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Identifying Barriers of Implementing IoT in Manufacturing Industry using Analytical Hierarchy Process (AHP): A Bangladeshi Perspective

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ABSTRACT
Internet of Things (IoT) is considered as the core of the fourth industrial revolution commonly known as, Industry 4.0. This area has acquired a significant amount of attention in the last few years. IoT represents an image of the future internet and considered as an ecosystem of interconnected devices while holding the ability to transfer data. It creates a network without requiring any kind of human interventions. IoT is proven to be profitable in the areas where rapid development and product quality are the important factors for ensuring financial feasibility in the long run. Manufacturing industry can be considered as a vital implementing field, and the Industrial Internet of Things (IIoT) has converted it digitally with concepts like big data, artificial intelligence (AI), and machine learning. However, IoT implementation is still considered as a challenge due to the presence of many difficulties. Therefore, this paper worked with an objective to identify and investigate the barriers in the implementation of IoT systems in the manufacturing industry from a Bangladeshi perspective. Thirteen (13) challenges and barriers for successful IoT implementation in the manufacturing industry of Bangladesh were identified from the literature review and professionals' opinions. Consequently, the Analytical Hierarchy Process (AHP) approaches were applied to analyze the challenges in IoT implementation in the manufacturing industry of Bangladesh. Key barriers of successful IoT implementation were identified and ranked according to their significance. The result of this study may help professionals and policymakers in removing the barriers for successful IoT implementation in the manufacturing industry. Finally, comparative analysis, conclusions and future research directions are presented.

Keywords: Internet of Things (IoT), Industry 4.0, Analytical Hierarchy Process (AHP)

1. Introduction

Internet of Things (IoT) is considered as a revolution in the technology industry for getting maximized output with minimized resource utilization. It can be defined as a new technology paradigm intended as a global network of machines and devices capable of interacting with each other. IoT is acknowledged as one of the most significant areas of future technology and is gaining vast attention from a wide range of industries [1, 2]. Internet of Things (IoT) is crafting a massive system of billions or trillions of "Things" connecting with one another, are going to face many technical and functional challenges in the upcoming days [3, 4]. Industrial IoT or, IIoT technologies are considered as the prime enablers behind the implementation of smart manufacturing concepts and digitalization of manufacturing factories [5].

Manufacturing industries around the world are targeting to progress in effectiveness through the convergence with innovative technologies in order to secure a new growth engine [6]. Industrial IoT authorizes contemporary businesses to implement the latest data-driven approaches while managing the global pressure with reduced efforts [7]. Many manufacturing industries have already started to implement IoT into factories and supply chain operations. Since some firms are yet exploring the market and planning out projects, others are ready to initiate full-fledged digital solutions [8-10]. In most manufacturing industries from developing countries, it is yet to be accepted and implemented widely [11].

For a developing country like Bangladesh, IoT is also not being accepted and implemented widely among the local manufacturing industries. IoT is being implemented in the global manufacturing industries considering the huge benefits associated with it [12]. Thus, IoT is being implemented in the manufacturing industries for the digitalization of factories, facility management, maintenance management, inventory management, plant security management, quality management, supply chain optimization, packaging optimization, and performing many other industrial activities more efficiently and safely [13]. IoT is considered as one of the most significant features behind the adaptation of fourth industrial revolution for the developing countries in upcoming days. So, the implementation of IoT in manufacturing industries still remains a huge challenge for these countries [14-16].

So, it is highly significant to identify and investigate the potential barriers in the implementation of IoT in the manufacturing industries of Bangladesh. This study has been carried out to obtain the following objectives-–

i. Identifying potential barriers for implementing IoT in the manufacturing industries;
ii. Ranking of identified barriers to recognize major challenges for implementing IoT.

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Here, AHP methodology has been used to solve this multi-criteria decision making (MCDM) problem by using pairwise comparison [17]. Related data analysis and discussions were done to rank the potential barriers.

2. Barriers of IoT implementation in manufacturing

Thirteen potential barriers of Internet of Things (IoT) implementation were identified from literature reviews. After that, these identified barriers were endorsed through industry experts' inputs and opinions. These identified potential barriers behind successful IoT implementation in manufacturing are explained below:

2.1 Substandard infrastructural facilities (B1)

Implementation of internet of things (IoT) involves standard infrastructural facilities to assist and operate the interconnected devices efficiently. Poor infrastructural facilities and power problems are identified as major barriers behind IoT implementation [18, 19].

2.2 Poor network coverages and technical facilities (B2)

Poor network coverage is the one of the key barriers in IoT implementation [20]. With limited access and coverage of internet connection across the country, it becomes a significant barrier for IoT implementation in remote manufacturing organizations [21].

