Industry 4.0 Benefits, Challenges, Critical Success Factors: A comparative analysis through the lens of Resource Dependence Theory across continents and economies

Purpose: As we enter a new era of digital transformation, Industry 4.0 promises to revolutionize the way we do business, providing unprecedented opportunities and challenges**.** This study aims to investigate empirically and comparatively analyse the benefits, challenges, and critical success factors of Industry 4.0 (I 4.0) across four continents and developing and developed economies.

Methodology: This study employed an online survey to explore the benefits, challenges, and critical success factors of developed and developing economies. In order to ensure the validity of the survey, a pilot test was conducted with 10 respondents. A total of 149 participants with senior managerial, vice-presidential, and directorial positions from developed and developing economies spanning four continents were invited to take part in the survey.

Findings: The study ranks benefits, challenges and CSFs across economies and continents. Further, the benefit of Industry 4.0 helping to achieve organizational efficiency and agility differed across the developing and developed economies. Further, the benefit *improves customer satisfaction* significantly differed across continents; in terms of challenges, *Employee resistance to change* had a higher proportion in developing economies. *Future viability of Industry 4.0 also differed across the continents. Regarding CSFs,* there was no difference across the developing and developed economies. Finally, change management and project management vary across the continents.

Implications: This study contributes to a balanced understanding of Industry 4.0 by providing empirical evidence for a comparative analysis. Moreover, it extends the concept of Resource-Dependent Theory (RDT) to explain how organizations in developing economies and developed economies deploy resources to manage external condition uncertainties to implement Industry 4.0. Furthermore, this study provides a structural framework to understand the specific benefits, challenges, and critical success factors of implementing Industry 4.0, which can be utilized by policymakers to promote Industry 4.0 in their economies or continents.

Originality of Value: As far as our knowledge goes, no studies have empirically demonstrated the comparative analysis of benefits, challenges and CSFs across economies and continents and distinguish an original contribution of our work.

Keywords: Industry 4.0; Competitive advantage; Company Performance

1. Introduction

Many organizations globally have adopted Industry 4.0, leveraging the use of modern digital technologies in their corporate strategies and supply chains. (Büyüközkan and Göçer, 2018). I 4.0 is vertical and horizontal integration within and across the organization (Enrique et al., 2022). Thus, there is a multi-stakeholder dependence within and outside the organization. In addition, I 4.0 relies on integration across the stakeholders such as suppliers, manufacturers, retailers, logistics providers, customers, and so on (Culot *et al.*, 2020; Kiel *et al.*, 2017)). The digital integration of multiple stakeholders further creates reliance in terms of technology, legal, political, and social infrastructure where the organization operates. Many studies have sought to understand the benefits, challenges, and critical success factors of I 4.0 (Kiel *et al.*, 2017, 2020; Moeuf *et al.*, 2020; Sony *et al.*, 2021), but none have taken into account the resource dependence theory (RDT) in a comparative analysis between developed and developing countries, or across continents. RDT explains organizations as open systems dependent on the contingencies of the external environment (Hillman *et al.*, 2009). RDT further suggests that the success of an organization is determined by the resources that are available to it. Resources are physical and intangible assets that can be used to create, deliver, and capture value. These resources can include physical assets, such as factories and equipment, or intangible assets, such as patents, copyrights, and trademarks. RDT recognizes that the contexts constrain every organization due to external factors impacting organizational behaviour (Pfeffer and Salancik, 2003). The implementation of I 4.0 is seen differently across developed and developing economies, with organizations in both types of economies taking measures to reduce environmental uncertainty and dependence (Bogoviz *et al.*, 2019). Developed economies have enacted legal legislation, policies, strategies, roadmap, technology and network strategy, investment policies and so on (Bogoviz *et al.*, 2019), whereas the developing economies are lagging. Thus, there is a need to empirically understand the comparative analysis of the benefits, challenges, and critical success factors of I 4.0. Further, in some continents, such as Africa, studies indicate that I 4.0 impact has been low in the African continent due to social-economic- technical factors (Bayo & Onyenma, 2019). One of the main challenges for future I 4.0 research is to carry out more empirical investigations and large-scale data analysis (Koh *et al.*, 2019). To fill this research gap, the present study seeks to answer the following research questions:

RQ1. *What are the differences in benefits of I 4.0 between developed and developing economies and across the continents?*

RQ2: *What are the differences in challenges of I 4.0 between developed and developing economies and across the continents?*

RQ3: *What are the differences in critical success factors of I 4.0 between developed & developing economies and across the continents?*

The present study has placed its focus on the manufacturing boundaries within the context of the supply chain. This approach was adopted due to the intricate nature of mapping the global supply chain, which presents significant challenges in survey research. Therefore, by concentrating on the manufacturing boundaries of the supply chain, this study aims to provide a comprehensive understanding of the subject matter. The present study contributes to the literature by offering a balanced understanding of I 4.0 through an empirical analysis of its benefits, challenges, and critical success factors across developing and developed economies and four continents. Additionally, this study furthers the application of Resource Dependence Theory to the understanding of how organizations in these regions deploy resources to deal with external condition uncertainties to effectively implement I 4.0. Finally, a framework is provided to understand the continent- or economy-specific benefits, challenges, and critical success factors in implementing I 4.0, which may aid policy makers in promoting I 4.0 in their regions. The paper is organized as follows; the next section is devoted to the literature review, followed by methodology, results, discussion, conclusion, limitation, and future research direction.

2. Literature Review

2.1 Resource Dependence Theory

The Institutional theory states that organizations are influenced by their external environment, which is composed of "institutions" such as the economy, laws, and social norms. Organizations must conform to these external pressures in order to survive and succeed(Gupta *et al.*, 2020; Lammers *et al.*, 2014; Sony and Aithal, 2020). The contingency theory states that organizations must respond to the changing needs of their environment in order to succeed. It suggests that there is no "one size fits all" approach to organizational success; instead, organizations must be flexible and responsive in order to survive and thrive (Bhatia and Kumar, 2023; Donaldson, 2001). The RDT proposes that organizations engage with the environment

to obtain resources and have been used to explain the organization and environment relationships(Pfeffer and Salancik, 1978). The main assumption in using this theory of I 4.0 implementation is based on the belief that most organizations are rarely self-sufficient concerning strategically important resources to implement I 4.0. Hence there are dependencies on other organizations to help in the implementation of I 4.0 completely due to horizontal and vertical integration of I 4.0 principles. Thus, organizations are thereby trying to reduce uncertainty and manage this dependency by carefully structuring the relationships with other organizations through formal and semi-formal means (Heide, 1994; Ulrich and Barney, 1984). RDT is a better explanation for the benefits, challenges and CSFs of I 4.0 because it emphasizes the importance of managing resources effectively in order to remain competitive. It also highlights the need for organizations to adapt to the changing environment in order to remain successful. This theory is important for organizations to understand how to manage their resources effectively in order to gain competitive advantages. Thus, the benefits, challenges and critical success factors for I 4.0 implementation will depend on how effectively organizations use these resources. By using RDT theory, we posit that I 4.0 can help organizations deal with conditions which are external to the organizations. In line with this theory, we posit that organizations use I 4.0 to change their internal processes to adapt to their organizational environment(Kiel *et al.*, 2017). Also, I 4.0 implementation helps to change organizational environments (Bogoviz *et al.*, 2019). Thus, we posit that I 4.0 implementation plays a significant role in facilitating internal and external roles in enabling organizations to deal with emergencies in their environment. The benefits, challenges and critical success factors for implementing I 4.0 depend on how well organizations deal with the external environment.

