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Exploring Data-Driven Culture in The Construction Industry: Insights from Industry Practitioners

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Abstractds

In previous studies, attributes, sub-attributes and indicators of data driven culture has been studied within the organizations specifically for the construction industry. Nevertheless, there has been no further study conducted on the perspective of construction industry personnels about their viewpoint on the indicators associated with a data-driven culture. Thus, the aim of this research is to cover the gap of data by identifying "perspectives" of industry practitioners on data driven culture in the construction industry. The study started by using Systematic Literature Review (SLR) as a method of literature study, then obtaining validation from 18 practitioners from construction industry analysed by using thematic analysis, and Relative Importance Index (RII). The highest RII value recorded based on each sub-attributes listed are: D1 – knowledge and expertise, ID3 – availability of fund, C4 – competency, U7 – building model exploration, P1 – register based statistics, P3 – information extraction and P8 – control strategy. The finding of this study benefit construction industry stakeholders to become more skilled, cooperative and dynamic through the documented acknowledgment of their perspective as practitioners in digital construction as emphasized in Malaysian Digital Construction and Industry 4.0 Roadmap 2020-2025.

1. Introduction

Data has been recognized as a valuable resource, equivalent to oil, that is essential for ensuring competitiveness (Anton, 2023). Businesses organizations with data driven practices have an enormous range of possibilities when it comes to establishing analytics infrastructures that collect and assess user data (Anton, 2023). A data-driven culture enables a firm to develop cooperation both within and outside organization, fostering engagement and adaptation mechanisms (Kollwitz, 2018). Instead of depending entirely on instinct or previous experience, companies shall aim to implement data-driven decision-making processes (Myrthe, 2020).

The rapid development of information and communication technologies (ICTs) and digital technologies overall has accelerated the process known as digitization, prompting firms to adopt a culture focused upon data-driven practice across many sectors (Chaudhuri, 2023). From a financial standpoint, a data-driven culture refers to the capability of using Big Data Analytics (BDA) to moderate the integration of internal Supply Chain Finance (SCF), which refer to managers' capacity for handling unanticipated risks and obstacles (Yu, 2021). According to Tiago (2024), Data-driven cultures in the healthcare sector have a significant influence through the implementation of knowledge management systems, the adoption of information-sharing behaviors, and the enhancement of patient care quality in a competitive environment. Within the field of retail, a data-driven culture has developed involving supply chain technologies like blockchain, Artificial Intelligence (AI), analytics, robotic process automation, and data centers. This culture is influencing business owners to revamp their supply chain strategies, making them more resilient, sustainable, and collaborative with suppliers, customers, and other stakeholders (Gong, 2023). Ghafoori (2024) agreed on data-driven cultures have a significant impact on organizational cultures via the process of digital transformation, including digitalization and enhanced operational performance within the manufacturing sector. Furthermore, the implementation of digital technology and the integration of data culture into educational system have been observed to enhance information and knowledge management (Eshbayev, 2023).

However, in construction industry, the establishment of a data-driven culture within the construction industry is needed to be further explored in order to maximize the use of advanced analytics in construction operations (Berndtsson et al. 2018). There is currently lack of comprehensive information on the categorization of the basic attributes that are associated with data-driven cultural practices within the construction industry. (Bilal et al., 2016; Alaka et al., 2018; Ngo et al., 2020; Yu et al., 2020). The impact of negligence of this research navigating construction industry to face inadequate strategic planning, ineffective communication, and insufficient teamwork which limit the productivity and project performance (Lu et al., 2021).

1.1 Data Driven Culture Attributes in Construction Industry

According to Hashim et al. (2023), data driven culture comprises of four (4) main attributes, five (5) sub-attributes, and thirty-three (33) indicators. Through a comprehensive thematic analysis by Hashim et al. (2023), the main attributes of data culture were found and categorized according to their respective categories which are; (i) data leadership; (ii) data literacy; (iii) data democratization; and (iv) data analytics. The research on data driven culture has been further investigate into the sub-attributes where according to the definition discussed and reviewed in the context of data-driven culture by Arbury et al. (2017) and Acker et al. (2019), the sub-attributes characterized the data cultures in construction industry through five perspectives: datafication, infrastructure of data, data cultivation, and cultures of use, and cultures of production. Hence, this research identifies the important key-indicators that contribute to the development of a data-driven culture in project teams. These indicators include the utilization of cultural and motivational mechanisms to leverage the information available for decision-making and task execution. Based on previous paper, Hashim et al. (2023) acknowledged that construction industry professionals confirmed the validity of 33 indicators related to 4 main attributes and 5 sub-attributes through the process of secondary data collection. The final discovery of 33 indicators is shown in Table 1.