2.3 Scarcity of talented and expert personnel (B3)

Implementation of IoT requires professionals who are expert in developing and implementing digital solutions [22]. In order to obtain the integrated system design for IoT implementation, high technical and functional skills are essential [23, 24].

2.4 High implementation cost (B4)

IoT implementation requires incorporation of highly expensive sensors and different actuators [25]. Thus, the associated higher implementation cost can be considered as a significant barrier [26].

2.5 Poor flexibility in existing system (B4)

As most of the existing manufacturing facilities do not possess flexible system, implementation of IoT is difficult due to their existing complexity in the system [26]. Thus, it becomes critical to provide IoT solutions that can be integrated with the existing infrastructure [27].

2.6 Lack of standards and reference architecture (B5)

The development of competent IoT architecture throughout a supply chain involves various technological features and architectures. Since the idea of adopting industry 4.0 and IoT is almost new, there is absence of standardization and referencing architectures [28-30].

2.7 Employment disruption (B7)

Most of the current manual jobs in the manufacturing industries can be automated through IoT implementation and will result in employment disruption and job losses [31]. Residual manufacturing jobs will require more technical skills and knowledge [32].

2.8 High power consumption (B8)

IoT devices generally require a significant amount of power supply. Considerable power consumption reduces the effectiveness of the entire IoT ecosystem [33]. Increased number of sensors for real time data acquisition will obviously increase in the energy requirement for the manufacturing system and overall supply chain [34].

2.9 High operating and maintenance costs (B9)

IoT implementation prerequisites efficient technical and infrastructural support. So, high operational and maintenance costs are associated with it [1, 26]. There also exists technological risks related to high financial losses. So, these factors act as a crucial barrier [35, 36].

2.10 Cybersecurity and privacy concerns (B10)

Cybersecurity plays an important part in any successful distribution of networks at small or large scale. There are enormous numbers of interconnected devices that generally share data among themselves to help the IoT system work efficiently and effectively. So, while implementing IoT, cybersecurity and related privacy issues are considered with utmost significance [37-39].

2.11 Poor data storage and device management (B11)

To implement the concept of smart and digital factories, multiple number of data capturing devices will be required. This will result into huge increase in the amount of real time data collection. Problems associated with poor data storage and device management works as an obstacle for IoT operations [40, 41].

2.12 Adaptation with organizational changes (B12)

For successful IoT implementation in the manufacturing industry, organizations will have to upgrade and adopt with new business and infrastructural models. This requires external and internal integration of the existing systems for any organization [42]. Due to poor flexibility in the existing systems, employees and owners are generally psychologically biased with the existing systems and prone to adapt with the organizational and process changes [43].

2.13 Legal and regulatory compliance issues (B13)

Regulatory compliances are the goals that organizations pursue to obtain through their efforts to ensure the awareness for compliances and regulatory policies. Sometimes these legal and regulatory compliances act as a hindrance in implementing new system replacing the previous one [44, 45].

3. Solution Methodology

For prioritizing, ranking, identification of relationships between factors there are several MCDM

(Multi-Criteria Decision Making) techniques present in the literature. Some examples are AHP, BWM, VIKOR, TOPSIS etc. For this study, AHP has been selected to prioritize the barriers of IoT implementation. AHP is an MCDM technique first introduced at the Wharton School of Business which allows decision-makers to model a complex problem in a hierarchical structure showing the correlation between the alternatives, categories, sub-categories and objectives [46]. For comparing the result from AHP, TOPSIS approach was used.

The motivations behind selection of AHP and TOPSIS are as follows:

- Enormous amount of criteria and sub-criteria can be handled [47];
- Objective and subjective judgments can be accommodated and priority among them can be determined [48];
- Tangible as well as intangible criteria which are derived from judgments of experienced individuals can be applied [49];
- Problems can be structured into criteria and sub-criteria levels which leads to a systematic solution of problems for helping quality managers and stakeholders [46].

For these reasons, AHP has been considered as the methodology to find weights of the barriers of IoT adoption for Bangladeshi manufacturing industries.
Following three steps are required for AHP analysis [49]:

- Selection of a purpose for the research i.e. to prioritize the barriers of to IoT implementation from the perspective of manufacturing industries.
- Making pair-wise comparisons between selected barriers using Saaty's nine-point scale.
- Calculating the weights for ranking the barriers using the geometric mean. The consistency index (CI) and the consistency ratio (CR) are also needed to ensure consistency in assessment process.

Table 1 Preference scaling for pair-wise comparison.

