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Preliminary Maturity Level Assessment of Industry 4.0 in the Context of Pakistani Industries †

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Abstract: The primary objective of this study is to evaluate the adaptability and inclination of industrial sectors of Pakistan with respect to Industry 4.0. A questionnaire with nine questions was developed and disseminated to 20 sampled industries. To analyze the variability in responses, a one-way analysis of variance test was used. The statistical analysis revealed that there is an awareness of the basic concept behind Industry 4.0 in Pakistani industries, but there is a reluctance to adopt digitization and to shift from conventional production systems. This study will be helpful and will provide a guide for new and already existing enterprises for achieving Industry 4.0 requisite attributes precisely.

Keywords: Industry 4.0; readiness; maturity; cyber–physical production systems

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1. Introduction

Developments in manufacturing technologies by introducing systems based on cyber–physical concepts, Internet of Things (IOTs), and artificial intelligence (AI) are considered as Industry 4.0. The concept features two main aspects: integration and interoperability [1,2]. Linked with several applications and software, Industry 4.0 enables sustainability in production and service [3,4]. Developed countries are creating their own version of Industry 4.0-related strategies like "China 2025" in China [5], "Industry 4.1J" in Japan [6], and "Advanced Manufacturing Partnership (AMP 2.0)" in the USA [7]. However, this concept is still in its embryological stages in developing countries, specifically Pakistan. There is considerably less access to modern technologies and a collective reluctance in adopting its application, as indicated by its global ranking on various indices. Therefore, an evaluation of the maturity of developing countries in adopting Industry 4.0 poses a significant challenge. Pakistan, for instance, ranks 110th out of 141 countries in terms of global competitiveness. According to Khan [8], there is a significant decline in growth of the textile industries of Pakistan, which will impact the Key Index, i.e., the GDP of Pakistan, which was 4.24% [9], as the share of the industrial sector in terms of GDP is 12.4% of whole GDP. To increase the GDP, the manufacturing industry should shift toward Industry 4.0 in terms of large- and small-scale manufacturing systems [10]. Industries are also facing a shortage of skilled workers and knowledge sets [11]. The logistic network of the country is also deficient compared with other neighboring countries like India, China, and Bangladesh [12]. To tackle this issue, the use a framework involving evaluating the readiness level of individual companies using maturity models. The term "maturity" denotes a "state of being complete, ready or perfect" and implies development. The established seriousness models are generally used as tools to assess and measure the inclination of an organization or a process [13]. Readiness models are exclusively designed to secure a first perspective and to enable the start of the development route [14]. These models are established by renowned expert firms worldwide and have proven effective in assessing the manufacturing sector. By utilizing such models, countries can gain insights into their current state and take necessary measures to embrace Industry 4.0 technologies and practices. Several countries have developed unique models to assess their Industry 4.0 state, including the IMPULS model by the German Association of Mechanical Engineers (VDMA), the Singapore Smart Industry 4.0 Readiness Index, and the Smart Manufacturing Readiness Model formed by the National Institute of Standards and Technology (NIST) in the United States of America. These models have been tailored to suit the specific situations and circumstances of technologically advanced nations. However, a challenge arises when applying these models in developing countries, as they have not been extensively utilized in such contexts [10]. These developed models are comprehensive, detailed, and resource-intensive. Thus, it is necessary to assess the preliminary maturity stage of Industry 4.0 in the manufacturing sector of Pakistan using the limited resources and a cost-effective way to provide a preliminary understanding of the adoption of Industry 4.0. A questionnaire was developed to frame close-ended questions related to the Industry 4.0 concept and its awareness, willingness, and maturity level. It will provide a basic understanding and conceptualization of the readiness level to implement Industry 4.0 in Pakistan's industrial sector.