2.2 Benefits of I4.0

Organizations have reported that after implementing I 4.0, customer needs are well met and satisfied. Further reports also observed that after implementing I 4.0 , organizations were better placed to develop smart products and services(Schmidt *et al.*, 2015). Further benefits include maximizing efficiency, cutting operational costs and remaining competitive in the business, efficient value creation, manufacturing cost mapping, flexibility, and better quality products (Kiel *et al.*, 2017; Peukert *et al.*, 2015; Sony *et al.*, 2021). The top benefits of I 4.0 are thus summarised in Table 1.

Table 1: Previous literature on Benefits

Benefits	Sources
Improve customer satisfaction Maximize efficiency, cut operational costs and remain competitive in the business Big data-based organizational decisions Meet increasing needs of smart products Achieve organizational effectiveness and agility Develop smart services Improve customer relationship management Improve customer service experience Optimum machine utilization Prediction of future utilization for production Standardization of production process Allowance of decreased waste and environmental impact/ Sustainability	(Schmidt et al., 2015) (Kiel et al., 2017; Peukert et al., 2015; Sony et al., 2021) (Arromba et al., 2020; Bag et al., 2021; Burritt & Christ, 2016; Kiel et al., 2020; Lee et al., 2015; Masood & Sonntag, 2020; Rossit et al., 2018; Weyer et al., 2015)(Bonnard et al., 2021; Khan et al., 2017; Müller et al., 2017) (Khan et al., 2017)

I 4.0 implementation to be a success, there are some socio-economic challenges as regards to where an organization is located (Tortorella *et al.*, 2021). The rate of technology adoption in developed economies is significantly faster than in developing economies, leading to a disparity in the benefits yielded from the implementation of such technologies(Castellacci, 2008). In addition, other factors such as ICT infrastructure, culture, level of education, economic & political instability can also interfere in the value perception and in the consequent level of investments in advanced technologies (Frank *et al.*, 2016). Thus, it can be argued that benefits of I 4.0 implementation will vary across the economies and across the continents, as socio-economic situations prevalent across these contexts will be different.

Thus, it is pertinent to examine the hypothesis.

H1: *The benefits of I 4.0 vary between the continents and across developed and developing economies*.

2.2 Challenges of I 4.0 Implementation

I 4.0 implementation is a complex assortment of technical and social systems, and hence implementation process is challenging (Avis, 2018; Sony and Naik, 2020). The key challenges of implementing I 4.0 were implementation costs, technology knowledge, and implementation

time(Masood and Sonntag, 2020). Infrastructure is one of the key elements for the successful implementation of I 4.0 , and the lack of availability of infrastructure is a perennial challenge (Zielinski *et al.*, 2019). The challenges of I 4.0 are tabulated along with the sources in Table 2.

Table 2: Challenges of I 4.0 from previous literature

Challenges	**Sources**
Huge cost Data security Lack of I 4.0 skills & know-how Unreliable internet connectivity Employee's resistance to change Unavailable infrastructure Future viability Too little standardization Legal issues/ lack of governmental support and policies Lack of global standards and data sharing protocols Difficulty of integration of technology platforms Decreasing job opportunities	(Avis, 2018; Sony & Naik, 2020) (Masood & Sonntag, 2020) (Zielinski et al., 2019) (J. M. Müller et al., 2018) (Galushkin et al., 2019; Sony & Aithal, 2020) (Nimawat & Das Gidwani, 2022) (Kumar et al., 2021) (Luthra & Mangla, 2018). (Moktadir et al., 2018 (Sony et al., 2021).

The challenges may also vary with respect to where the organisation is located. To cite an instance the challenge of decreasing job opportunity due to I 4.0 implementation may be severe in a developing country compared to developed countries due to high rate of unemployment in a developing country(Momen *et al.*, 2022). Similarly, huge cost for I 4.0 implementation will a huge burden in a developing country compared to developed countries. Thus, it can be argued that challenges of I 4.0 implementation will vary across the economies and across the continents, as socio-economic situations prevalent across these contexts will be different.

H2: *The challenges of I 4.0 vary between the continents and across the developed and developing economies*.

2.3 Critical Success Factors

The critical success factors for I 4.0 are those factors; if they are present within the organization, the chances that I 4.0 implementation will succeed are remarkably high. I 4.0 implementation requires huge investment(Krishnan, 2021), and for the success of I 4.0 , the availability of funding for this initiative is very critical. The organisation's availability of IT-enabled

technologies (Sigov *et al.*, 2022) is critical to implementing I 4.0 technologies. People are important for the success of Industry, and the availability of skilled manpower is a pertinent factor for the success of I 4.0 (Bonekamp and Sure, 2015; Ramos *et al.*, 2022). The critical success factors and sources are explicated in Table 3.

Table 3: CSF on I 4.0 from literature

Critical success factors	**Sources**
Aligning the I 4.0 initiatives with organizational strategy Top management support to I 4.0 initiatives Employees will be important for the success of I 4.0 Make your products or services smart Make efforts to digitize the supply chain Digitize the organization Change management Project management Operational, economic, environmental, and social sustainability of I 4.0 Availability of sufficient funding Availability of Skilled personnel Accessibility of IT-enabled Technologies Excellence of Customer Service	(Bonekamp and Sure, 2015; Krishnan, 2021; Moeuf *et al.*, 2020; Oliva *et al.*, 2022; Pozzi *et al.*, 2021; Ramos *et al.*, 2022; Sigov *et al.*, 2022; Sony *et al.*, 2021)

The above CSFs will have contextual significance. To cite an instance the availability of skilled personnel in a developing will be a major challenge in a developing economy compared to developed countries. Thus, it is pertinent to examine the hypothesis

H3: *The critical success factors of I 4.0 vary between the continents and across the developed and developing economies*.