Table 1 *Adapted from Acker et al. (2019) and Arbury et al. (2017).*

No	Indicator	Sub-Attribute	Code	Main Attribute
1	Knowledge and expertise	Datafication (D)	D1	Data Leadership
2	Professionalism		D2	
3	Code of conduct		D3	
4	Progress monitoring		D4	
5	Risk		D5	
6	Quality		D6	
7	Legal		D7	
8	Data security	Infrastructure of Data (ID)	ID1	
9	Availability of infrastructure		ID2	
10	Availability of fund		ID3	
11	Technical knowledge	Cultivation of Data (C)	C1	Literacy of Data
12	Willingness to adapt into new technology		C2	
13	Ease of learning experience		C3	
14	Competency		C4	
15	Experience		C5	
16	Training		C6	
17	Coordination		C7	

No	Indicator	Sub-Attribute	Code	Main Attribute
18	Data interoperability	Culture of Use (U)	U1	Data Democratization
19	Compatibility with other organization		U2	
20	Collaborative work processes and modeling standards		U3	
21	Internal support		U4	
22	External support		U5	
23	Data standardization		U6	
24	Building model reading and exploration		U7	
25	Availability of time to use		U8	
26	Register-based statistics	Culture of Production (P)	P1	Data Analytics
27	Detail data collection		P2	
18	Information extraction		P3	
29	Outcome expectations		P4	
30	Data estimating		P5	
31	Prevention		P6	
32	Mitigation action		P7	
33	Control strategy		P8	

Note: D1 = Knowledge and expertise; D2 = Professionalism; D3 = Code of Conduct; D4 = Progress Monitoring; D5 = Risk; D6 = Quality; D7 = Legal;
ID1 = Data security; ID2 = Availability of infrastructure; ID3 = Availability of fund;
C1 = Technical knowledge; C2 = Willingness to adapt into new technology; C3 = Ease of learning experience; C4 = Competency; C5 = Experience; C6 = Training; C7 = Coordination;
U1 = Data interoperability; U2 = Compatibility with other organization; U3 = Collaborative work processes and modeling standards; U4 = Internal support; U5 = External support; U6 = Data standardization; U7 = Building model reading and exploration; U8 = Availability of time to use;
P1 = Register-based statistics; P2 = Detail data collection; P3 = Information extraction; P4 = Outcome expectations; P5 = Data estimating; P6 = Prevention; P7 = Mitigation action; P8 = Control strategy.

1.2 Stakeholders' Involvement in the Spectrum of Data Driven Culture

The above thirty-three (33) indicators have the potential to foster the integration of digital culture in the construction sector by establishing a basis for future policy development on digitalization in construction, while also considering the perspectives of stakeholders in the industry. Throughout this research, the understanding of data driven culture were established within organization internally from each stakeholder. According to Freeman's fundamental interpretation (1984), stakeholders are persons or organizations who are actively engaged in the project. Stakeholders' actions throughout the construction industry are influenced by several factors, such as people or groups of organizations that are affected by the project and able to impact its future direction (Yuan et al., 2018). For example, the stakeholders in construction sectors are clients, contractors and consultant, which are the member of project construction (Andrade-Rhor et al., 2019). All of the stakeholders involved in a construction project have distinct roles and duties in addressing DDC concerns throughout the project. Hashim et al. (2023) have suggested an approach for associating DDC attributes with the participation of construction stakeholders in construction projects. This research aims to delve further into the actual perspectives of DDC from construction industry practitioners with a specific focus on identifying the discrepancies related to opinions of practitioners in the construction industry.

1.3 The Context of Data Driven Culture in Malaysia Through Construction Industry

Construction Industry Development Board (CIDB) Malaysia defines data driven through Malaysia's Construction 4.0 implementation in construction industry. There are twelve technologies which are currently use which are Building Information Modelling (BIM), pre-fabrication and modular construction, autonomous construction, augmented reality and virtualisation, cloud and real-time collaboration, 3D scanning and photogrammetry, big data and predictive analysis, Internet of Thing (IoT), 3D printing and additive manufacturing, advanced building materials, blockchain, and artificial intelligence. The Malaysian government strives to promote a data-driven culture as outlined in the Twelfth Malaysia Plan 2021-2025, specifically in Chapter 11: Boosting Digitalisation and Advanced Technology. This initiative aims to encourage organizations to enhance their capabilities, agility, and collaboration in the process of digital transformation. In the spectrum of legislative, the research also relates to the Occupational Safety and Health (Construction Work) for Design and Management Regulation 2024.

2. Method

This chapter comprises of literature review on the identification of data driven culture attributes, sub-attributes and indicators for construction industry. Following with the development of relevant questionnaire for identification process of DDC attributes, and detail explanation on the strategy used for face-to-face interview.

