Impact of digital readiness factors on implementation of Industry 4.0 tools for the manufacturing industries of Karnataka - An Analytical Study

Samapika Satapathy
Research Scholar, School of Management Studies
GIET University, Gunupur, Odisha, PIN-765022, India
Email Id:samapika.satapathy@giet.edu

Dr. M A Rasheed
Professor, School of Management Studies
GIET University, Gunupur, Odisha, PIN-765022, India
E-mail Id: rasheed.mhrm@gmail.com

Dr. Santanu kumar Das
Dean Academics, Gandhi Global Business Studies,
Berhampur, Odisha, PIN-760002, India
Email Id: santanu.das.kumar@gmail.com

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Abstract: *Implementation of digital technologies brings a significant industrial revolution in manufacturing processes, often referred to as Industry 4.0. However, manufacturing industries in Karnataka face numerous challenges in adopting these advanced technologies. The manufacturing industry needs to constantly evolve itself with various smart manufacturing techniques. They need to be digitally equipped to adapt to these advanced technologies. The digital readiness of these manufacturing industries plays an important role in the digital implementation and adaptation of advanced technologies in the manufacturing process. Various pieces of literature have been reviewed to understand the influential factors i.e Digital operational efficiency, Supply chain integration and logistics, Product quality and customization, Technological enablers, Skill Competencies of employees, Financial Support, Cyber security, Product Innovation Development and Process innovation Development, impacting the digital readiness of the organization towards implementation. A survey through a questionnaire was conducted to collect data from 50 manufacturing industries in the Karnataka, India. These industries were working towards achieving digital implementation. The primary data was collected through the survey and it was supplemented by the secondary data sources such as data from books, research papers, journals, annual reports, and websites etc. This consolidated data were analysed using Minitab (V_17) software, using descriptive statistics, Validity and reliability analysis, correlation analysis, and linear-regression analysis. The findings reveal moderate to strong correlations between various digital readiness constructs and the digital implementation of the manufacturing industries. Based on this study, Karnataka's manufacturing industries demonstrate a high level of readiness and capacity for digital transformation, suggesting that broad-based initiatives could effectively support their adoption of Industry 4.0 technologies. This study provides actionable insights for policymakers and business leaders to facilitate the successful adoption of Industry 4.0 tools.*

Keywords: *Industry 4.0, Manufacturing Industries of Karnataka, Digital Readiness Constructs, Digital Implementation*

Introduction

In the present scenario, the main driving factors for the integration of I4.0 tools in manufacturing industries have become crucial to increasing production efficiency, improved product quality, and competitiveness (Wong and Kee, 2022; Yaqub and Alsabban, 2023). In order to have better profitability and business results, Industries are adopting various Industry 4.0 (I4.0) solutions, such as digital industry transformation, smart manufacturing technologies, etc. (Ghobakhloo and Ching, 2019; Rauch et al., 2019). A more adaptive and robust manufacturing environment has been created by leveraging cutting-edge technologies, which have enhanced the capabilities of human workers (Madsen, 2019). In order to sustain themselves in the global economy, manufacturing companies have to invest in the various I4.0 tools applicable to the respective industries based on their financial capabilities and the needs of the industry. By implementing I4.0 advanced technologies such as Artificial Intelligence (AI) , Machine Learning (ML), Predictive Analytics, Cloud Computing, Augmented Reality(AR), Virtual Reality(VR), Digital Twin, Internet of Things (IoT), Additive Manufacturing, 3D printing and Industrial automation (Bai et al., 2020; Ghobakhloo, 2018), the manufacturing industries can increase productivity, efficiency, flexibility, product quality, delivery time, waste reduction, and system downtime (Wong and Kee, 2022; Pandya and Kumar, 2022). Digital tools like the Industrial Internet of Things (IIoT) and Cyber physical Systems (CPS) can create smart factories (Andulkar et al., 2018), which provide complete control of technology and events by integrating physical devices such as actuators, sensors, machines, and microcontrollers with computers. As this is a fully automated and flexible system, machines communicate and provide data on daily activities to improve the production capacity of the manufacturing industry (Wong and Kee, 2022; Kumar et al., 2022). I4.0 tools require advanced technological infrastructure, significant financial investments in research and development (R&D), and play an important role in enhancing products and services by mitigating various issues related to data management and other technological issues (Haseeb et al., 2019). In contrast, the implementation of I4.0 tools faces various challenges in developing nations like India, which include limited access to advanced technologies, insufficient R&D investments, and a lack of skilled workers. However, these regions also present significant opportunities for leapfrogging to advanced manufacturing technologies by leveraging digital solutions to address specific industrial challenges (Pozzi et al., 2021). Despite the promising prospects of Industry 4.0, several challenges hinder its widespread adoption globally. The significant barriers to the adoption of I4.0 tools are financial investment for the implantation of these technologies, lack of a skilled workforce who can manage the operation and maintenance of these advanced digital systems (Enrique et al., 2021), data security and privacy, as well as the potential ethical implications of increased automation and AI. Implementation and adoption of I4.0 in an existing manufacturing industry is a critical and thoughtful decision. Lack of clarity about the factors that affect the implementation of I4.0 technologies could be a challenge for small-scale industries. Therefore, it is important to investigate the readiness for implementation of I4.0 tools in industry before making such a significant decision (Wong and Kee, 2022). The critical readiness assessments provide a foundation for these companies to decide on digital transformation towards I4.0 (Khourshed et al., 2023). As a conclusion, the main objective of this study is to analyse the critical factors towards digital readiness and provide a framework that will help to implement I4.0 in Karnataka's industrial sector.