2.4 Critical Analysis of Literature

The implementation of I 4.0 has been widely discussed and researched but there is still a need to critically analyse the different CSFs, benefits, and challenges of this technology in both developing and developed economies. While the technology behind Industry 4.0 has been generally accepted as necessary for modern economies, the impact of its implementation and the benefits it offers are not equally accessible to all countries. Developing countries are in a

less advantageous situation due to a lack of resources and infrastructure, and this has led to a lower level of adoption of Industry 4.0 in these areas. On the other hand, developed countries have better access to resources and policy frameworks and have been able to implement Industry 4.0 more successfully. This discrepancy between developing and developed countries must be addressed in order to ensure that the benefits and advancements of Industry 4.0 are not only accessible to the wealthier countries. Governmental policies, legal frameworks, and other socio-economic and technical factors must be taken into consideration and be modified to properly address the differences in access to resources and infrastructure between the two different economic environments. Furthermore, a comprehensive study of the CSFs, benefits, and challenges of I 4.0 in both developing and developed economies must be conducted in order to better understand the implications of its implementation. Without such a comprehensive study, the full potential of Industry 4.0 and its impact on the global economy may not be realized. Thus, it is imperative to investigate the differences in CSFs, benefits, and challenges of I 4.0 between developing and developed countries in order to maximize the potential of this technology and ensure that all countries, regardless of their economic status, may benefit from its implementation.

3. Methodology

Survey research plays an important role when it comes to collecting primary data, and it will result in collecting large amount of data in standardised manner(Kotzab, 2005). This study used an online survey using a descriptive survey research design to examine the performance of the benefits, challenges, and critical success factors in developed and developing economies and across continents. A descriptive survey research design was used because it helps for understanding the phenomenon and describing it in a population (Forza, 2002). Further, these studies are designed to provide a "snapshot" of the current state of events related to an phenomenon gain a deep understanding (Rungtusanatham *et al.*, 2003). This survey designs employ a methodology where in a single respondent who provides responses for all items, including both the independent and dependent variables. This was critically chosen because since we are studying the benefits, challenges, and CSFs these types of constructs are monadic, and they focus on a single perspective(Flynn *et al.*, 2018). The online survey was selected as the data collection method of choice due to its many advantages. It is flexible, globally accessible, and convenient for data entry and rapid data collection. It also allows for innovative questionnaire design and the use of multiple channels for questionnaire distribution. Furthermore, respondents can quickly answer the same questionnaire from any location as

online surveys can be easily sent out electronically.(Ball, 2019; Evans and Mathur, 2018). The study was conducted between October 2020 to May 2022.

3.1 Questionnaire Design

The questionnaire was developed in three parts. The first part was devoted to the collection of demographic information. To avoid social desirability bias(Grimm, 2010), the participant's name was optional. The second part of the questionnaire was devoted to the benefits and challenges of Industry 4.0, which was captured in a literature review. Respondents were asked to select their answers regarding the benefits for organizations that implement Industry 4.0 from a set of tick boxes. Respondents also had the option to write in any other benefits in the text box provided. The third part focused on the critical success factors. This study used a five-point Likert scale from 1 "Strongly Disagree" to 5 "Strongly Agree". Five-point scales are the most widely used and are easy to comprehend and have good psychometric properties(Leung, 2011). Questions were developed based on the literature review and their sources are provided in Table 1, 2 and 3.

3.2 Questionnaire validation

The piloting of the online questionnaire (Boynton and Greenhalgh, 2004) was conducted with 10 respondents, comprising of five academics and five senior industry professionals. The selected academics had extensive knowledge on Industry 4.0 and had published at least five peer-reviewed international articles on the topic. The industry professionals were chosen based on their experience in implementing I 4.0 in manufacturing, with a minimum of five years of senior management experience. The respondents reported positive feedback, which allowed the researcher to simplify the questionnaire. It was estimated that the questionnaire would take 9 ± 3 minutes to complete. A study suggests that if the time taken to complete the questionnaire is less than 15 minutes, the response rate improves(Saleh and Bista, 2017). Furthermore, piloting was conducted to identify any issues with the wording or structure of the questions, thus reducing common method bias(Babbie, 2020). Google Forms was determined to be the best survey software for this survey due to its anonymity, customisable layout, and reliability based on the results of the pilot run. It was thus decided to use Google Forms as the survey hosting platform(Boccardo, 2022; Reinhardt *et al.*, 2020).

3.3 Questionnaire Distribution

The study participants were senior professionals in different roles, such as senior managers, vice presidents, and directors from developing and developed economies. The classification of economies into developed and developing economies was based on Organisation for Economic Co-operation and Development (OECD) (OECD, 2021). In order to ensure the validity of the responses, it was decided to recruit senior professionals from organizations with at least five years of experience in the implementation of Industry 4.0. Specifically, the manufacturing sector was chosen since I4.0 implementation can vary across different industrial sectors, as they have different levels of maturity. Greeting survey participants with a personalised invitation can significantly increase response rate. Additionally, when individuals are requested for assistance by authority figures or when they are addressed as a part of a particular selected group chosen to complete the survey, they will be more likely to respond to the survey request (Reinhardt *et al.*, 2020). Thus, this survey had designed personalised emails to the targeted respondents. The contact details of the respondents were obtained from the popular professional networking site, LinkedIn(Prodromou, 2015; Zide *et al.*, 2014). Previous studies have used Linkedin to collect information from senior management professionals (Antony et al., 2019; 2020; Cortez & Dastidar, 2022; Sony et al., 2021). The authors selected I 4.0 experts to participate in the survey by identifying them through the most relevant professional groups on LinkedIn. To do so, they performed a search using the keywords "Industry 4.0 experts" and its variants such as Industry 4.0 specialists, Industry 4.0 professionals, Industry 4.0 consultants, Industry 4.0 thought leaders, Industry 4.0 gurus and so on. We identified as many as I 4.0 groups too. Further we identified experts with Industry 4.0 experience inside the members sections of each group. Care was taken they were senior professionals with at least five years of experience in the implementation of Industry 4.0. The experts were invited to participate in the survey by sending them personalised messages outlining the objectives of the study, informing them that the data would be used for research purpose and no identifying information would be asked. They were also informed that they could stop their participation at any point in the survey and that the data would only be used for research purpose. If they agreed to participate, the consent form and the questionnaire were electronically distributed to them. The process of identifying the experts and communication to the experts and getting response from them to participate took six months' time. The final questionnaire was distributed to 500 respondents. A screening question was included in the survey to verify whether the respondent had implemented I 4.0 in the organization. Those who responded negatively were thanked and not allowed to proceed with the survey. All the questionnaires were sent at the same time. One reminder was sent to them after three weeks We received 157 responses over the period of

three months period. Out of it, 8 were incomplete as the missing data was more than 50% and were discarded. The final sample size was 149. The research process chart is depicted in Figure 1.