2. Methodology

The current report is exploratory and not based on any previously developed framework and primarily emphasizes an evaluation of the industrial sector of Pakistan, as well as the profiling of industrial concepts. The outcome of this study will be helpful and will provide guidelines for the development of strategies in Pakistani industries in the future. Close-ended questions are considered the most suitable way to conduct qualitative research. First, a comprehensive literature review was conducted to obtain a clear understanding of the Industry 4.0 paradigm. To find a suitable model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises in Pakistan, the method in Figure 1 was adopted. It contains four steps to analyze the industrial sector of Pakistan [10]: the first step comprises the questionnaire development and its dissemination; the second step consists of data collection from industrial experts, top management, decision makers, and AI experts of the Pakistani industrial sector through a questionnaire; in the third step, the data are processed using statistical software; the last step consists of a data analysis, the findings, and the conclusions upon obtaining the answers and feedback.

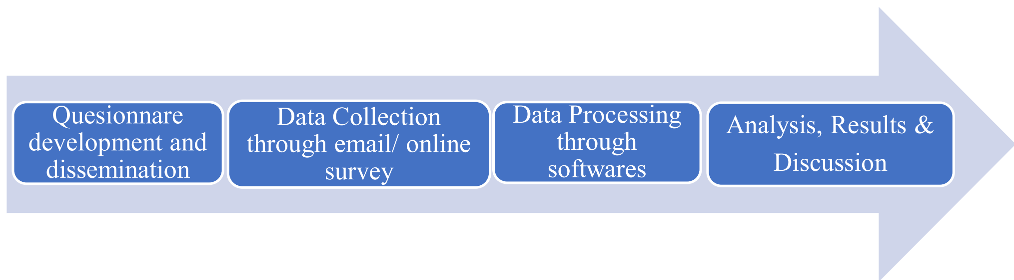

Figure 1. Steps adopted to analyze maturity and readiness.

2.1. Questionaire Development

The questions were in line with the major issues identified from the literature review and validated by the industrial and academic experts. The questionnaire consists of 9 questions, as given in Appendix A, with a complete set of data having the following three parts:

Part 1: Basic knowledge of Industry 4.0 (Questions 1–3);
Part 2: Readiness for Industry 4.0 (Questions 4–6);
Part 3: Maturity level (Questions 7–9).

2.2. Dissemination and Data Collection

In this step, an online survey was developed and disseminated through email, WhatsApp, and other social media platforms. The developed survey was filled out by industrial experts, production engineers, consultants, and top management from selected 20 industries. The sample size was calculated using random sampling (Equation (1)).

$$P = 1 - (1 - \left(\frac{1}{N}\right))n. \quad (1)$$

where n = sample size; N is the population size, which was 400; and P is the probability, which was 5% in this study.

The industries are categorized as the textile, automotive, and manufacturing industries, as tabulated in Table 1.

Table 1. List of companies.

Sr. no	Company Name	Sr. no	Company Name
1	Hattar Group of Industries, Haripur, Pakistan	11	Carriage Factory, Islamabad, Pakistan
2	HIT, Taxila, Pakistan	12	Macter International Limited, Karachi, Pakistan
3	Elektro Control Industries (Pvt.), Ltd. Islamabad, Pakistan	13	Rani & Company (Private) Limited, Karachi, Pakistan
4	Pothohar Industries Rolling Mills, Islamabad, Pakistan	14	International Polymer Industries (Pvt) Ltd., Islamabad, Pakistan
5	Dawn Electric Industries, Islamabad, Pakistan	15	The Indus Basin Company, Karachi, Pakistan
6	Faisalabad Textile Mills, Faisalabad, Pakistan	16	Heavy Mechanical complex, Taxila, Pakistan
7	Bestway Cement, Chakwal, Pakistan	17	Cherat Cement, Nowshera. Pakistan
8	Askari Fuels, Rawalpindi, Pakistan	18	POF Wah Cantt, Punjab, Pakitan
9	Auto Industry Chaklala, Rawalpindi, Pakistan	19	Wah Brass Mill, Wah Cantt, Pakistan
10	Poly Foils Pvt Ltd., Rawat, Pakistan	20	Coca Cola factories, Lahore, Pakistan

2.3. Data Processing

To process the data, Microsoft Excel was used to preprocess, compile, analyze, and visualize the responses. The collected data were analyzed to remove any blank entries and redundant data. Then, the data were compiled in such a way as to make it suitable for statistical analysis. The assembled data were modelled by amassing personal opinions about each variable into clusters to obtain a response rating distribution of these groups as a suitable means of reviewing the data.