2.1 Literature Review on the Identification of DDC Attributes in Construction Project

To identify DDC attributes in construction project, a literature study has been conducted consisting of Systematic Literature Review (SLR) process (i.e., journal selection and selection of articles), thematic analysis. In order to choose appropriate sources for journal selection, the Scopus Database, a well-known search engine, was chosen as the main source of literature due to its ability to integrate existing terms and create a comprehensive search string. The decision to utilize Scopus databases as a search tool is based on the enhanced integration of research and literature subjects on Scopus compared to other search engines like Web of Science (WoS), Google Scholar, PubMed, and others. This is due to a greater diversity of document types that can be retrieved from Scopus, as well as a substantial degree of overlap in terms of indicators or keywords (Suarez, 2022).

The first steps in SLR were to utilize search strings through Scopus Database such as: “data driven” OR “data capacity” OR “data culture” OR “big data” OR “data analytic” OR “data mining” OR “construction industry” throughout 2019 to 2024. The next step referred to as screening, included refining the search parameters using the Scopus database characteristics. The selection of time limitations, language exclusions, and article types are all part of the screening process (David, 2023). Five years were set aside from the date of publication of the most recent update pertaining to the study field in order to guarantee the relevance of research input (Poojary et al. 2014). An additional step in the screening process included choosing research publications, written only in English, from journals and conference proceedings. According to Saggese et al. (2015), concentrating on a single language throughout research might lessen the issue of term misunderstandings for research review quality. The third phase in the SLR process is eligibility, which verifies that the author thoroughly read over each article and journals as affirmative steps to ensure that after the screening process, every last one complied with the requirement set by researchers to focus on data driven culture in construction industry. According to Krippendorff (2013), it's important to emphasize that the method of material analysis may be used to look at component identification and analyses trends and patterns within a certain context. The process entails a meticulous examination of the abstract and title to ascertain whether any publications are relevant to the data-driven culture that has been selected. Lastly, in order to assess the relevant research, the writers actively study each article's abstract and content throughout the inclusion stage. A set of inclusion and exclusion criteria are used in accordance with the inclusion and exclusion approach outlined by Beske-Janssen et al. (2015) in order to concentrate and reduce the overall quantity of selected literatures. Thus, after carefully going over each article's titles, abstracts, keywords, and general contents, the researcher sorted the articles.

The research continues with thematic analysis, where the authors have examined patterns, clusters, counts, similarities, and ties in the retrieved data to identify and classify themes and sub-themes. The thematic analysis able to identified frequent trends that emerged from the data gathered from the assessed articles. In order to reduce redundancy of attributes with similar definitions, a sorting approach was used to exclude attributes that have the same meanings. During this procedure, the authors have categorized characteristics into main and sub-attributes and have consistently examined all the attributes to ensure the reliability of the data. During the development of the indicators, the researchers actively participated in brainstorming sessions to detect any inconsistencies or differing ideas that may arise from various interpretations of the data. The procedure continued until initial agreement was achieved upon the definitive four (4) main attributes, five (5) sub-attributes and forty-one (41) indicators. Based on 18 construction industry practitioners involved, a validated four (4) main attributes, five (5) sub-attributes and thirty-three (33) indicators were finalized, as a result of reviewed attributes and indicators due to: 1) redundancy of keywords; 2) and practicality of key-indicator over current construction project.

2.2 Developing Questionnaire in Identifying DDC Attributes in Construction Project

A questionnaire based on a series of literature review was developed in response to the attributes listed on the DDC. It has two important sections: 1) demographic information, where participants must achieve a minimum of 11 points using the point system proposed by Hallowell and Gambatese (2010) in which to guarantee the level of competencies of industrial practitioners (as shown in Table 2); and 2) an assessment of participant "perspectives" regarding the significance of the DDC attribute in the construction industry. In the second section, each participant is mandated to assess each of the DDC indicators based on the likert scale to justify priority which are: i) 1 – very low; 2 – low; 3 – intermediate; 4 – high; 5 very high. To assess the data from the questionnaire survey, data analysis was conducted. A descriptive analysis has been selected to identify the data distribution throughout this study. Indicators with high values will be recommended as one of the important indicators for development of data driven culture in digital construction, whereas indicators with low values would be counted as low-priority indicators. In order to enable participants from the construction sector to further contribute their perspectives on existing attributes, improvements to current attributes, or the addition of new attributes, a "remark" area has been added to the second section of the questionnaire.