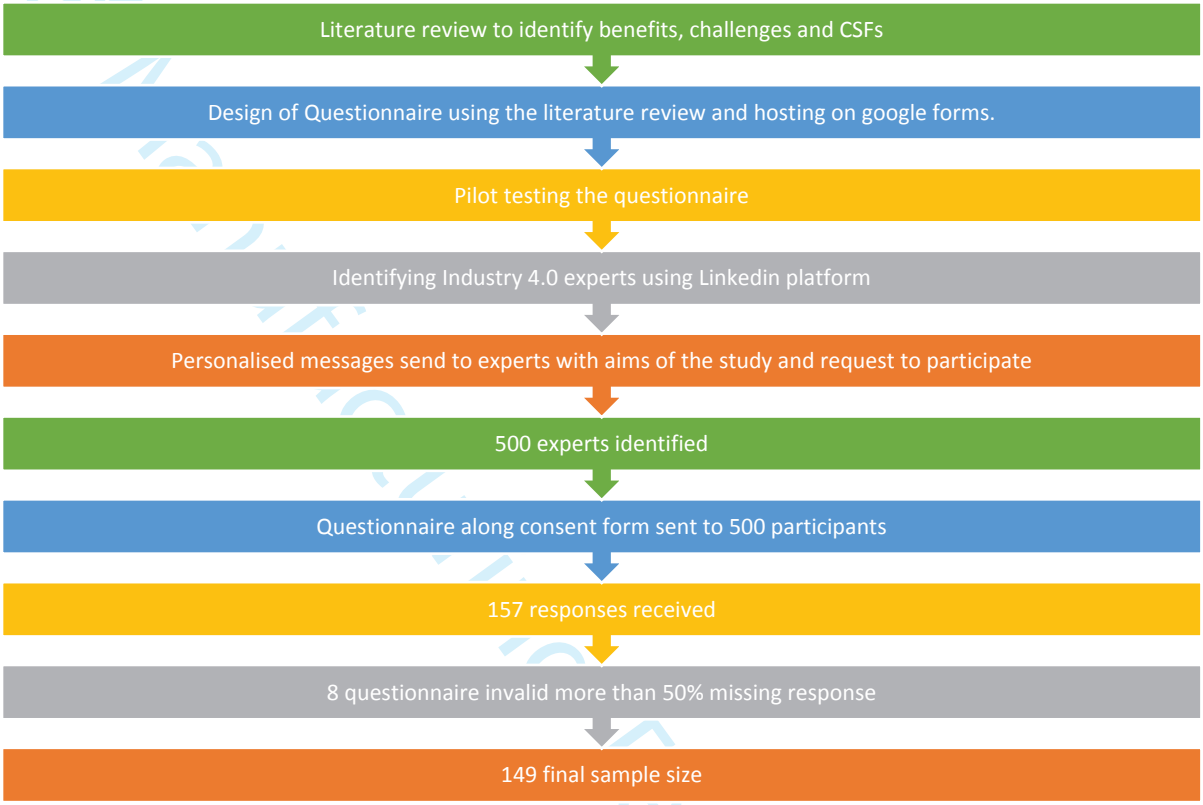

Figure 1: Research process chart

3.4 Sample Description and Data analysis

The response rate was 29.8%. It is usual in an online survey to have a low response rate, and a response rate above 20 % is considered adequate for the survey (Easterby-Smith *et al.*, 2012). The sample size of 149 was considered adequate for the analysis, as studies have been conducted with sample sizes less than 100 for emerging phenomena (Antony, 2004; Antony *et al.*, 2005; Sony *et al.*, 2021). The table 4 depicts the sample description. 149 respondents completed the study, 58 were from developing economies, and the remaining were from developed economies, as depicted in Table 4.

Table 4: Sample Demography

Row Labels	Developed	Developing	Grand Total
Africa		45	45
Female		11	11
Male		34	34
Asia		22	22

Table 4: Sample Demography

Row Labels	**Developed**	**Developing**	**Grand Total**
Female		3	3
Male		19	19
Europe	48	1	49
Female	14	1	15
Male	32		32
Prefer not to say	2		2
North America	33		33
Female	8		8
Male	25		25
Designation			
Chief Manufacturing Officer	17	Production Manager	12
Chief Operating Officer	15	Quality Manager	11
Manufacturing Director	14	Logistics Manager	10
Vice President of Manufacturing	16	Purchasing Manager	14
Plant Manager	12	Maintenance Manager	6
Operations Manager	14	Engineering Manager	8

Internal consistency of the questionnaire was measured using Cronbach Alpha and was found to be 0.842. A value of 0.7 and above is considered acceptable (Nunnally, 1994) and suggesting reliability of the questionnaire . The non-response bias was tested with time trend extrapolation (Armstrong and Overton, 1977). The respondents were classified into two groups The respondents who answered in the first four weeks were classified as early respondents, and the last four weeks were classified as late respondents (Etter and Perneger, 1997; Lambert and Harrington, 1990). Chi-square analysis was conducted on variables, and it was found to be not significant (p-value > 0.05). Frequency analysis was conducted to rank the benefits and challenges. This was done as responses in questionnaire were sought in terms of prevalence of the benefits and challenges based on literature review. Further, to test whether the benefits and challenges, differed across developed and developing economies, a 2 sample proportion test(Montgomery *et al.*, 2009). To compare the benefits and challenges across continents we compared multiple proportions using the Marascuillo procedure (NIST/SEMATECH, 2014; Wagh and NA, 2016) with a 5% level of significance used in this study. The Chi-Square test

only concludes that not all population proportions are equal. Marascuilo procedure determines which pairs of sample proportions differ by comparing every pair of samples. This procedure first calculates the critical for each pair of sample proportions. A specific pair is critically different if the absolute difference is greater than the critical ratio (David and others, 2017). To compare CSF's, t-test and Anova were conducted as responses for CSFs were elucidated on a five point scale. The analysis plan is depicted in Figure 2.