Review of Literature

There are critical challenges and notable opportunities for the secure and sustainable implementation of I4.0 technologies in manufacturing industries. However, the primary challenges include financial constraints, skill gaps, management support, IT-based infrastructure, and technological barriers. Lack of awareness about government policies (Kumar et al., 2020b). Financial constraints often limit SMEs' ability to invest in new technologies, which is critical for staying competitive in the rapidly evolving market landscape. Skill gaps present another substantial challenge, as the workforce needs to adopt handling advanced technologies like IoT, AI, and data analytics. Lack of awareness of I4.0 digital technologies and their advantages for broader adoption could be a potential barrier for the manufacturing industry. There are few readiness assessments that are currently available to explain the challenges and basic requirements associated with implementing I4.0. These assessments can help industries understand the basic preparedness required for organizational transformation to adapt to I4.0 (Khourshed et al., 2023). Various pieces of literature have been reviewed to understand these digital readiness assessments, i.e., readiness factors impacting I4.0 implementation in Egypt (Khourshed et al., 2023) and identify the level of maturity in the implementation of I4.0 tools in Poland (Stawiarska et al., 2021). Driving factors for I4.0 readiness among SMEs in Malaysia (Wong and Kee, 2022), identifying the determinants of SMIDT adoption within manufacturing SMEs in Malaysia and Iran (Ghobakhloo and Ching, 2019), and strategies to implement I4.0 in the sub-Saharan African SME manufacturing sector (Peter et al., 2023). Based on various digital adoption readiness studies, it has been observed that, the digitization model consists of four major steps: first, determining the current level of digitization available in the company; second, analysing and determining the goals of digitalization; third, developing a roadmap for digitization; and finally, determining where implementation should happen. These steps need to be repeated until complete digitization is achieved (Wong and Kee, 2022; Singh et al., 2023). This study represents a monumental shift in manufacturing paradigms for the manufacturing industries of Karnataka. The rationale for choosing Karnataka is that it has been one of the states that has been at the forefront of adopting new technology, techniques, and methods in all areas of business, especially the manufacturing industry. This research relied on questionnaire-based data collected from some of the manufacturing industry associations in Karnataka, i.e., the 'Karnataka Small Scale Industries Association' and the 'Bangalore and Peenya Industries Association. This study analyses the level of digital readiness of the manufacturing industries in Karnataka towards the adoption of I4.0 technologies. The readiness levels were assessed through the Digital Readiness Constructs (DRC) analysis. The findings reveal moderate to strong correlations between various DRCs and the digital implementation of the manufacturing industries. Based on the literature review, in this study, a total of nine DRCs were identified for the surveyed manufacturing companies, which were directly or indirectly impacting the digital implementation of I4.0 tools. The details of these individual DRCs are defined in the below table [Table 1].

Table-1: Digital Readiness Constructs (DRCs)

DRC	Description	Code	DRC Type	Reference Literature
Digital Operational Efficiency	The usage of I4.0 tool helps in predicting process failures in complex systems, significantly reducing cost by reducing waste and improving product service quality, which in turn increases the operational efficiency of the organization.	DOE	IC	(Yaqub and Alsabban, 2023; Khan et al., 2023; Genest and Gamache, 2020; Machado et al., 2021)
Supply chain Integration and Logistics	I4.0 tool integrates digitally physical activities with a real network of people, machines, and materials. This improves the operational efficiency and real-time scenario of the digital network in the organization. To make supply chain more efficient, robust, and buoyant, this tool transformed the production system and supply chain logistics into a fully digitally integrated end-to-end system.	SCIL	IC	(Stawiarska et al., 2021; Sony et al.,2020)
Product quality and customizatio n	I4.0 tool is needed for customer-centric businesses as it generates customer-specific data through Big Data Analytics (BDA) , Internet of Things (IOT). These data are further analysed to understand customer preferences and to facilitate manufacturing firms for mass customization and improve Product quality.	PQC	IC	(Yaqub and Alsabban, 2023; Khourshed et al., 2023)
Technologic al enablers	In order to enhance product quality, I4.0 digital technology tools like AR/VR, Cloud computing, Big data Analytics, 3D Printing, Autonomous Robots, Cyber Security, simulation, and the Internet of Things (IOT) are implemented in manufacturing industries ,These tools can be referred as technological enablers.	TE	IC	(Stawiarska et al., 2021; Machado et al., 2021)
Skill competencie s of employees	Hire sufficient qualified staff with the required skills. Training and development programs to enhance employee skill sets, One of the important aspects for digital Implementation.	SC	IC	(Khourshed et al., 2023; Bakhtari et al., 2021; Ghobakhloo, 2018)
Financial Support	It is one of the most influential factors in I4.0 implementation. Various financial sources, like financial aid, funding strategies, and financial resources, can support implementing digital technologies in the industry.	FS	IC	(Khourshed et al., 2023; Rauch et al., 2019)