2.4. Data Analysis

To investigate and assess deviations in the data, standard deviation (SD) is a useful tool in statistics. It is the distribution of a dataset compared with its normal value. Data points that are distant from the mean indicate a higher deviation within the dataset. As a result, the data become more dispersed, leading to an increased value for the standard deviation. An SD cannot be negative as it is calculated by squaring the parameter. Mean is the average of a certain set of observations. A one-way analysis of variance (ANOVA) was conducted to measure the inconsistency in the collected data. A p-value less than 0.05 depicts the significance of the data. A p-value of 0.003 was obtained in the comparison of data obtained directly from interviews and those obtained indirectly from mail.

3. Results and Analysis

In total, 150 responses were recorded and received from the 20 sampled industries. The average results of these responses are summarized in Table 2. The complete results regarding basic knowledge of, readiness/adaptability for, and level of understanding/maturity regarding Industry 4.0 were determined using a Microsoft Excel sheet and verified using SPSS 28.0.1; the overall average for the results is 1.9, as shown in Table 2. This means that the overall readiness/adaptability in the selected industries is below average. As far as awareness is concerned, the average score is 2.4, which means the bulk of industries in Pakistan are conscious of Industry 4.0 and only a few of them do not know about Industry 4.0. For example, cement manufacturing companies work manually via ordinary labor, as they work with ordinary methods and there are no digital manufacturing processes.

Table 2. Summary of averages for the results from the survey responses.

Question \ Customer	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	Average
Q 1	2	2	4	3	2	1	1	1	3	2	2	4	3	4	2	1	2	2	4	3	2.4
Q 2	1	1	2	1	2	1	1	2	2	1	1	2	1	2	3	2	1	1	2	1	1.5
Q 3	2	3	3	2	2	1	0	1	1	2	3	3	2	1	3	1	2	3	3	2	2
Q 4	3	1	2	2	1	2	1	2	1	3	1	2	2	3	2	1	3	1	2	2	1.85
Q 5	2	3	3	3	2	1	0	2	2	2	3	3	3	2	3	2	2	3	3	3	2.35
Q 6	1	2	2	4	2	1	0	1	6	1	2	2	4	2	2	1	1	2	2	4	2.1
Q 7	2	1	1	2	3	2	1	1	4	2	1	1	2	3	3	2	2	1	1	2	1.85
Q 8	1	1	2	1	2	2	0	2	3	1	1	2	1	1	4	4	1	1	2	1	1.65
Q 9	1	2	1	3	1	1	0	1	2	1	2	1	3	3	5	1	1	2	1	3	1.75
Average	1.6	1.7	2.2	2.3	1.8	1.3	0.4	1.4	2.6	1.6	1.7	2.2	2.3	2.33	3	1.6	1.6	1.7	2.2	2.3	1.9

Total number of questions = 9, number of respondents = 20, total score (rating) = 5, any data that were not known took a value of zero, 0 = least effective, 5 = most effective.

The commutative aggregate of the ratings of these three major categories are illustrated in Figures 2–4. It is depicted in Figure 1 that the number of peaks above average are more than below average, which means that most companies are aware of the basic idea of Industry 4.0, the suitability of Industry 4.0 technology for production, and that it is better than manual production systems. The rating for readiness for Industry 4.0 is shown in Figure 3. It can be noticed that the number of below-average peaks are greater than the number of above-average peaks, which clearly explains the lack of readiness of industries due to a preference for manual work rather than Industry 4.0 technology. Industries are assuming that conventional methods are better for manufacturing their products. Therefore, industries have less awareness about the efficiency of Industry 4.0 production processes, and they resist converting their conventional production systems into digital systems. The maturity levels of Industry 4.0 in selected industries are shown in Figure 4. It is evident that the number of below-average peaks are much greater than the number of above-average peaks, which depicts a lack of Industry 4.0 maturity for industries due to a greater adaptability to manual work than to Industry 4.0 technology. Industries assume that conventional methods are easier to use in manufacturing processes. Thus, industries are more adaptable to manual work, consider the quality of production through Industry 4.0 to be less, and believe that there are safety risks in the context of the modern paradigm.

