing discipline-specific assessments to maintain a uniform focus.
- Projects with N/A scores to ensure completeness.
- Projects that scored "0" across all indicators, as such data provided no actionable insights into digital maturity.

After applying the cleanup criteria, the dataset was reduced to a refined subset of 256 projects, which forms the basis for further analysis.

Data Analysis and Findings

In the first step, mean, standard deviation and minimum and maximum values of each indicator were calculated as given in Table 3. Figure 1 illustrates the average scores for each indicator.

Based on the key observations from descriptive statistics, most indicators have relatively low means, particularly indicators such as "08. Data" (mean: 0.656) and "17. 4D Construction Sequencing" (mean: 0.656). This reveals underutilization or limited development in these areas. Indicators such as "09. Project Environment / CDE" (std: 1.57) and "15. Virtual Design Reviews (VDR)" (std: 1.51) exhibit higher variability. This suggests uneven adoption or performance across different samples or projects or countries.

Some indicators, like "04. Document Controlling" (mean: 3.02), show higher overall scores, indicating relative maturity. The reason could be a company specific global document controlling procedure. This contrasts with

underdeveloped areas like "11. Workflow and Automation" (mean: 0.80), which requires greater attention due to their lower scores.

Indicators such as "08. Data" (22 outliers), "11. Workflow and Automation" (33 outliers), and "14. Adapt" (33 outliers) show significant deviation from the norm (Table 2). For "08. Data," the high number of outliers might indicate systemic challenges in data collection, storage, or analysis. "11. Workflow and Automation" and "14. Adapt" suggest potential issues in adopting streamlined processes or flexible practices.

Table 2: Outliers

Indicators	Outliers
01. Digital Inception	0
02. Common ways of working	0
03. Digital Leadership	0
04. Document Controlling	0
05. Knowledge Sharing	0
06. Client Digital Requirements	0
07. Digital Contracts	0
08. Data	22
09. Project Environment / CDE	0
10. Digital Tool Use	0
11. Workflow and Automation	33
12. Digital Communication	0
13. Deliverables & Reporting	20
14. Adapt	33
15. Virtual Design Reviews (VDR)	0
16. Open Standard Deliverables	0
17. 4D Construction Sequencing	13
18. 5D Quantity, Cost and Carbon	0

After obtaining indicator specific result, the country specific results were analyzed. The analysis categorizes the participating countries into nine distinct groups as Italy, Netherlands, Denmark, Spain, Poland & Serbia, Ireland Group 1, Ireland Group 2¹, Germany, Türkiye.

¹ Ireland is part of the Europe region within the company and operates through two groups. Group 1 focuses on advisory, cities planning & design, digital, and infrastructure services while Group 2 specializes in

transport, energy, water & resources, and property, science & industry portfolios.

Table 3: Mean, Standard Deviation, Min and Max values

Indicators	mean	std	min	max
01. Digital Inception	1.371094	1.245771	0	5
02. Common ways of working	2.289062	1.434326	0	5
03. Digital Leadership	2.015625	1.386118	0	5
04. Document Controlling	3.023438	1.386008	0	5
05. Knowledge Sharing	1.257812	1.287929	0	5
06. Client Digital Requirements	1.535156	1.377243	0	5
07. Digital Contracts	1.136719	1.433787	0	5
08. Data	0.656250	1.10923	0	5
09. Project Environment / CDE	2.480469	1.571689	0	5
10. Digital Tool Use	1.019531	1.420994	0	5
11. Workflow and Automation	0.804688	1.185260	0	4
12. Digital Communication	0.859375	1.260155	0	5
13. Deliverables & Reporting	0.710938	1.052745	0	5
14. Adapt	0.742188	1.219103	0	5
15. Virtual Design Reviews (VDR)	2.078125	1.513906	0	5
16. Open Standard Deliverables	1.906250	1.558972	0	5
17. 4D Construction Sequencing	0.656250	1.032321	0	5
18. 5D Quantity, Cost and Carbon	1.039062	1.229713	0	5