Cyber security	Data being accessible online may raise cyber security concerns. It is highly necessary to improve cyber security in order to improve digitization in the organization.	CS	IC	(Stawiarska et al., 2021; Singh et al., 2023; Bakhtari et al., 2021;Ghobakhloo, 2018)
Product Innovation Development	The main aim of I4.0 in production is to improve efficiency and effectiveness to develop product innovation. It is the process of developing new products, improving existing products, or using new materials or components in existing products.	PID	IC	(Stawiarska et al., 2021; Rauch et al., 2020; Sony et al.,2020)
Process innovation Development	By implementing the I4.0 tools, process development phases during new product development, including opportunity recognition, idea generation, product evaluation, analysis, and selection, can be complemented.	PRID	IC	(Stawiarska et al., 2021; Sony et al.,2020; Trstenjak et al., 2022)
Digital Implementation	Due to the implementation of digital manufacturing technologies like the Industrial Internet of Things (IIoT), Cyber-physical systems (CPS), 3D printing, artificial intelligence (AI), Robotic automation, and cloud computing, there is a revolutionary shift in automation and data exchange from machine to machine and man to machine. This helps industries achieve operational efficiency and flexible production systems.	DI	DC	(Wong and Kee, 2022;Genest and Gamache, 2020)

Note: IC is independent construct and DC is Dependent construct

Hypotheses and model development

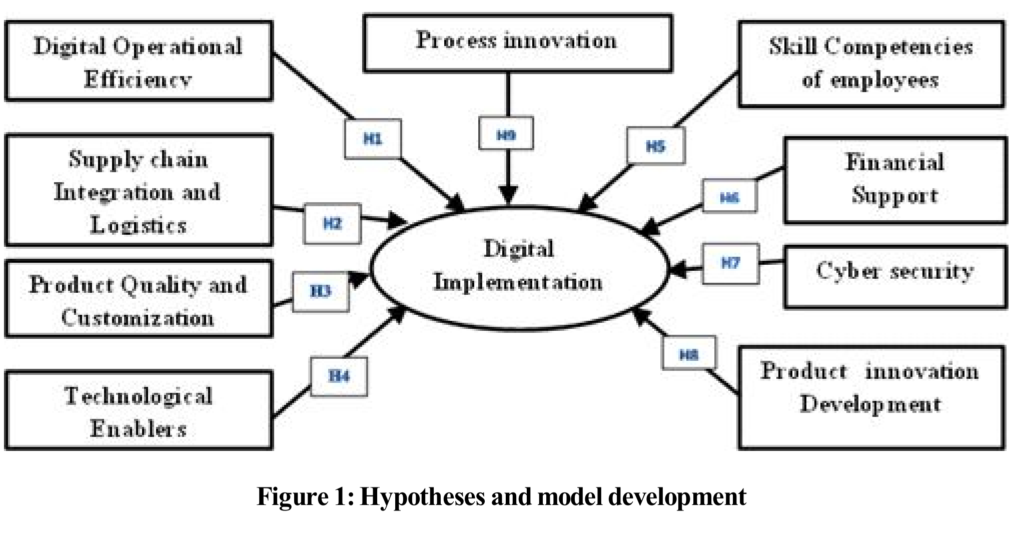


Figure 1: Hypotheses and model development

While developing the digital readiness constructs (DRCs), the present study draws inspiration from the Smart Manufacturing: Related Information and Digital Technologies (SMIDT) adaptation and implementation study (Ghobakhloo and Ching, 2019). There are nine digital readiness constructs considered for this study, such as (i) Digital Operational efficiency (DOE) (ii) Supply chain Integration and Logistics (SCIL) (iii) Product quality and customization (PQC) (iv) Technological enablers (TE) (v) Skill Competencies of Employees (SC) (vi) Financial Support (FS) (vii) Cyber security (CS) (viii) Product innovation & Development (PID) (ix) Process innovation & Development (PRID) . The above nine DRCs are considered independent constructs. The present study considers Digital Implementation (DI) as a dependent construct of the manufacturing industries, which is dependent on the nine independent constructs. Considering the above dependency, the below hypothesis is derived [Table 2].

Table-2: Hypothesis Relationship

Hypothesis	Relationship	Symbolize
H0	There is no relation between Digital Readiness Constructs (DRC) and digital implementation (DI)	DRC?DI
H1	Digital Operational efficiency (DOE) is directly impacting Digital implementation (DI).	DOE? DI
H2	Supply chain Integration and Logistics (SCIL) is directly impacting Digital implementation (DI).	SCIL? DI
H3	Product quality and customization (PQC) is directly impacting Digital implementation (DI).	PQC? DI
H4	Technological enablers (TE) are directly impacting Digital implementation (DI).	TE? DI
H5	Skill Competencies (SC) of employees are directly impacting Digital implementation (DI).	SC? DI
H6	Financial Support (FS) is directly impacting Digital implementation (DI).	FS? DI
H7	Cyber security (CS) is directly impacting Digital implementation (DI).	CS? DI
H8	Product innovation & Development (PID) is directly impacting digital implementation (DI).	PID ? DI
H9	Process innovation & Development (PRID) is directly impacting digital implementation (DI).	PRID? DI

Research Objectives

RO1: To identify various digital readiness constructs (DRCs) affecting the adoption of I4.0 digital tools in the manufacturing industries of Karnataka.