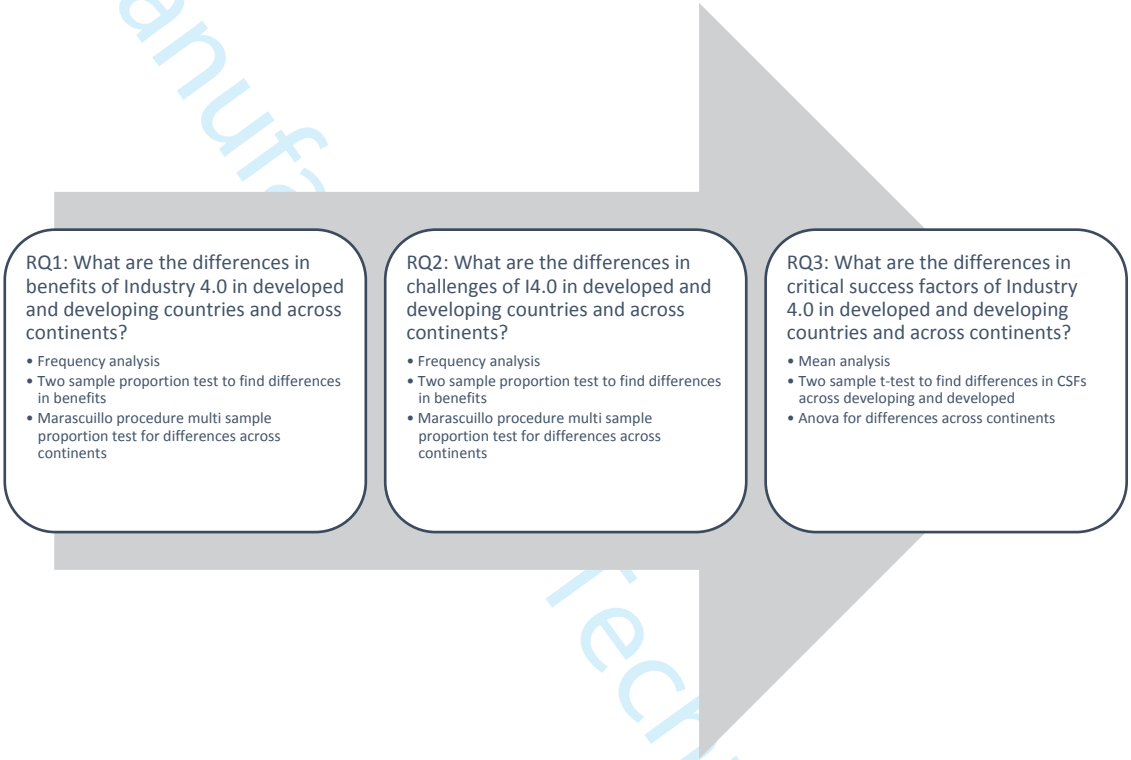

Figure 2: Analysis Plan

4. Results

The *first research question explicated in the study was what are the differences in benefits of I 4.0 in developed and developing economies and across the continents?* The benefits of implementing I 4.0 in a developing country are explicated in Table 5 below.

Table 5: 2 sample proportion tests between developed and developing economies

	Developing	Developed	Developing(P1)	Developed (P2)	Pooled sample statistic	Test Statistic	P-value
Improve customer satisfaction	35	33	0.515	0.407	0.456	1.310	0.095
Maximise efficiency, cut operational costs and remain competitive in the business	36	46	0.529	0.568	0.550	-0.470	0.681
Big data based organizational decisions	22	36	0.324	0.444	0.389	-1.508	0.934
Meet increasing needs of smart products	21	26	0.309	0.321	0.315	-0.159	0.563
Achieve organizational effectiveness and agility	26	20	0.382	0.247	0.309	1.783	0.037
Develop smart services	19	34	0.279	0.420	0.356	-1.782	0.963
Improve customer relationship management	17	21	0.250	0.259	0.255	-0.129	0.551
Improve customer service experience	21	17	0.309	0.210	0.255	1.380	0.084
Optimum machine utilization	18	34	0.265	0.420	0.349	-1.978	0.976
Prediction of future utilization for production	19	26	0.279	0.321	0.302	-0.551	0.709
Standardization of production process	25	23	0.368	0.284	0.322	1.089	0.138
Allowance of decreased waste and environmental impact/ Sustainability	22	24	0.324	0.296	0.309	0.358	0.360

In developed economies, the top five benefits of technology are maximizing efficiency and cutting operational costs to remain competitive in the business, making organizational decisions based on big data, developing smart services, improving machine utilization and customer satisfaction. In developing countries, the top five benefits are the same as in developed countries, but also include achieving organizational effectiveness and agility, standardizing production processes and improving customer satisfaction.

Table 6: Frequency of benefits across continents

Sample Size	45	22	49	33
Benefits	**Africa**	**Asia**	**Europe**	**North America**
Improve customer satisfaction	20	15	17	16
Maximize efficiency, cut operational costs and remain competitive in the business	24	12	24	22
Big data-based organizational decisions	14	8	20	16
Meet increasing needs of smart products	13	8	18	8
Achieve organizational effectiveness and agility	18	8	13	7
Develop smart services	10	9	21	13
Improve customer relationship management	10	7	12	9
Improve customer service experience	13	8	10	7
Optimum machine utilization	11	7	21	13
Prediction of future utilization for production	12	7	17	9
Standardization of production process	16	9	15	8
Allowance of decreased waste and environmental impact/ Sustainability	12	10	17	7

A 2 sample proportion test (Montgomery et al., 2009) was conducted to test whether the benefits differ across developed and developing economies. It was found that achieving

organizational efficiency and agility had a higher proportion in developing economies, and the difference was statistically significant. To investigate whether the benefits differed across the continents. As we did not have data from South America and Australia, we carried out the analysis across four continents. Table 6 depicts the same.Overall, the top three benefits of industrial automation are maximizing efficiency, cutting operational costs and remaining competitive in the business, improving customer satisfaction, and increasing organizational effectiveness and agility. This is true across all regions, though there are slight variations based on local needs, such as the emphasis on sustainability in Asia and the focus on smart services and machine utilization in Europe. By leveraging the power of industrial automation, businesses can reap these benefits and gain a competitive edge in their respective markets. For comparing the benefits across continents, we compared multiple proportions using the Marascuillo procedure was found that between the continents, the benefit *improves customer satisfaction* significantly across 1) Africa and North America and 2) Asia and North America. We carried out the procedure by designing a Microsoft Excel sheet. The table is given in the Appendix.

The *second research question was, what are the differences in challenges of I4.0 in developed and developing economies and across the continents?* The challenges of implementing I 4.0 in developing economies are in Table 7.

Table 7: 2 sample proportion tests between developed and developing economies

	Developing	Developed	Developing	Developed	Pooled sample statistic	Test Statistic	P-value
Huge cost	22	28	0.32352941	0.34567901	0.294117647	-0.29556	0.616216
Data security	18	25	0.26470588	0.30864198	0.253792083	-0.61384	0.73034
Lack of Industry 4.0 skills & knowhow	24	39	0.35294118	0.48148148	0.374028857	-1.61515	0.946861
Unreliable internet connectivity	11	8	0.16176471	0.09876543	0.109322974	1.227506	0.109816
Employee's resistance to change	25	16	0.36764706	0.19753086	0.234739179	2.440349	0.007337
Unavailable infrastructure	14	16	0.20588235	0.19753086	0.17573067	0.133416	0.446932
Future viability	12	12	0.17647059	0.14814815	0.139844617	0.496504	0.309769
Too little standardization	12	19	0.17647059	0.2345679	0.183869774	-0.91185	0.819077
Legal issues/ lack of governmental support and policies	9	14	0.13235294	0.17283951	0.136330004	-0.71737	0.763428
Lack of global standards and data sharing protocols	11	20	0.16176471	0.24691358	0.184794673	-1.33384	0.908872
Difficulty of integration of technology platforms	23	26	0.33823529	0.32098765	0.286903441	0.231842	0.408331
Decreasing job opportunities	13	14	0.19117647	0.17283951	0.157787643	0.305833	0.379866

In developed economies, the top five challenges with implementing I 4.0 are lack of skills and know-how, difficulty in integrating technology platforms, data security, lack of global standards, and data sharing protocols. In developing countries, the top challenges include employee resistance to change, lack of I 4.0 skills and know-how, difficulty in integrating technology platforms, huge costs, and data security. These challenges must be addressed for

successful implementation of I 4.0. A 2 sample proportion test(Montgomery et al., 2009) was conducted to test whether the benefits differ across developed and developing economies. It was found that *employee resistance to change* had a higher proportion in developing economies and the difference was statistically significant.