Table 2 *Point system for qualification of experts. Source: adapted from Hallowell and Gambatese (2010)*

ID	Achievement of Experience	Point
A	Years of professional experience in the construction industry	1 point for every year
B	Advanced degree in the field of civil engineering or other related areas	Bachelor's degree: 1 point
C	Involved in any related digital data project construction	Master: 2 points
D	Member (or chair) of professional committee(s)	PhD: 4 points
E	Leading position(s) held in current/previous organization related to digital data	2 points for each related software used for project construction
F	Publication on the topic of digital data in construction	Member: 1 point for each membership
G	Attended any related digital data training in construction	Chair: 3 points for each membership

2.3 Face-to-Face Structured Interview

Li et al. (2018) stated that structured interviews were deemed appropriate since the approach enables researchers to engage in comprehensive interaction with experts in order to verify the DDC attributes, which were derived from the Systematic Literature Review (SLR) method. Experts which comprise of various position in construction project stakeholders such as client, contractor and consultant were requested to provide an in-depth and extensive perspective of DDC relevancy in the construction industry. Started from February until July 2024, face-to-face interview were conducted with 18 practitioners who were chosen based on their eligibility with construction industry, from variety of job scope and years of experience. Hallowell and Gambatese (2010) state that an adequate number of expert interviewers to validate construction research indicators is between eight and twelve. Kordi et al. (2022), Yin and Caldas (2020), Jafari et al. (2019), Tsolakis et al. (2019), Loosemore and Reid (2019), and Awwad et al. (2016) have collaborated with 15, 12, 11, 14, 12, and 15 specialists, respectively, in their research. Furthermore, the research team has chosen experts from various disciplines of expertise in order to prevent any potential biases towards certain attributes (Karakhan et al., 2020).

3. Results and Discussions

In this section, the results and findings related to the respondent profiling and the evaluation of DDC in construction industry are describe as following;

3.1 Demographic Information

There are 18 participants from construction industry practitioners who were eligible to participate and evaluate DDC indicators by sharing their "perspectives". All of the participant fulfilling requirement of point system for expert panelist adapted from Hallowell and Gambatese (2010) as shown in Table 3.

Table 3 *List of qualified experts based on point system for expert panelist adapted from Hallowell and Gambatese (2010)*

Participant		Discipline	Position	A	B	C	D	E	F	G	Total Point
A-1	Contractor	Project Mngt	Project Engineer	6	1	2				3	12
A-2	Contractor	Civil	Site Engineer	3	1	4				3	11
A-3	Contractor	Structural	BIM Modeller	3	1	4				4	12
A-4	Contractor	Eng. Services	BIM Modeller	3	1	2				5	11
A-5	Contractor	Civil	BIM Modeller	3	1	2				6	12
B-1	Consultant	Electrical	BIM Modeller	5	1	2				3	11
B-2	Consultant	Civil	BIM Modeller	5	1	2				4	12
B-3	Consultant	Civil	Lead Modeler	6	1	4		3		4	18
B-4	Consultant	Civil	BIM Trainer at MyBIM	28	1	4				7	40
B-5	Consultant	Civil	BIM Modeler and Coordinator	9	1	4				3	17
B-6	Consultant	Architect	Modeler	6	1	2				3	12
B-7	Consultant	Civil	BIM Modeller	3	1	4				3	11
B-8	Consultant	Civil	BIM Modeller	3	1	4				3	11
B-9	Consultant	Civil	BIM Modeller	5	2	6				1	14
B-10	Consultant	Asst Town Planner / Asst Architect	BIM Modeller	4	2	4				1	11
B-11	Consultant	Civil	BIM Coordinator	12		4					16
C-1	Client	Civil	BIM Modeler and Coordinator	10	2					2	14
C-2	Client	Project Mngmt	Project Engineer	4	2	2			5	1	14

The demographic of participant was categorized into three distinct groups: 1) A – Contractor; 2) B – Consultant; and 3) C – Client. There are five (5) number contractors from various discipline such as project management (n=2), civil (n=2) and structural (n=1), which consists from variety of job position such as modeller (n=3), site engineer (n=1) and project engineer (n=1). Apart from contractor, there is another larger cluster of participant consists of industrial stakeholder known as consultant. There is total eleven (11) participants from this group coming from several disciplines which are civil (n=8), architecture (n=2), and electrical (n=1), where there are only three job positions acknowledged which are BIM modeller (n=8) and BIM coordinator (n=2) and BIM Trainer (n=1). The third group of participants for data driven culture research are clients from construction projects. Researchers noticed there are two (2) participants which are eligible to contribute their perspective, where their practices are from project management (n=1) and civil engineering (n=1) discipline and currently hold positions as BIM modeller (n=1) and project engineer (n=1) in construction project.

3.2 DDC Attributes Within Organization in Construction Industry

The main objective of the research is to be documenting the perspective agreed by the construction industry practitioners of the attributes and indicators of DDC in order to advancing the performance of current and future construction sector. The perspective was allocated based on the sub-attributes of data-driven culture established by Hashim et al. (2023): datafication, infrastructure of data, cultivation of data, culture of use and culture of production. To ensure the perspectives on the indicators are measurable in quantifiable value, the research utilizing Relative Importance Index (RII) analysis as stated by Tholibon et al. (2021), RII is a comprehensive analysis which have ability to populate the ranking of every indicator according to degree of relevance through the index value of an indicators with highest RII value of 1.0. The detail calculation of RII analysis is shown as Formula Equation 1.