RO2: To study the impact of digital readiness constructs (DRCs) on the digital adoption of I4.0 tools for manufacturing industries in Karnataka.

Research Methodology

In this study, a systematic analysis of the identified nine DRCs for the manufacturing industries of Karnataka towards implementation of Industry 4.0 tools. Primary data were collected through structured questionnaires and in-depth discussions with officials from fifty manufacturing industries of Karnataka, ensuring a diverse representation of manufacturing industry perspectives. The collected responses were calculated using the five-level Likert scale, and scores were generated for each DRC for various industry groups. This data was further meticulously analysed using MiniTab V17 software, enabling detailed statistical analysis that includes descriptive statistical analysis, data reliability analysis, correlation analysis, and linear regression analysis. This analysis identifies the significant dependencies of these DRCs on the digital implementation of Industry 4.0 tools for the manufacturing industries of Karnataka. Secondary data were sourced from a range of scholarly books, research papers, journals, annual reports, and reputable websites, offering a robust theoretical foundation and contextual background for the study. This methodological framework (Figure-2) ensures a holistic understanding of the impact of digital readiness constructs on digital implementation for the manufacturing industries of Karnataka.

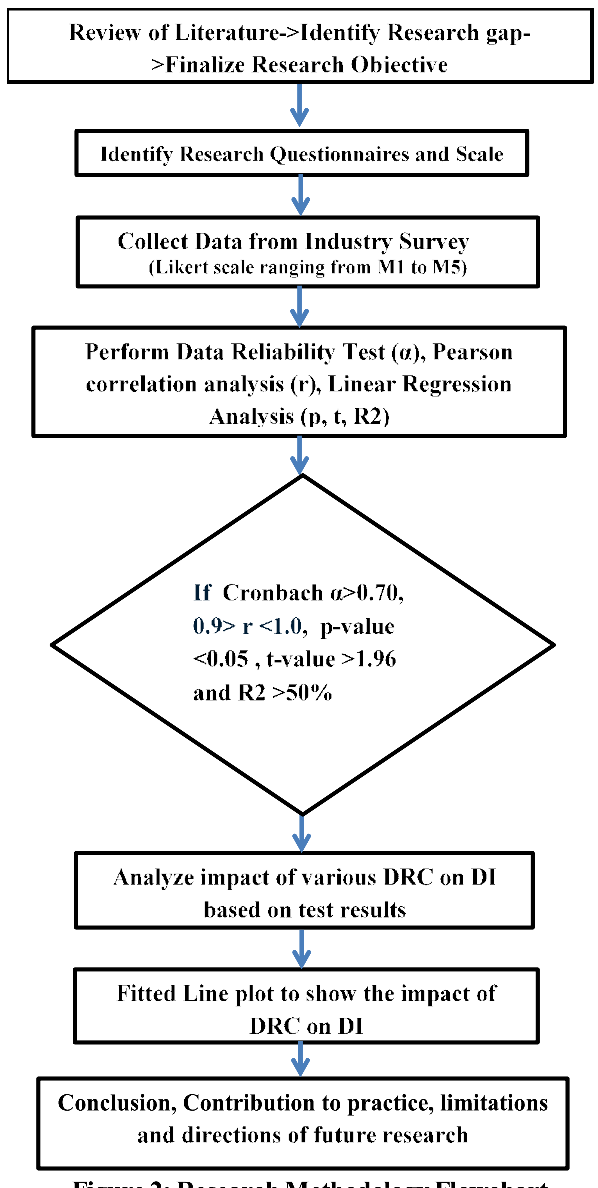


Figure 2: Research Methodology Flowchart

Sampling and data collection

For this research study, a survey was conducted on a sample of fifty manufacturing industries from the industrial suburb located in the city of Bangalore in the state of Karnataka in India [Table 3]. This sample includes representations of five specific manufacturing industries, e.g., 'Aircraft Components', 'Automobile Parts', 'Agricultural Machinery Components', 'Chemical Products', and 'Construction Machinery Components'. For each specific category of manufacturing companies, various types of industries, including large-scale industries (OEMs), medium-scale industries (Tier 1), and small-scale industries (Tier 2), have been considered for this analysis. The survey was addressed to the top management and engineering staff of the surveyed companies. Initially the respondents were contacted personally through telephone, emails, and an in-person visit and explained about the research process. Once formal communication was received from these industries to initiate the survey, the actual survey was conducted. The questionnaires [Table 4] were primarily focused on the level of availability of identified DRC for digital implementation. This survey was conducted online using Google Forms. The responses collected from these surveys were reviewed with guidance from the experts to consider only relevant responses for further processing. The digital readiness of the organization was measured by the individual respondent representing each industry responding to the survey, and the result was calculated considering the score generated on a Likert scale. 85 responses were collected from these various manufacturing organizations, out of which 50 responses were selected, which are considered to be 58.82 % across various types of manufacturing industries. These sets of responses were further used for the statistical data analysis.