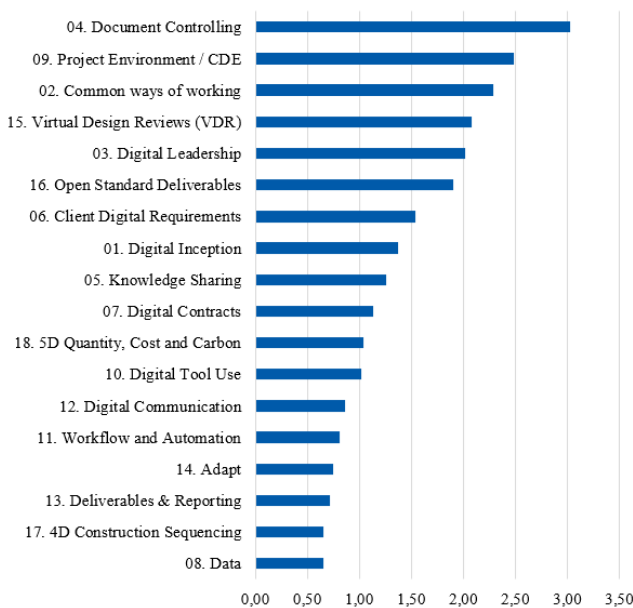


Figure 1: Average scores by each indicator

Each group's digital maturity is evaluated based on the number of projects included and their corresponding scores. The details are given in Figure 2 and 3.

Higher scores indicate greater digital maturity, reflecting more advanced adoption and integration of digital improvement in digital transformation efforts at a regional level. This analysis helped to identify areas of strength and opportunities for improvement in digital

transformation efforts at a regional level. Italy (1.79) and Netherlands (1.73) lead the rankings, suggesting relatively advanced levels of digital transformation. These countries likely benefit from higher investment in digital infrastructure, a skilled workforce, and favorable policies for innovation. These results align with findings in the literature, which indicate that countries with high digital maturity often invest in R&D and prioritize digital upskilling (Westerman et al., 2015).

Türkiye (0.87) holds the lowest score, indicating potential challenges in adopting digital practices. A significant gap between Türkiye and the other countries (mean score:

~1.48) indicates that more focused interventions are needed to improve digital maturity. The number of projects executed in each country also provides context for interpreting digital maturity scores. Despite the high volume of projects, digital maturity remains moderate in Ireland Group 2 (63 projects, score: 1.37) and Germany (37 projects, score: 1.22). This may reflect uneven adoption of digital practices across different projects. Although the number of projects is relatively low, Italy has the highest score. Denmark's maturity score (1.64) is much higher than Türkiye's score (0.87), despite both countries having the same project volume. This indicates that factors beyond project count, such as technological infrastructure, workforce skills, or leadership, play a key role in digital maturity. Despite being part of the same country, Ireland Groups 1 and 2 groups exhibit slightly different digital maturity scores values (1.41 and 1.37, respectively).