$$Relative\ Importance\ Index = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (1)$$

Note: w = Mark for each Scale; n = number of respondents answered by each scale; A = Maximum Scale; N = Total Number of Respondent;

3.2.1 Datafication

Assessing the perspective of construction industry practitioners against the indicators found on the sub-attribute of datafication is crucial in a data-driven culture management. Figure 1 shows the highest RII value which indicates the top priority of indicator in datafication, which is D1 – knowledge and expertise with 0.989. Experts emphasizes throughout semi-structured interview of the research on the important to have mastery over BIM ISO 19650. The second highest RII value in datafication is D6 – quality (0.978), where researcher acknowledging the important to implement data culture in construction with guidance of ISO 9001:2015. Following with the third highest RII value which is D4 – progress monitoring (0.922). Experts stated that project progress monitoring in culture of data of construction industry is essential to ensure effective work progress such as the used of BIM software, to forecast the possible delay, on-time scheduling, and early finish work. The lowest RII value recorded from participant on the sub-attribute of datafication is 0.8, D3 – code of conduct.

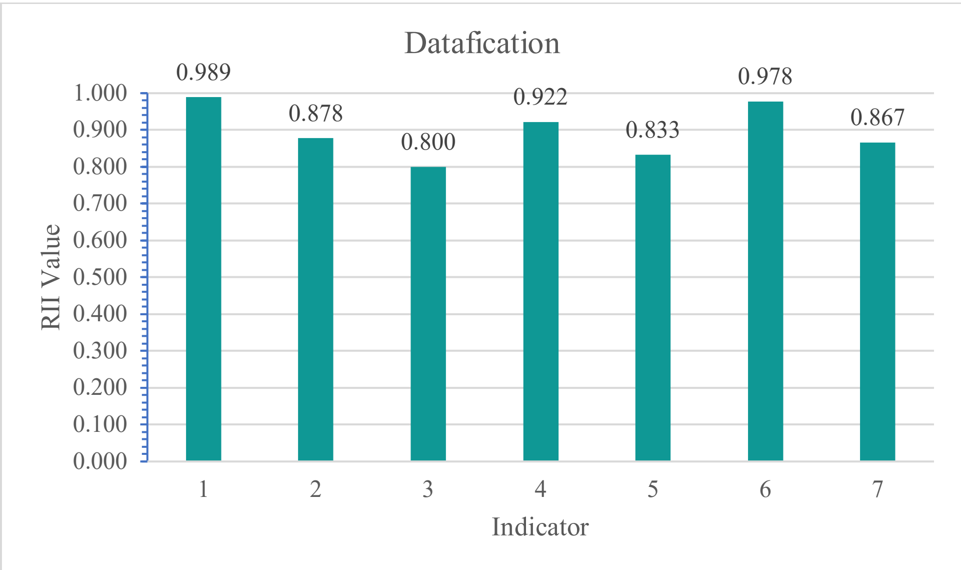

Fig. 1 *Perspective of construction industry practitioners on indicators of datafication*

3.2.2 Infrastructure of Data

The research continues by evaluating the industry practitioner's perspective on the sub-attribute, which is also known as the infrastructure of data. In Figure 2, indicator ID3 – availability of fund gained the highest value of RII with 0.978. Industrial practitioners of construction industry agree that to implement data driven culture within organization requires adequate financial capabilities. The succeeding indicator log throughout the research is ID2 – availability of infrastructure. Experts have positive responses on the infrastructure of data in construction such as provision for advanced digital infrastructure (i.e., 3D, 4D for scheduling, 5D for estimating, 6D for sustainability, 7D for facility management) for construction project phases. Next, the lowest RII value recorded is ID1 – data security with 0.956. Even though the ID1 as in record, stated as the lowest RII value, participants emphasizing the importance of having data security such as firewall system in digital construction.