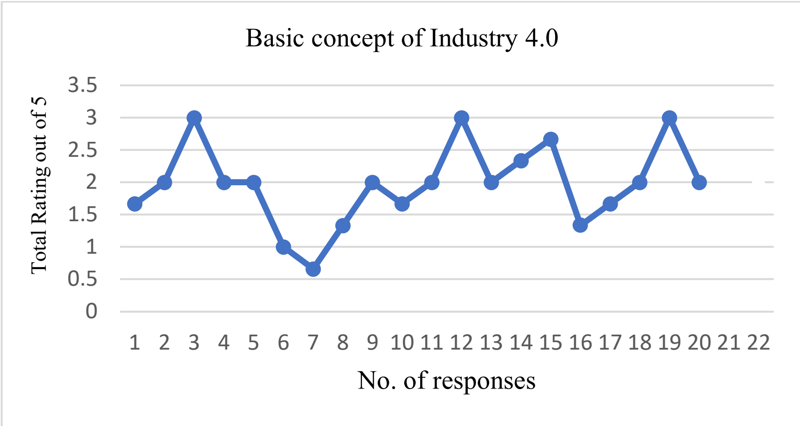

Figure 2. Basic concept of Industry 4.0 in Pakistan.

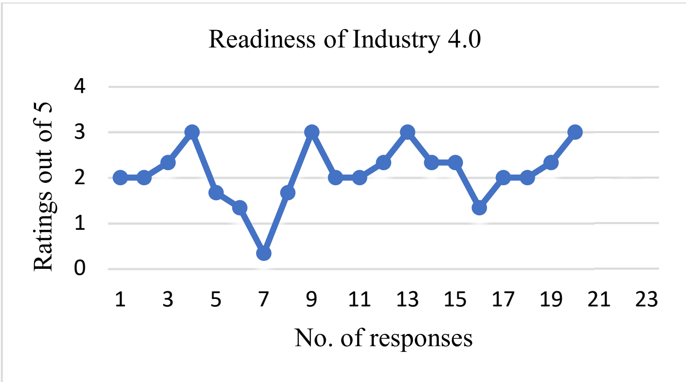

Figure 3. Readiness/adaptability.

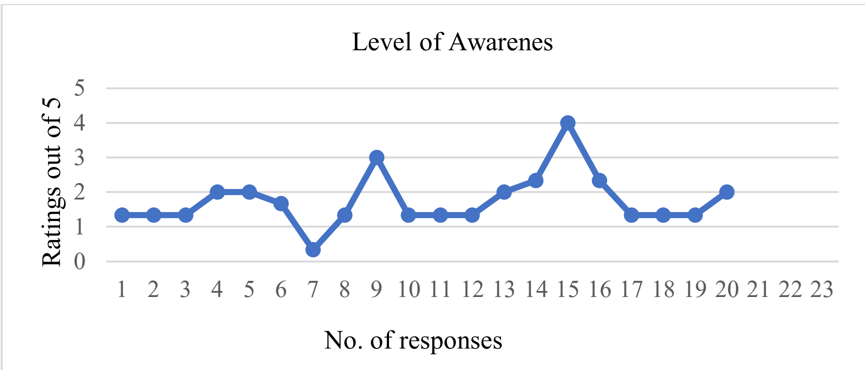

Figure 4. Maturity level of Industry 4.0.

A one-way analysis of variance (ANOVA) was carried out to assess the unevenness in data collected from industrial experts, production engineers, consultants, and top management. A *p*-value less than 0.05 depicts the significance of the data. The grouped data were modelled by amassing individual observations of a variable into groups, so that a response rating distribution of these groups was obtained. A variable was only significant when its f-stat was greater than 4 (>4) and its probability was less than 5% (<5%). Here, we can see that the variable under "within people", i.e., between treatments, is a major determinant in estimating Tukey's equal variances, having an f-stat of 20.4 and a probability of 0.001. Therefore, any variation in "between treatments" will cause a major variation in the dependent variable.