Table 3: Demographic table of Manufacturing Industries

Demographics	Frequency	Percentage
Firm Size		
Large (OEMs)	16	32%
Medium (Tier 1)	15	30%
Small (Tier 2)	19	38%
Number of Employees		
1-500	19	38%
501-1000	10	20%
1001-1500	12	24%
1501-2000	9	18%

Age of the Company		
1-10 years	27	54%
11-20 years	16	32%
21-30 years	7	14%
Manufacturing Industry Type		
Aircraft components	6	12%
Automobile parts	9	18%
Agricultural machinery component	8	16%
Chemical products	14	28%
Construction machinery component	13	26%
Respondent's Job Position		
IT Project Manager	8	16%
Supply Chain Manager	6	12%
Process Engineering Manager	7	14%
R&D Manager	3	6%
Quality Engineering Manager	7	14%
Operation Manager	4	8%
General Manager	2	4%
Technician	13	26%

Source: *Field Survey*

Table-4: Survey Questionnaires

Digital Readiness Constructs	Questionnaires	Scale Type
Digital operational efficiency (DOE)	Is there any automated connection between various machines and production system?	Likert
	Is there any information or data exchange between the human-to-machine interfaces?	
	Is there any internal communication of the production system with other functional components of the organization?	
	Is there any data generated and processed automatically to monitor production system?	
Supply Chain Integration and Logistics (SCIL)	Is there any system available for the automated exchange of communication between machines and devices?	Likert
	Is there any system available for the exchange of information during the material flow process?	
	Is there any internal communication of the supply chain systems with other functional components of the organization?	
	Is there any data collected and processed during further stages of material flow?	
	Is there any automated communication with suppliers or customers takes place?	
Product quality and customization (QMS)	How does the company respond to quality management system?	Likert
	How the quality processes are monitored?	
	How the company does product customization?	
	How the best practices are identified and implemented in the organization?	
Technological enablers(TE)	IIOT (Industrial Internet of Things)	Likert
	CPS (Cyber Physical System)	
	Big data collection and analysis	
	Additive manufacturing	
	Cloud computing technology	
	Collaborative or autonomous robots	
	Augmented/virtual Reality	
	Artificial intelligence	
	Flexible manufacturing system	
	Enterprise resource planning	
	Manufacturing simulation and analysis of virtual models	
	Cyber Security	
Skill Competencies of Employees (SC)	Are the employees aware about I4.0 tools?	Likert
	What is the level of skill of the employees?	
	Whether the employees need training to implement I4.0 tools?	
Financial Support(FS)	Whether the company have required financial Support to implement I4.0 tool?	Likert
Cyber security(CS)	What is the readiness level of cyber security for the implementation of I4.0?	Likert
Product Innovation Development (PID)	What is the readiness level of product innovation for the implementation of I4.0?	Likert
Process Innovation Development(PRID)	What is the readiness level of process innovation for the implementation of I4.0?	Likert
Digital Readiness(DR)	What is the readiness level of social and environmental factors for the implementation of I4.0?	Likert

The questions within each dimension of the survey could be rate using the five-point scale. Likert scale (Brozzi et al., 2018; Machado et al., 2019) ranging from M1 considered as 'Digitisation initiation', M2 considered as 'Basic digitisation', M3 considered as 'Departmental digitisation', M4 considered as 'Inter departmental digitisation', and M5 considered as 'Full digitisation' [Table 5]. On a scoring scale ranging from M1 is considered a '1' point to M5 is considered a '5' point, The average score received on each Digital Readiness Construct is further considered for statistical calculations.

Table 5: Likert scale score definition

Measure	Parameters	Description
M1	Digitisation initiation	Digitisation is not initiated.
M2	Basic digitisation	Digitisation is initiated, but there are major inconsistencies in its implementation.
M3	Departmental digitisation	Digitisation is initiated, but there are minor inconsistencies in its implementation.
M4	Inter departmental digitisation	Digitisation is initiated and effectively implemented.
M5	Full digitisation	Digitisation has been initiated and effectively implemented and has shown improvements in its execution in the last 12 months.

Data analysis and interpretation

This section describes the details of the data analysis carried out for the surveyed data. Minitab V_17 was used for performing different statistical analyses.

Validity and Reliability Analysis: First of all, reliability analysis was done to assess the validity of the measurement instrument and scales [Table 6]. Based on the Cronbach analysis result of á value greater than 0.70 meeting the recommended values mentioned in the literature review (Ghobakhloo and Ching, 2019), high internal consistency reliability was observed. A variable is declared reliable if the Cronbach á value is > 0.60 (Wong and Kee, 2022). Based on the below table, all digital readiness constructs are highly reliable, as the Cronbach á > 0.70.