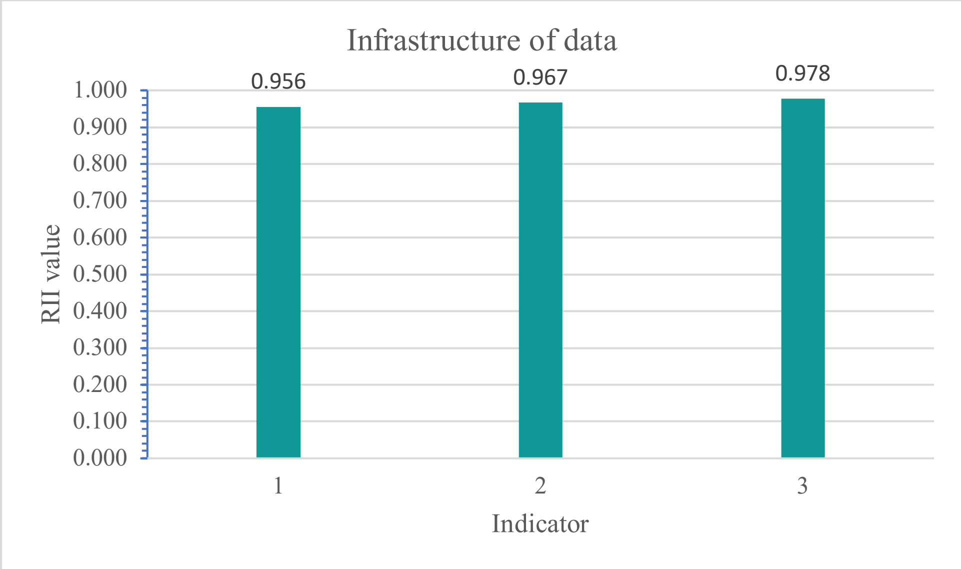

Fig. 2 *Perspective of construction industry practitioners on indicators relates to infrastructure of data*

3.2.3 Cultivation of Data

The RII analysis continue to justify perspective of experts in construction industry throughout sub-attribute of data cultivation through Figure 3. In developing data driven culture, the cultivation of data culture is essential for the development of data driven practices in construction industry. The highest RII value recorded from listed indicator of data cultivation is C4 – competency (0.989). Experts highlight the importance to have competency in delivering project construction deliverables and have capacity to handle unforeseen challenged or complexities during construction process. Next, the second highest RII value is C6 – training (0.978), where according to experts that participated throughout this research, the training is vital to ensure every team member of construction project have same understanding on the construction digital technologies tools (i.e., BIM, VR, AR). In this research, researcher acknowledge the lowest RII value calculated is C1 – technical knowledge (0.722).

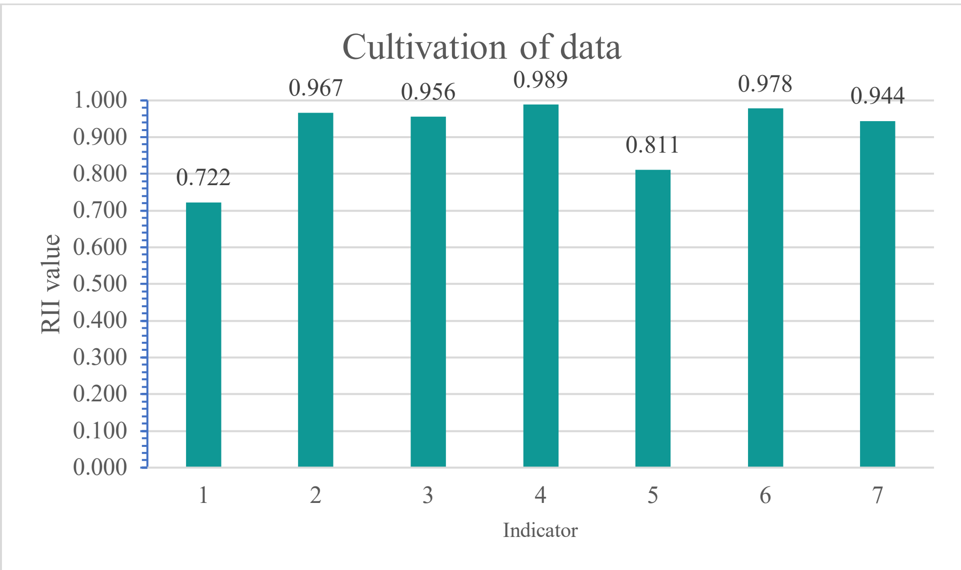

Fig. 3 *Perspective of construction industry practitioners on indicators relates to cultivation of data*

3.2.4 Culture of Use

The perspectives of expert panellist of this research shows that U7 – building model exploration (0.944) have the highest priority in implementing data driven culture in construction industry through sub-attribute of "culture of use". According to expert, the implementation of digital technology in the construction industry increases the capacity to collaborate in term of visualizing building models exploration, and making decisions using Building Information Modeling (BIM), virtual design, and Augmented Reality (AR). The second highest RII value recorded in the culture of use is U1 – data interoperability (0.933). based on participants of this research, the understanding dan practices of data interoperability or data sharing is important to ensure the practicality files transfer from one software across another software (i.e., ARCHICAD, Revit, Staad-Pro, Aecosim Building Designer, Tekla). In this sub-attribute, the lowest RII value recorded is U5 – external support (0.656).