To investigate whether the challenges differed across the continents. As we did not have South America and Australia data, we analysed four continents, as shown in Table 8.

Table 8: Frequency of challenges across continents

Challenges	**Africa**	**Asia**	**Europe**	**North America**
Huge cost	15	7	14	14
Data security	13	5	11	14
Lack of I 4.0 skills & know-how	17	7	23	16
Unreliable internet connectivity	9	2	5	3
Employee's resistance to change	19	6	9	7
Unavailable infrastructure	9	5	9	7
Future viability	8	4	11	1
Too little standardization	9	3	10	9
Legal issues/ lack of governmental support and policies	7	2	10	4
Lack of global standards and data sharing protocols	7	4	12	8
Difficulty of integration of technology platforms	14	9	16	10
Decreasing job opportunities	8	5	7	7

The top three challenges in Africa were 1) employee resistance to change, 2) lack of I 4.0 skills & know-how, and 3) huge cost. The top three challenges in Asia were 1) difficulty in integrating technology platforms, 2) huge cost, and 3) lack of I 4.0 skills & know-how. The top three challenges in Europe were 1) lack of I 4.0 skills & know-how, 2) difficulty in integrating technology platforms, and 3) huge cost. Finally, the top three challenges in North America are 1) lack of I 4.0 skills & know-how, 2) huge cost, and 3) data security.

For comparing the differences across continents, we conducted comparing multiple proportions using the Marascuillo procedure was found that between the continents, the *huge cost challenge* significantly differed across 1) Africa and North America. The challenge *future viability also* varied across Europe and North America. We conducted the procedure by designing an Ms Excel.

The third research question in this study was *what are the differences in critical success factors of I4.0 in developed & developing economies and across the continents?*

Table 9: Mean and t-test developing and developed economies

Critical Success Factor	Developed (Mean)	Developing Mean)	T-value	P-value
Aligning the I 4.0 initiatives with organizational strategy]	4.2727	4.359	-0.396	0.7
Top management support to I 4.0 initiatives	4.2687	4.5128	-1.16	0.279
Employees will be important for the success of I 4.0	4.1791	4.3947	-1.059	0.329
Make your products or services smart	3.9701	4.2564	-1.297	0.198
Make efforts to digitize the supply chain	4	4.1795	-0.84	0.441
Digitize the organization	3.9692	4.2308	-1.172	0.268
Change management	3.8154	3.9744	-0.643	0.525
Project management	3.7164	3.9744	-1.09	0.277
Operational, economic, environmental, and social sustainability of I 4.0	3.9846	4.1538	-0.794	
Availability of sufficient funding	4.0896	4.1026	-0.068	0.949
Availability of Skilled personnel	4	4	0	1
Accessibility of IT-enabled Technologies	4.1194	4.359	-1.189	0.259
Excellence of Customer Service	3.6818	4	-1.388	0.177

The top three critical success factors for developed economies are 1) aligning the I 4.0 initiatives with organizational strategy, 2) top management support to I 4.0 initiatives and 3) employees will be important for I 4.0 . Conversely, the top three critical success factors for developing economies are 1) top management support to I 4.0 initiatives, 2) employees will be important for the success of I 4.0 and 3) aligning the I 4.0 initiatives with organizational strategy.

Table 10: Mean and Anova across continents					
Critical Success Factor	**Europe**	**Asia**	**Africa**	**North America**	**P-Value**
Aligning the I 4.0 initiatives with organizational strategy]	4.407	3.647	4.514	4.346	0.053
Top management support to I 4.0 initiatives	4.667	3.824	4.472	4.231	0.080
Employees will be important for the success of I 4.0	4.615	3.765	4.306	4.154	0.081
Make your products or services smart	4.111	3.941	4.306	3.808	0.339
Make efforts to digitize the supply chain	4.370	3.647	4.111	3.960	0.218
Digitize the organization	4.407	3.750	3.972	4.040	0.289
Change management	4.481	3.412	3.583	3.958	0.009
Project management	4.333	3.471	3.500	3.923	0.020
Operational, economic, environmental, and social sustainability of I 4.0	4.259	3.529	4.059	4.154	0.165
Availability of sufficient funding	4.259	3.647	4.222	4.038	0.187
Availability of Skilled personnel	4.259	3.375	4.111	3.962	0.051
Accessibility of IT-enabled Technologies	4.519	3.882	4.361	3.885	0.062
Excellence of Customer Service	4.074	3.765	3.778	3.560	0.465

The top three CSFs for I 4.0 initiatives in Europe, Asia, Africa, and North America include top management support, employees as a key factor, accessibility of IT-enabled technologies, and alignment with organizational strategy. As the data was available on a 5-point Likert scale, a t-test was conducted between developed and developing economies to compare the CSFs. Normality is the variable assessed with the KS test (Hair *et al.*, 1998) and was found to be normally distributed. It was found that there was no difference in CSFs across the developing and developed economies. To test the difference in CFSs across the continents, we carried Anova. It was found that change management and project management varied across the continents. To find out where exactly the difference lies, we conducted a post hoc analysis using LSD (Williams and Abdi, 2010).

5. Discussion

The top-ranked benefit of implementing I 4.0 in both developed and developing economies, also across Africa, Europe and North America was to maximize efficiency, cut operational costs and remain competitive in the business. Only in Asia, the top-ranked benefit was to improve customer satisfaction. As Asian markets are becoming bigger and bigger, their impact on the world economy is increasing (Yi and Nataraajan, 2018). Thus, organizations in Asia indulge in satisfying the customer and penetrating the world markets. Thus, organizations use

I 4.0 to improve customer satisfaction. The benefit of I 4.0 helping to achieve organizational efficiency and agility differed across the developing and developed economies, with higher scores in developed economies. In developing economies, the organisation's efficiency and agility were lower than in developed economies. In a developing country, there is poor IT infrastructure; the markets are uncertain, shorter product life cycle, changing customer needs, and diverse stakeholders warrant organization to be more agile so as survive in the marketplace(Jafari-Sadeghi *et al.*, 2021; Ojha and Chandra, 2010; Panda and Rath, 2018). Thus, from an RDT perspective, organizations in developed economies can use external resources to deal with uncertain environments while implementing I 4.0 to achieve organizational efficiency and agility. The benefit of I 4.0 improving customer satisfaction varies significantly across continents. From an RDT perspective, during the implementation of I 4.0 , resources are key to organizational success in meeting the customer changing needs(Pozzi *et al.*, 2021). Organizations' access and control over resources is a basis of power and key to customer satisfaction (Schiele *et al.*, 2015). In economies such as Africa and Asia, resources are frequently controlled by various organizations compared to North America. This is because certain economies, especially in some regions of Asia, or Africa, are served by relatively few logistics service providers, under less than favourable operating conditions, and where risks are higher (Banomyong, 2010; Fessehaie, 2012). I 4.0 implementation results in vertical and horizontal integration(Krishnan, 2021; Wang *et al.*, 2016); therefore, resources are rarely in the organisation's control. This means that organizations in Asia and Africa must deploy effective strategies to maintain open-access resources while implementing I 4.0. In terms of challenges in developed economies, lack of I 4.0 skills & know-how was the top challenge. Many firms in developed economies are implementing I 4.0 (Dalenogare *et al.*, 2018). Hence there is a shortage of employees with I 4.0 skills and know-how. However, employees' resistance to change was the top-ranked challenge in developing economies. In addition, employee resistance differed statistically across developing and developed economies. In developing economies, there are few avenues for employees to upgrade their skills (Raj *et al.*, 2020; Yunus, 2020); hence, employees' resistance to I 4.0 would be higher. Thus, dealing with employee resistance is a challenge for organizations. In North America and Europe, lack of I 4.0 skills & know-how was the top challenge. In Africa, it was employees' resistance to change, and in Asia, it was the difficulty of integrating technology platforms. This indicates that the importance of challenges is varied across the continents. The huge challenge *cost* significantly differed across 1) Africa and North America, which is understandable due to the socio-economic prevalence in African continents. Also, the challenge *to the Future viability*