Table 6: Validity and Reliability Analysis

Variables	Abbreviation	Mean Standard deviation	Cronbach α
Digital Operational efficiency	DOE	6.80	0.87
Supply chain Integration and Logistics	SCIL	16.39	0.75
Product quality and customization	PQC	18.25	0.74
Technological enablers	TE	18.64	0.71
Skill Competencies of employees	SC	19.75	0.74
Financial Support	FS	29.93	0.71
Cyber security	CS	14.65	0.72
Product innovation Development	PID	25.64	0.73
Process innovation Development	PRID	14.52	0.77
Digital Readiness	DR	20.22	0.70

Source: *Field Survey*

Pearson Correlation Analysis: To further test the relationships between the independent DRC factors, Pearson correlation analysis was carried out [Table 7]. The analysis matrix indicates a few extremely high correlation (Ghobakhloo, 2018) values (r = 0.98) for DRC factors PQC and SCIL, which indicates that both factors have a positive correlation, whereas another factor SC shows a high correlation value (r = 0.99) with FS. (r = 0.95) for CS with PRID, similarly high correlations (r=0.94) were observed for PQC and TE and (r = 0.90) were observed for SCIL with TE and Moreover, most of these digital readiness constructs are highly correlated with each other, except for few variables, like cyber security and digital operational efficiency, which show a negative correlation. Other than that, the remaining digital readiness constructs are mostly correlated with each other.

Table 7: Pearson Correlation Analysis between Digital Readiness Constructs

	DOE	SCIL	PQC	TE	SC	FC	CS	PID	PRID
DOE	1.00								
SCIL	0.77	1.00							
PQC	0.67	0.98	1.00						
TE	0.60	0.90	0.94	1.00					
SC	0.10	0.48	0.58	0.80	1.00				
FS	0.07	0.47	0.58	0.80	0.99	1.00			
CS	-0.01	0.23	0.20	0.45	0.75	0.69	1.00		
PID	0.31	0.69	0.82	0.88	0.79	0.83	0.22	1.00	
PRID	0.12	0.48	0.45	0.64	0.80	0.75	0.95	0.39	1.00

Source: *Field Survey & Data Analysis*

Table 8: Linear Regression Analysis

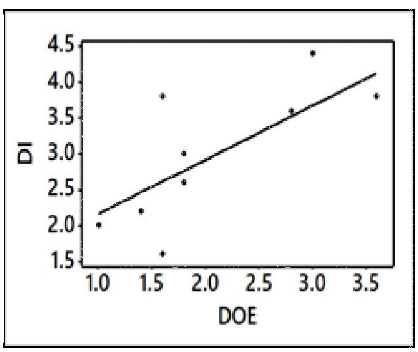
Dependent Variable	Independent Variable	R^2	t-value	p-value	Significance
DI	**DOE**	0.5766	3.3007	0.010847	Yes
	SCIL	0.8307	6.2658	0.000242	Yes
	PQC	0.8348	6.3584	0.000219	Yes
	TE	0.8086	5.8145	0.000399	Yes
	SC	0.8599	7.0063	0.000112	Yes
	FS	0.8919	8.1264	0.000039	Yes
	CS	0.8861	7.8900	0.000048	Yes
	PID	0.7836	5.3825	0.000660	Yes
	PRID	0.8534	6.8232	0.000135	Yes

Source: *Field Survey & Data Analysis*

Linear regression analysis: In order to investigate the impact of dependent variables on the independent variables, a linear regression analysis was carried out. In this study, digital implementation (DI) is the only dependent variable, whereas other nine digital readiness constructs such as Digital operational efficiency (DOE), Supply chain Integration and Logistics (SCIL), Product quality and customization (PQC), Technological enablers (TE), Skill Competencies of employees (SC), Financial Support (FS), Cyber security (CS), Product Innovation Development (PID), Process innovation Development (PRID) are considered independent variables [Table 8].

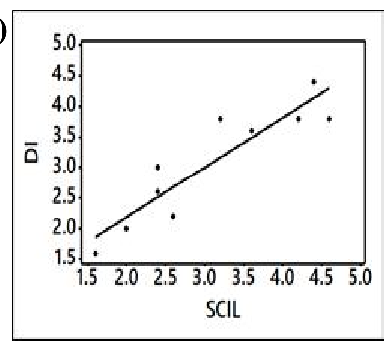
Based on the results of linear regression analysis, it was observed that the DRCs are statistically significant as their correspondence p-value is <0.05 and t-value >1.96 at 95% significance level (Khourshed et al., 2023; Ghobakhloo, M. (2018); Wong and Kee, 2022). Therefore, all DRCs are individually useful in achieving success in Digital implementation which indicates that there is a direct relationship between the independent Digital Readiness Constructs on Digital implementation. The Coefficient of Determination (R^2) is to determine the presence of changes in dependent variables (Digital Implementation) caused by independent variables (DRCs) (Wong and Kee, 2022). From the above analysis, it was evident that the R^2 value for each independent variable with the dependent variable is above 0.5, which means this analysis predicts more than 50% of the relationship between the dependent and independent variables (Ghobakhloo and Ching, 2019). The R^2 value for financial support and digital implementation shows the highest value of 89%. That means digital implementation is highly dependent on financial support. Similarly the Skill competencies of employees, Technological enablers, Supply chain Integration and Logistics, Product quality and customization and Process innovation Development show a high R^2 value to define a strong relationship with digital implementation. Figure 3 shows the graphs for Digital readiness constructs Vs Digital implementation.