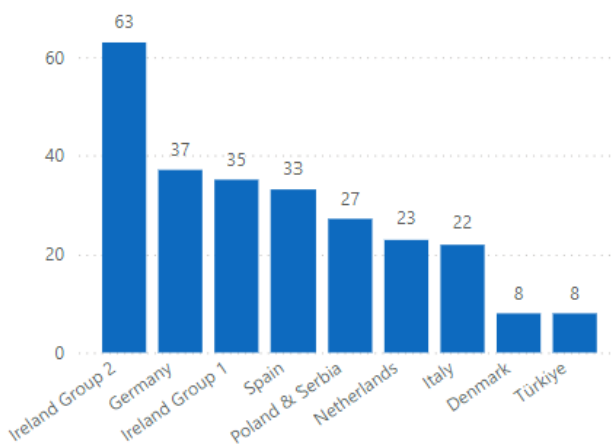


Figure 2: Number of projects by country

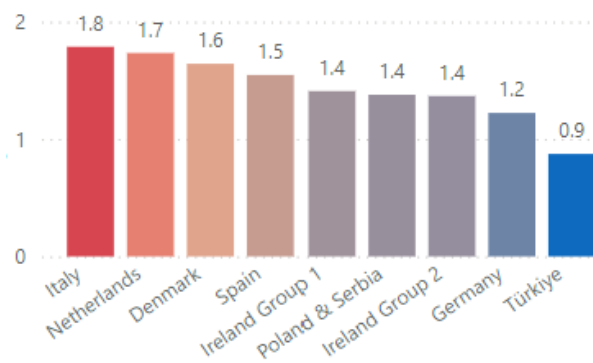


Figure 3: Digital maturity scores by country (groups)

When comparing the performance of countries across each indicator, several observations were made (Figure 4). The Netherlands, which holds the second-highest average score overall, leads in multiple indicators: 02. Common Ways of Working (3.17), 03. Digital Leadership (3.35), 09. Project Environment/CDE (3.13), and 16. Open Standard Deliverables (3.09), surpassing Italy in these categories. However, Italy demonstrates a clear advantage in 10. Digital Tool Use (2.05) and 15. Virtual

Design Review (2.86), when compared with other countries in these areas.

Ireland Group 2 stands out in 04. Document Controlling, achieving the highest score of 3.46 among all countries. On the other hand, certain indicators show low performance across the board. For instance, 17. 4D Construction Sequencing consistently scored below 1 in all countries, while 13. Deliverables & Reporting exceeded a score of 1 only in Italy (1.05), remaining below 1 in all other countries.

Discussions

The findings reveal significant disparities in digital maturity across different countries, even though these projects were performed within the same company. This suggests that digital transformation is influenced not only by company-wide strategies but also by external factors, such as national infrastructure, mandates, policies, and workforce digital skills. The relatively low overall maturity scores (with the highest at just 1.79 out of 5) indicate that the construction sector, even in digitally advanced countries, still has substantial potential for improvement.

A closer look at the data shows that while some digital aspects, such as "Document Controlling," are well established (possibly due to standardized company global procedures), other areas, particularly "Workflow and Automation" and "4D Construction Sequencing," are severely underdeveloped. The presence of outliers in critical indicators like "Data" and "Adapt" implies systemic challenges in data management and flexibility, possibly pointing to resistance to change, inconsistent implementation strategies, or technological barriers.

Also, the uneven performance among countries raises questions about whether external factors such as government regulations, culture, educational initiatives, or industry collaboration efforts are influencing digital maturity more than internal company strategies.

Some countries (e.g., Ireland Group 2, Germany) have significantly more projects than others (e.g., Denmark, Türkiye). This imbalance may skew comparative results, as a larger sample size can provide more stable findings, whereas a smaller sample may exaggerate anomalies.

Conclusions

The findings of this research highlight the critical role of measuring digital maturity in driving the construction industry toward greater digital transformation. By applying a digital maturity measurement tool to a diverse set of European projects, this research underscored differences in digital adoption across countries and identifies key areas for improvement. Indicators such as "Data" and "Workflow and Automation" reveal systemic challenges, while high-performing areas like "Document Controlling" demonstrate opportunities to build on existing strengths.

By examining the digital maturity scores and the number of projects represented, this analysis provided a nuanced