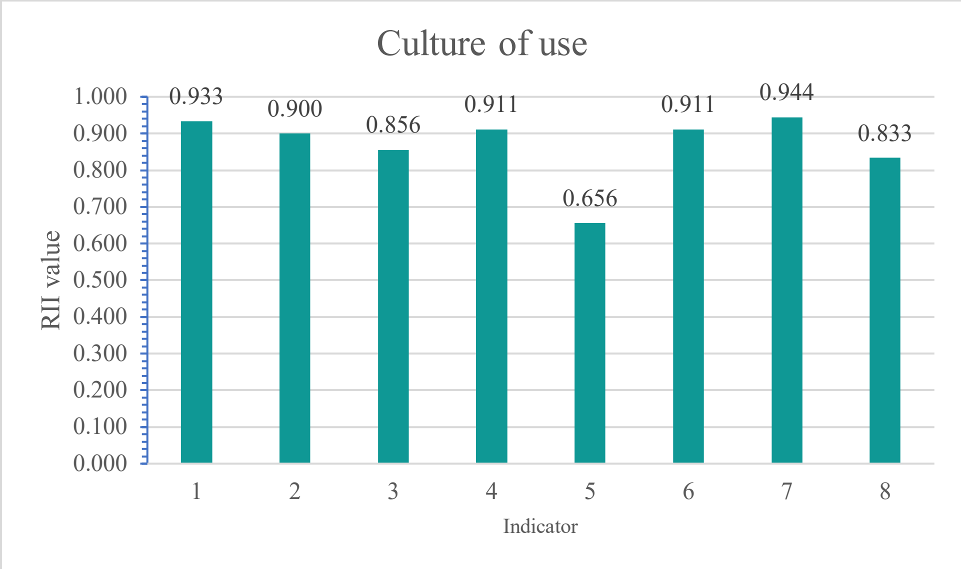

Fig. 4 *Perspective of construction industry practitioners on indicators relates to culture of use*

3.2.5 Culture of Production

Experts pointed their perspective related to important practices of data driven culture through culture of production in Figure 5, where P1 – register based statistics, P3 – information extraction and P8 – control strategy shared the highest and equal RII value which is 0.922. Experts acknowledged that register-based statistic in BIM software enhance the personnel capability to register construction deliverables accurately (i.e., type and quantity of materials, the hours of labour required, weather and temperature conditions, environmental concerns, a market feasibility analysis, and the translation of data into tabulated formats such as histograms, pie charts, and graphs). The lowest recorded value of RII and least priority of indicator from the perspective of expert panelists is P5 – data estimating (0.722).

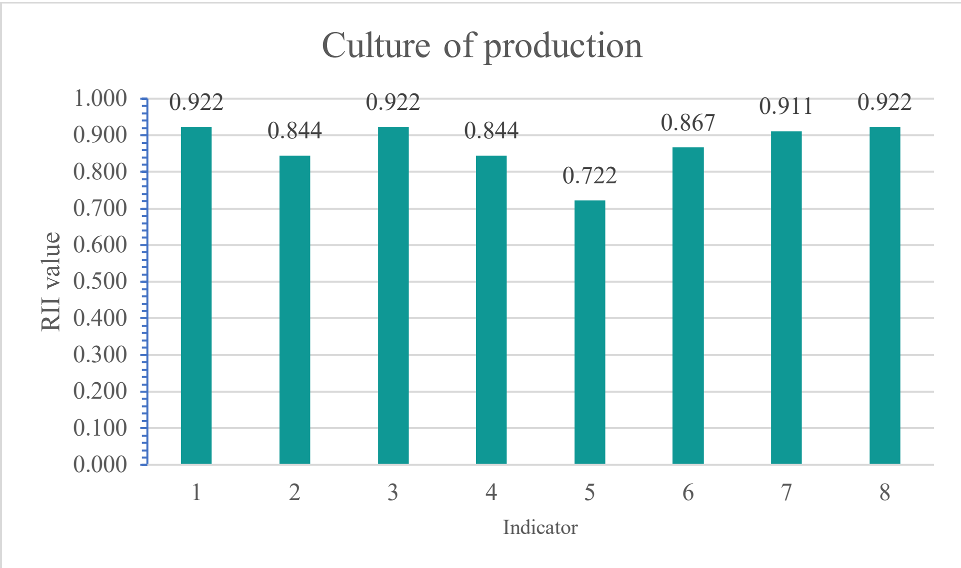

Fig. 5 *Perspective of construction industry practitioners on indicators relates to culture of production*

3.3 Perspectives of Data Driven Culture in Construction Industry

In general, 18 participants have delivered their point of view regarding “perspectives” of the implementation of data-driven culture attributes and indicators. The first main attributes identified which is knowledge management, in line with following sub-attributes (i.e., datafication and infrastructure of data), concern shall focuses on following indicators: 1) knowledge and expertise of personnel on BIM ISO 19650; 2) quality relates to practicality of data culture in construction with guidance of ISO 9001:2015; 3) progress monitoring to guarantee the efficiency of workmanship by using BIM software for job duties in forecasting potential delays, creating on-time schedules, and executing work ahead of schedule; 4) availability of fund to implement data driven culture within organization.