a)



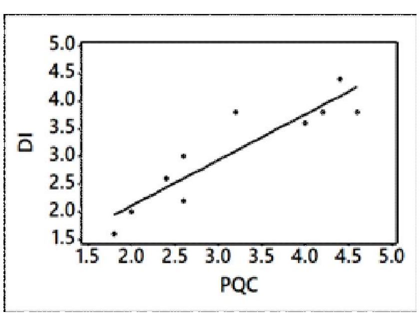
DI vs. DOE

b)



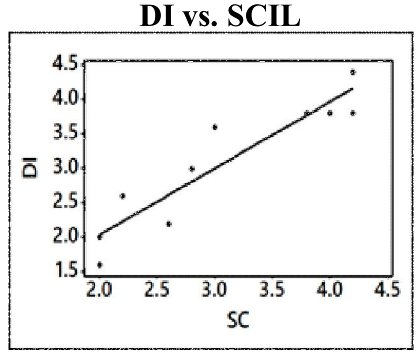
DI vs. SCIL

c)



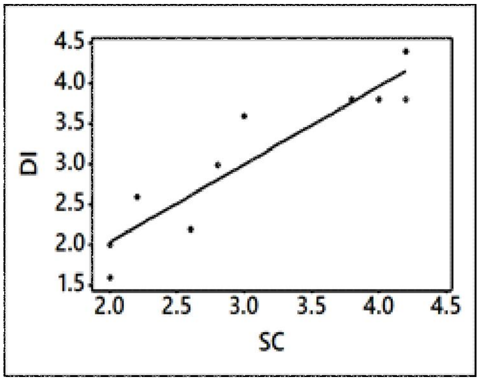
DI vs. PQC

d)



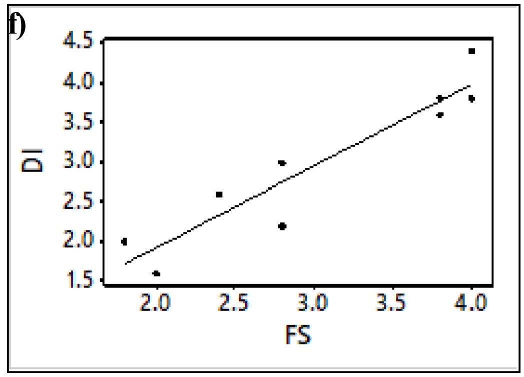
DI vs. TE

e)



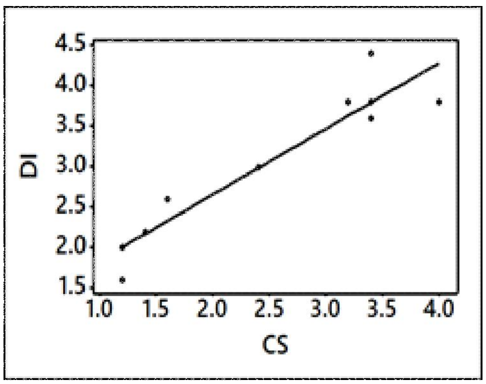
DI vs. SC

f)



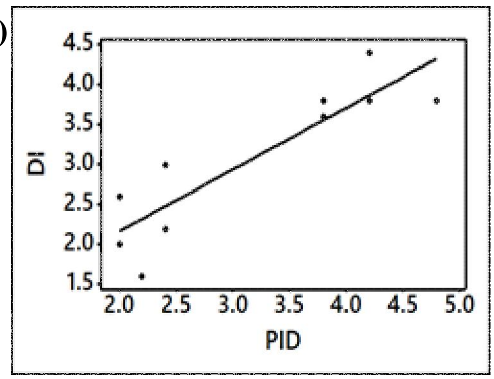
DI vs. FS

g)



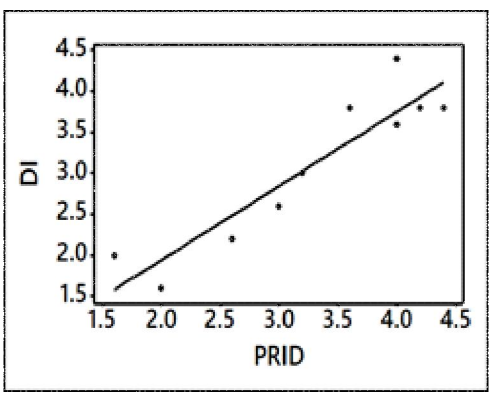
DI vs. CS

h)



DI vs. PID

i)



DI vs. PRID

Figure-3 : Linear Regression Analysis of Various Digital Readiness Constructs(DRC) vs. Digital Implementation(DI) (a) DI vs. DOE (b) DI vs. SCIL (c) DI vs. PQC (d) DI vs. TE (e) DI vs. SC (f) DI vs. FS (g) DI vs. CS (h) DI vs. PID (i) DI vs. PRID