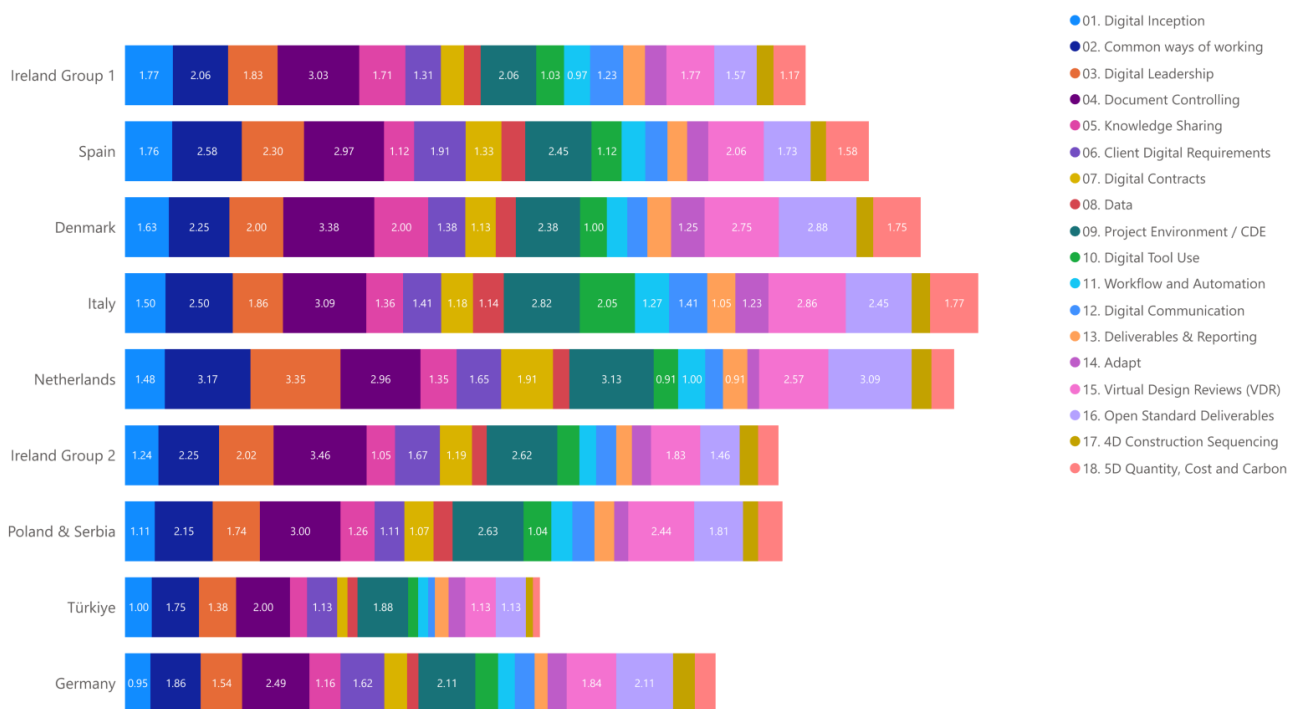


Figure 4: Indicators per country

view of regional digital capabilities and sets the stage for targeted improvements across Europe. Italy and Netherlands lead the rankings whereas Türkiye exhibits the lowest score. The findings reveal significant digital maturity disparities across countries, despite being within the same company. This shows that digital transformation is shaped not only by company strategies but also by external factors like infrastructure, policies, and workforce digital skills. Also, the variability in digital maturity scores across geographies emphasizes the need for country specific strategies, enhanced investment in digital infrastructure, and workforce upskilling to bridge the gap.

The analysis also reveals significant variation in digital maturity within the company, with best country scoring twice as high as lowest country. This highlights the need for collective digital transformation to bridge gaps. Moreover, the relatively low maximum digital maturity score highlights a significant opportunity for enhancing digital integration across the construction sector. These insights provide a valuable foundation for guiding future efforts in advancing digital integration and optimizing the transformative potential of technologies such as BIM in the construction sector.

On the other hand, the study has some limitations. Since the study is based on projects from a single global firm, the findings may not be fully generalizable to the entire construction industry. Different companies might have varying levels of investment, training, and digital adoption strategies, leading to different maturity scores. In the future, similar studies across companies can be conducted for construction industry. Also, the effect of factors like government policies and cultural attitudes on the maturity scores of countries are not considered within

the scope of this study. The future work includes exploring reasons behind low scores in certain indicators in terms of country-wide factors. Finally, it provides a snapshot but does not track digital maturity trends over time. In the future, the authors will conduct similar research with a larger data set (over 2000) including countries beyond Europe, to explore how the indicators pattern and digital performance varies across different regions. This will be also an opportunity to review the change of maturity over time. The outcome of this research aims to provide a more comprehensive global perspective.

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