of I 4.0 varied across Europe and North America. Technologies to attain a state of revolution warrants a shift in terms of the techno-scientific sphere to the socio-economic sphere paradigm (Perez, 2010). I 4.0 technologies acceptance has been in a varied manner. To cite an instance, a study by McKenzie states that a large number of organizations are still stuck in the pilot purgatory phase; they are still struggling to capture the full potentiation of their transformation efforts or return on investment (Ewelina et al., 2022). This study also points out that in Europe, respondents felt that the future viability of I 4.0 technologies might be challenging. From the RDT lens, organizations change their external environment to secure access to the resources they need to survive (Hillman *et al.*, 2009). During I 4.0 implementation, firms need to acquire social and technological resources (Davies *et al.*, 2017). Thus, the future viability of I 4.0, how well the resources are acquired, is determined they deal with their external resources and hence will determine the competitiveness. The top three CSFs for the developed and developing country was the same, with only a change in ranking and the difference was not significant, indicating their importance irrespective of the economies. However, across continents, it was found that change management differed across Europe and Africa, Europe and Asia. I 4.0 is highly popular in Europe (Capello and Lenzi, 2021; Nowotarski and Paslawski, 2017) compared to Asia and Africa. As the organizations mature in I 4.0 implementation, the respondents have realized that change management is important compared to other aspects. The critical success factor of project management also differed across Africa and Europe, Asia, and Europe. For I 4.0 to succeed, the portfolio, program and projects must be a success (López-Robles *et al.*, 2020; Richard *et al.*, 2020). The project being the lowest unit of analysis, its importance in its success is incredibly significant. Hence continents such as Europe, where I 4.0 is extremely popular, the respondents have realized its importance compared to Asia and Africa, where I 4.0 is picking up. From an RDT perspective, for a project to be successful, there is a focus on external parties in terms of acquiring and managing resources effectively to meet the I 4.0 objectives of the organizations. How well the projects, programmes and portfolios are implemented will determine the success of implementing I 4.0 projects. In terms of reliability and validity of the study we have collected data in the manufacturing sector, from developed and developing countries, and across continents. For reliability, internal consistency of the questionnaire was calculated was found to be above 0.7. For validity, we have piloted the survey, accounted for socially desirable responding and the responses were tested for the non-response bias.

6. Implications

From a theoretical lens, this research has shown that, from an RDT perspective, organizations in developed economies can use external resources to deal with uncertain environments during the implementation of I 4.0 in order to achieve organizational efficiency and agility. Further, the benefit of I 4.0 in terms of improving customer satisfaction was found to vary significantly across continents, indicating the ability of organizations to orchestrate and manage resources according to RDT to achieve benefits in different contexts. Regarding challenges, the research revealed that employees' resistance to change differed statistically across developing and developed economies, indicating the need for resources to develop employee adaptability in developed economies. The huge cost and future viability of I 4.0 implementation were also found to vary across the continents. The top three CSFs for both the developed and developing country were the same, indicating their importance irrespective of the economy; however, it was determined that the importance of change management as a CSF differed across the continents.

The findings of this study can provide valuable insights to organizations and policy makers in developing and developed economies. The findings suggest that organizations need to consider the differences between developing and developed economies and across continents to ensure successful I 4.0 implementation. Organizations in developing economies should focus on strategies to improve their efficiency and agility while in developed economies they should focus on acquiring the required I 4.0 skills and know-how. In addition, organizations in developing economies need to focus on strategies to deal with employee resistance while in developed economies they should focus on change management. Furthermore, organizations should focus on the CSFs identified in this study to ensure successful I 4.0 implementation from a practitioner's and policymakers' point of view, the knowledge of the investigated relationships also provides an appropriate impact. First, identifying the differences in benefits across the continents and economies indicates that policymakers should plan to deploy the legal, technological, political, and social enablers while encouraging the implementation of I 4.0. Second, the continent's special variation in challenges should help policymakers develop country-specific policies. To cite an instance, employee resistance to change differed across continents, indicating a need for economies to share the resources and orchestrate and manage intercountry resources within the continent to train employees. Third, in terms of critical success factors, they were the same across the economies. This indicates that irrespective of the economies where the organization should consider equally the importance of each of the critical success factors while implementing I 4.0. This research also presents certain economic

and societal implications that are relevant to highlight. This study was conducted on four continents and across developed and developing economies. I 4.0 implementation will play a major role in the next decade in terms of the socio-economic well-being of a country (Dutta and Lanvin, 2019; Enrique *et al.*, 2022). By clearly delineating the benefits, challenges and CSFs across continents, this study is helping organizations in various economies to strategize the implementation of I 4.0 and improve the competitive advantage of organizations.

6. Conclusions, Limitations and Scope for future research

This study aimed to examine the I 4.0 benefits, challenges, and critical success factors using a comparative analysis through the lens of RDT. Therefore, this research is among the first studies focused on investigating the I4.0 technologies in developing and developed economies. As far as our knowledge goes, no studies have empirically demonstrated such a relationship, which distinguishes an original contribution of our work. Our study presents several limitations that are imperative to consider for future studies to consider. More specifically, concerning the study's dataset. Australia and South American data were unavailable for this study, and future studies should explore the data collected from these continents. It is important to note that the current study solely concentrates on the manufacturing boundaries within the supply chain context. This approach was deemed necessary to identify suitable respondents in the survey research. However, it is recommended that future studies undertake a more comprehensive examination of the subject matter by exploring other pertinent aspects of the supply chain. Further studies should also explore the benefits, challenges, and CSFs in service and public sector, in other words non-manufacturing setup. This will help the developing and developed countries, as regards to the benefit, challenges, and CSFs of I 4.0 implementation. Such studies will further help in exploring how I 4.0 technologies can be used to improve service delivery in a non-manufacturing setup. Furthermore, research should also investigate the potential for I 4.0 technologies to provide greater economic benefits to developing countries through improved service delivery. Additionally, research should also explore the CSFs for successful implementation of I 4.0 technology in public sector organisations, including the need for appropriate infrastructure, skilled personnel, and a culture of innovation and collaboration. Another interesting study would be exploring the data collected across countries within a continent to find differences in benefits, challenges, and CSFs. Studies should be targeted to understand how these challenges were overcome by companies to implement I 4.0, such studies will help to understand in detail the implementation frameworks which will help in future implementation. Another area of future research would be exploring within a continent and

across continents how the benefits, challenges and CSFs vary across different sub-sectors. This study was a cross-sectional and longitudinal study that would help the understanding of the variety of benefits, challenges, and CSFs as a time-oriented phenomenon. To cite an instance, employee resistance to the implementation of I 4.0 or early and late adopters (Antony *et al.*, 2021). I 4.0 is a developing phenomenon, and its comprehension and implementation will expand in the days to come as such these will also motivate further research in this area.