Findings

The present study reveals several key insights into the digital implementation of manufacturing industries in Karnataka towards Industry 4.0 digital tool implementation. Digital Operational efficiency, Supply chain Integration and Logistics, Product quality and customization, Technological enablers, Skill Competencies of employees, Financial Support, Cyber security, Product innovation Development and Process innovation Development are critical factors influencing the implementation of advanced manufacturing technologies. The result of the linear regression analysis summarized in (Table 8) shows there is a direct relationship between individual DRCs and the digital Implementation of manufacturing industries. Considering the results of Linear regression analysis, hypotheses H1, H2, H3, H4, H5, H6, H7, H8, and H9 are accepted; however, null hypothesis H0 has to be rejected. From the results of the correlation analysis between the DRCs , it is evident that the digital readiness constructs are not only impacting the digital adoption of manufacturing industries. They also have a high correlation with each other. There is a strong correlation between Supply chain Integration and Logistics with other DRCs, which are required to be set up in order to maintain the inventory all the time. A strong inventory system supports the overall organization. Product Quality Control is another important factor where the product has to be sustained in terms of quality factors. A high quality product is always fit to further implement advance technologies to study the product features and determine the improvement areas. Best practices and innovations are identified and implemented in the product development to create a benchmark for product's future landscape. Technological enablers will create a digital platform for system to system communication; this platform will enable the overall organization to implement I4.0 tools. Industry 4.0 digital tools like IIOT(Industrial Internet of things), CPS(Cyber Physical System), Big data collection and analysis, Additive manufacturing, Cloud computing technology, Collaborative / Autonomous Robots, Augmented/virtual Reality, Artificial intelligence, Flexible manufacturing system, Enterprise resource planning, Manufacturing Simulation/ analysis of virtual models and Cyber Security need strong data and information system within the organization to monitor various product components.

It is vital to understand the DRCs also need continuous improvement in order to implement advance technologies. Workforce skill competency is one of the crucial element. Technological Enabler and Skill Competencies 80% of correlation factors show a dependency on developing a skilled workforce. The organization needs a trained, skilled workforce to support the implementation of digital manufacturing tools. The workforce should be trained, cross-skilled in digital technologies, and prepared to work on advance technologies. The implementation of structured training programs and continuous learning opportunities is crucial for building a competent workforce that can effectively utilize advanced technologies. Financial support shows a high R^2-0.8919, which indicates a strong influence on the digital implementation of the manufacturing industries. Most organizations are struggling to implement digital technology due to the high cost factor. However this study highlights that while financial constraints are a major challenge, strategic cost management practices can mitigate these challenges by optimizing cost structures and improving financial performance. This, in turn, facilitates the adoption of Industry 4.0 technologies, which require significant initial investment but offer long-term benefits in terms of productivity and sustainability. There is a negative correlation between Cyber Security and Digital operational efficiency once an organization is working towards digital implementation; there is a high chance of its internal data being accessible in the public domain. Hence, the organization's staff should have sufficient awareness and knowledge about data security and cyber threats. Cybersecurity becomes an important aspect of digital implementation. A secure system is highly required to implement any futuristic technologies. Product innovation and development are essential parts of digital readiness analysis. The product innovation is highly required to keep the organization relevant to the market and continue growing and improving over time. . The organization should have a basic tracking mechanism in place to understand the product innovation requirements. In order to determine product innovation readiness, there are many things to be monitored, such as product trend analysis, performance, audits of operations, etc. The study reveals that a well-trained workforce is extremely important for the successful implementation of Industry 4.0 digital technologies. This involves not only technical skills but also an understanding of the new business models and processes enabled by these technologies.

Conclusion

This study on the impact of digital readiness constructs in implementing Industry 4.0 tools for manufacturing industries in Karnataka provides a complete understanding of the readiness constructs and their effect on digital implementation for manufacturing enterprises. Based on the findings reveal that there is a strong dependency on strong Digital Operational efficiency, Supply chain Integration and Logistics, Product quality and customization, Technological enablers, Skill Competencies of employees, Financial Support, Cyber security, Product innovation Development and Process innovation Development in advance technology implementation for the manufacturing industries. The interrelated nature of these constructs underscores the need for inclusive approaches to support the digital transformation of industries. The moderate to strong correlations between digital readiness constructs indicate that improvements in these digital readiness constructs can positively impact digital implementation. The independent factors identified in this research indicate the need to understand digital readiness before planning to implement Industry 4.0 tools. However, the study concludes that a balanced approach focusing on continuous improvement of digital readiness constructs is critical for the successful implementation of Industry 4.0 in the manufacturing sector.

Scope for Future Study

The purpose of our study was to understand the digital readiness of these organizations and derive a relationship between digital readiness constructs and the digital implementation study of identified manufacturing industries. This study is based on the responses received on questionnaires' distributed to a sample of manufacturing organizations in the state of Karnataka, India. In order to confirm the findings for a wider variety of manufacturing organizations, a large sample can be collected. Further digital readiness benchmark models can be analysed considering industries that have already implemented digitalization. The implementation approach followed by these organizations can be studied to prepare a digital readiness model. This paper studied the impact of digital readiness constructs to implement advanced technologies for manufacturing organizations; however, the effects of technological level of products, level of digital flexibility and size of the organization on Industry 4.0 transformation are some of the impacting factors for digital implementation; these parameters can be further studied.

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