The result details are written in Table 3.

Table 3. ANOVA results.

	1	2	3	Total	
N	20	20	20	60	
$\sum X$	54	31.5	42	127.5	
Mean	2.4545	1.5	2	1.992	
$\sum X^2$	156	54.25	100	310.25	
Std.Dev.	1.0568	0.5916	0.8944	0.9449	
Source	**SS**		**df**	**f-Value**	***p*-Value**
Between treatments	9.7915		2	20.4	0.001
Within treatments	46.4545		61		
Total	56.2461		63		

4. Discussion

The results of this sectoral survey and its analysis reveal that the score for the first group in awareness of the basic concept is 1.96 out of 5 (40%), which is very low compared with the results of similar international industrial markets. The main reason behind this is the fact that management of main industrial sectors are significantly not related in terms of educational backgrounds and there is a loose arrangement in the job selection process. However, it also expresses that the respondents realize that Industry 4.0 technology is not suitable for their current production setups, as they feel more comfortable with manual work. These results correspond with those of with previous research [8]. The result for Group 2 is 2.1 out of 5 (42%). The readiness level is also below average. The main reason for this is that most industries prefer manual processing rather than digitization. The conventional methods are more suited for manufacturing the products. The result for maturity level (group 3) is 1.75 out of 5 (35%), which indicates that industries in Pakistan are not mature enough to embrace Industry 4.0, which corresponds with the outcomes of Hameed et al. [12]. Industries are adaptable to manual work, consider the quality of production through Industry 4.0 to be less, and believe that there are safety risks in the context of the modern paradigm. So, we can say that this maturity and readiness assessment research has critical value in the field of assessment of Industry 4.0 with regard to checking the fundamental knowledge, readiness, and maturity of Pakistani industries. Major stakeholders such as the Government of Pakistan and industrialists should take urgent measures to promote the use of this technology and to embrace the concept of Industry 4.0 in the manufacturing, hospital, and agriculture sectors as an increase in industry development means growth in the GDP of the country.

5. Conclusions

The motive behind this questionnaire-based survey was to assess the preliminary readiness and maturity level of Pakistan's industrial sectors with reference to Industry 4.0. It is concluded that the basic conceptualization of Industry 4.0 can be suitably checked using the designed questionnaire. Further, the distribution of responses in various industrial sectors such as the textile, automotive, and manufacturing industries also adds credibility. The questionnaire was validated using a statistical analysis. It was revealed that there is an awareness of the basic concept of Industry 4.0 across major Pakistani industries, but they are reluctant to adopt digitization and still prefer conventional production systems. A possible reason for this may be their better adaptability to conventional or manual technology and the low financial requirements. The current study provides a theoretical contribution to the subject in terms of assessments and has managerial implications as it can be used by top management involved in promoting the acceptance of Industry 4.0 processes. The findings of this research can be used for decision-making processes when converting conventional factories into smart manufacturing systems or when implementing Industry 4.0 processes.

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Appendix A. Questionnaire on Basic Knowledge, Readiness, and Maturity Level

Questions	Category	Detail	Rating				
			1	2	3	4	5
Q 1.	Concept of Industry 4.0	How much do you know about the fourth industrial revolution?					
Q 2.		How suitable is Industry 4.0 technology for production?					
Q 3.		Is one-command production suitable for production or manual work?					
Q 4.	Readiness of Industry 4.0 in Pakistan	Do you prefer to work manually or digitally?					
Q 5.		How appropriate are conventional methods of production for products?					
Q 6.		How much more efficient is Industry 4.0 than conventional methods?					
Q 7.	Maturity level of Industry 4.0	Which method makes work easier, digital or manual?					
Q 8.		What is the quality of production through Industry 4.0?					
Q 9.		Rate the safety risks in Industry 4.0.					

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