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Appendix

Table 1

	45	22	49	33		Critical Value					Difference					
Row Labels	Africa	Asia	Europe	North Ame	Af-As	Af-Er	Af-NA	As-Er	As-Nr	Er_NA	Af-As	Af-Er	Af-NA	As-Er	As-Nr	Er_NA
Improve customer satisfaction	0.12	0.153	0.346939	0.484848	0.253719	0.233399	0.278369	0.286653	0.293036	0.308685	0.033	0.226939	0.364848	0.193939	0.331848	0.13791
Maximise efficiency, cut operational costs and remain competitive in the business	0.533333	0.545455	0.489796	0.666667	0.362349	0.288235	0.309596	0.357671	0.351447	0.304109	0.012121	0.043537	0.133333	0.055659	0.121212	0.176871
Big data based organizational decisions	0.311111	0.363636	0.408163	0.484848	0.345575	0.275223	0.310436	0.34746	0.349338	0.312534	0.052525	0.097052	0.173737	0.044527	0.121212	0.076685
Meet increasing needs of smart products	0.288889	0.363636	0.367347	0.242424	0.343334	0.269708	0.281371	0.345351	0.333905	0.283829	0.074747	0.078458	0.046465	0.003711	0.121212	0.124923
Achieve organizational effectiveness and agility	0.4	0.363636	0.265306	0.212121	0.351968	0.269755	0.285059	0.336584	0.329934	0.265831	0.036364	0.134694	0.187879	0.09833	0.151515	0.053185
Develop smart services	0.222222	0.409091	0.428571	0.393939	0.340423	0.262822	0.294206	0.353454	0.352065	0.309191	0.186869	0.206349	0.171717	0.019481	0.015152	0.034632
Improve customer relationship management	0.222222	0.318182	0.244898	0.272727	0.327231	0.243946	0.277468	0.326431	0.329694	0.276524	0.09596	0.022676	0.050505	0.073284	0.045455	0.027829
Improve customer service experience	0.288889	0.363636	0.204082	0.212121	0.343334	0.248159	0.274327	0.328797	0.329934	0.2559	0.074747	0.084807	0.076768	0.159555	0.151515	0.00804
Optimum machine utilization	0.244444	0.318182	0.428571	0.393939	0.330361	0.266709	0.297683	0.340768	0.339326	0.309191	0.073737	0.184127	0.149495	0.11039	0.075758	0.034632
Prediction of future utilization for production	0.266667	0.318182	0.346939	0.272727	0.333205	0.264759	0.284488	0.336452	0.329694	0.288285	0.051515	0.080272	0.006061	0.028757	0.045455	0.074212
Standardization of production process	0.355556	0.409091	0.306122	0.242424	0.354492	0.271424	0.288593	0.346047	0.339355	0.278155	0.053535	0.049433	0.113131	0.102968	0.166667	0.063698
Allowance of decreased waste and environmental impact/ Sustainability	0.266667	0.454545	0.346939	0.212121	0.349334	0.264759	0.271182	0.352433	0.338715	0.275162	0.187879	0.080272	0.054545	0.107607	0.242424	0.134818

	45	22	49	33		Critical Value					Difference					
Row Labels	Africa	Asia	Europe	North Ame	Af-As	Af-Er	Af-NA	As-Er	As-Nr	Er_NA	Af-As	Af-Er	Af-NA	As-Er	As-Nr	Er_NA
Huge cost	0.12	0.153	0.285714	0.424242	0.253719	0.225584	0.276016	0.280327	0.291533	0.300657	0.033	0.165714	0.304242	0.132714	0.271242	0.138528
Data security	0.288889	0.227273	0.22449	0.424242	0.313148	0.251879	0.305814	0.300252	0.318343	0.292595	0.061616	0.064399	0.135354	0.002783	0.19697	0.199753
Lack of Industry 4.0 skills & knowhow	0.377778	0.318182	0.469388	0.484848	0.343346	0.283805	0.316184	0.341741	0.341906	0.314441	0.059596	0.09161	0.107071	0.151206	0.166667	0.015461
Unreliable internet connectivity	0.2	0.090909	0.102041	0.090909	0.239049	0.205914	0.21762	0.209694	0.206249	0.184893	0.109091	0.097959	0.109091	0.011132	0	0.011132
Employee's resistance to change	0.422222	0.272727	0.183673	0.212121	0.335893	0.257448	0.28626	0.3072	0.31163	0.251976	0.149495	0.238549	0.210101	0.089054	0.060606	0.028448
Unavailable infrastructure	0.2	0.227273	0.183673	0.212121	0.300286	0.227377	0.259548	0.293766	0.298395	0.251976	0.027273	0.016327	0.012121	0.043599	0.015152	0.028448
Future viability	0.177778	0.181818	0.22449	0.030303	0.279695	0.230546	0.179845	0.283919	0.239855	0.186347	0.00404	0.046712	0.147475	0.042672	0.151515	0.194187
Too little standardization	0.2	0.136364	0.204082	0.272727	0.263858	0.231717	0.273421	0.260271	0.271052	0.26996	0.063636	0.004082	0.072727	0.067718	0.136364	0.068646
Legal issues/ lack of governmental support and policies	0.155556	0.090909	0.204082	0.121212	0.228408	0.220723	0.219176	0.235083	0.215282	0.226124	0.064646	0.048526	0.034343	0.113173	0.030303	0.08287
Lack of global standards and data sharing protocols	0.155556	0.181818	0.244898	0.242424	0.275057	0.228705	0.257498	0.286944	0.286592	0.270159	0.026263	0.089342	0.086869	0.06308	0.060606	0.002474
Difficulty of integration of technology platforms	0.311111	0.409091	0.326531	0.30303	0.350844	0.268875	0.295359	0.34777	0.345768	0.291702	0.09798	0.01542	0.008081	0.08256	0.106061	0.0235
Decreasing job opportunities	0.177778	0.227273	0.142857	0.212121	0.296261	0.211931	0.25488	0.286207	0.298395	0.243121	0.049495	0.034921	0.034343	0.084416	0.015152	0.069264