This paper too reveals the perspectives of construction industry practitioners on the spectrum of second main attributes which is data literacy that involved skills related to the understanding of computer science through sub-attribute of cultivation of data. Competency, training and project coordination in executing project deliverables are essential indicators to practice data driven culture. The skills to understand and utilizing construction technologies benefiting personnel to have ability over Malaysian Construction 4.0 technology such as pre-fabrication and modular construction, advanced building materials, 3D printing and additive manufacturing, augmented reality and virtualisation, Internet of Thing (IoT), autonomous construction, BIM, artificial intelligence (AI), and blockchain.

The third main attributes which is data democratization, as stated in sub-attribute of culture of use, indicator such as building model exploration, data interoperability, and control strategy are the highest priority concerned by expert panellist. The integration of digital technology in the construction sector enhances the ability to cooperate through the implementation of Building Information Modelling (BIM), virtual design, and Augmented Reality (AR) which improving visualization of building models and facilitates decision-making processes by using cloud and real-time collaboration technologies.

Experts shared perspectives in data analytic (which recorded as fourth main attribute) consists of descriptive analysis, diagnostic analysis, predictive analysis and prescriptive analysis. Throughout mentioned analysis in digitalization of construction industry, indicators that highest concern are register based statistics, information extraction, and data standardization. BIM software improves the ability of workers accurately track construction deliverables, including the type and quantity of materials, labour hours required, weather and temperature conditions, health and safety, environmental considerations, market feasibility evaluation, and the incorporation of data into tabulated formats such as histograms, pie charts, and graphs.

4. Conclusion

According to Srinavin et al. (2021), the absence of a proper data culture would limit the industry's capacity to advance its digital adoption to the next level. Understanding the data-driven culture mechanisms is crucial to fulfilling the digital needs of the construction industry. Thus, researchers have studied the root causes of related factors related to this culture. To identify attributes, sub-attributes and indicators related to data driven culture, the study started by using Systematic Literature Review (SLR) as a method of literature study, then obtaining validation from 18 practitioners from construction industry through the method of structured interviews, then the study has further investigated by using thematic analysis, and Relative Importance Index (RII) analysis. Selected practitioners of construction industries validate that data driven culture comprises of four (4) main attributes, five (5) sub-attributes, known as: 1) datafication; 2) infrastructure of data; 3) cultivation of data; 4) culture of use; 5) culture of production, which relates to thirty-three (33) indicators. The practitioners agreed that the 33 indicators are positioned in sub-attribute as: 1) seven (7) indicators in datafication; 2) three (3) indicators relates to infrastructure of data; 3) seven indicators in cultivation of data; 4) eight (8) indicators relates to culture of use; and 5) eight (8) indicators placed in culture of production. Based on RII analysis conducted, Malaysian government through Ministry of Work shall concentrate on several indicators with highest RII value which represented perspectives of Malaysia construction industry practitioners.

D1 – knowledge and expertise, D6 – quality, and D4 – progress monitoring, are the highest indicators in datafication, while ID3 – availability of fund is the highest indicator in infrastructure of data agreed by expert panellists. The highest priority also shown through indicators located at cultivation of data, (i.e., C4 – competency, C6 – training, and C7 – coordination), culture of use (i.e., U7 – building model exploration, U1 – data interoperability, and U6 – data standardization), and culture of production (P1 – register based statistics, P3 – information extraction and P8 – control strategy). The opinions of industry practitioners on the implementation of DDC into construction industry as defined through selected indicators above are the areas of focus for construction sector to improve for d=digitalization in construction practices.

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Conflict of Interest

The authors affirm that the research presented in this paper was not influenced by any competing financial interests or personal affiliations.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Adib Hashim, Che Khairil Izam Che Ibrahim, Nurul Elma Kordi;* ***data collection:*** *Muhammad Adib Hashim;* ***analysis and interpretation of results:*** *Muhammad Adib Hashim, Che Khairil Izam Che Ibrahim;* ***draft manuscript preparation:*** *Muhammad Adib Hashim. All authors evaluated the findings and sanctioned the final version of the paper.*

Appendix A: Calculation Example for RII for D1

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Data								
Total Surveyed, N								18
Total Likert Scale								5
Step 1: Calculation Number of Respondent Agreed by Each Scale, n	**Code**	**Scale**						**Total**
		1	**2**	**3**	**4**	**5**		
	D1	0	0	0	1	17		18
Step 2: Calculation Mark of Each Scale, w	**Code**	**Scale**						**Total Mark Scale, ∑w**
		1	**2**	**3**	**4**	**5**		
	D1	0	0	0	4	85		89
Step 3: Calculation of Maximum Scale, A x Number of Respondent, N	Maximum Scale						A	5
	Number of Respondent						N	18
	Maximum Scale, A x Number of Respondent, N						AN	90
Step 4: Calculation of RII, where ∑w / AN	Total Mark Scale						∑w	89
	Maximum Scale, A x Number of Respondent, N						AN	90
	RII						∑w / AN	0.989

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