1	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Extreme or absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

The flowchart for this study is given in the figure below:

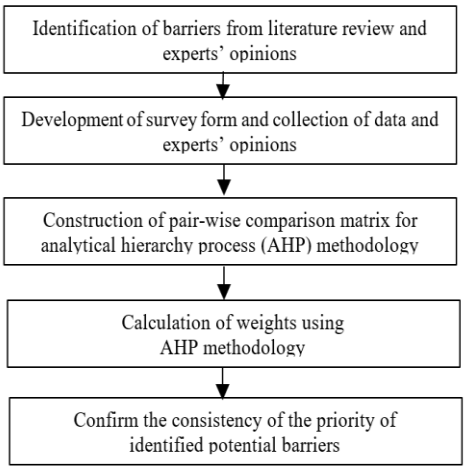

Fig. 1 Study methodology flowchart

4. Data analysis and result

At first, previous literatures were reviewed thoroughly to search and identify for potential barriers behind successful IoT implementation in the manufacturing industry. Thirteen barriers were identified from the related existing literatures. Furthermore, experts were also consulted for the validation of the barriers as literature from Bangladeshi perspective is not that common. In this study, a total number of 10 experts participated in the survey. All of them possess working experiences in the Bangladeshi manufacturing industry from different sectors. As a result, complete picture of whole Bangladeshi manufacturing industry culture has been reflected from a non-biased point of view. The experts made pair-wise comparison of the barriers showing the relative importance of one barrier with another using the Satty scale. The Table 3 showing pairwise comparison matrix for expert-1 and Table 4 showing calculated average weight and ranking using AHP methodology from industry experts' opinions are given below:

Table 3 Pair-wise comparison based on first decision-maker opinion

Expert-1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	Weight	Rank
B1	1	1/7	1/7	1/5	1/9	1/3	1/3	1	1/3	1/9	1/5	1/9	1/3	0.013071	12
B2	7	1	1	3	1/3	5	5	7	5	1/3	3	1/3	5	0.100043	4
B3	7	1	1	3	1/3	5	5	7	5	1/3	3	1/3	5	0.100043	4
B4	5	1/3	1/3	1	1/5	3	3	5	3	1/5	1	1/5	3	0.053726	6
B5	9	3	3	5	1	7	7	9	7	1	5	1	7	0.187768	1
B6	3	1/5	1/5	1/3	1/7	1	1	3	1	1/7	1/3	1/7	1	0.025754	8
B7	3	1/5	1/5	1/3	1/7	1	1	3	1	1/7	1/3	1/7	1	0.025754	8
B8	1	1/7	1/7	1/5	1/9	1/3	1/3	1	1/3	1/9	1/5	1/9	1/3	0.013071	12
B9	3	1/5	1/5	1/3	1/7	1	1	3	1	1/7	1/3	1/7	1	0.025754	8
B10	9	3	3	5	1	7	7	9	7	1	5	1	7	0.187768	1
B11	5	1/3	1/3	1	1/5	3	3	5	3	1/5	1	1/5	3	0.053726	6
B12	9	3	3	5	1	7	7	9	7	1	5	1	7	0.187768	1
B13	3	1/5	1/5	1/3	1/7	1	1	3	1	1/7	1/3	1/7	1	0.025754	8
C.I.= 0.048756, C.R.=0.031254															

Table 4 Calculated average weight using AHP methodology from experts' opinions

Potential barriers	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5	Exp-6	Exp-7	Exp-8	Exp-9	Exp-10	Average	Rank
Substandard infrastructural facilities (B1)	0.013	0.078	0.086	0.086	0.233	0.026	0.072	0.097	0.101	0.039	0.083	5
Poor network coverage and technical facilities (B2)	0.100	0.016	0.086	0.195	0.109	0.063	0.149	0.202	0.101	0.086	0.111	3
Scarcity in talented and expert personnel (B3)	0.100	0.173	0.029	0.033	0.109	0.164	0.033	0.045	0.101	0.039	0.083	6
High implementation cost (B4)	0.054	0.034	0.086	0.086	0.109	0.063	0.149	0.045	0.101	0.039	0.076	7
Poor flexibility in the existing system (B5)	0.188	0.173	0.086	0.086	0.109	0.063	0.072	0.097	0.101	0.178	0.115	2
Lack of standards and reference architecture (B6)	0.026	0.078	0.086	0.033	0.047	0.164	0.016	0.045	0.022	0.019	0.054	9
Employment disruption (B7)	0.026	0.078	0.086	0.033	0.047	0.063	0.033	0.021	0.045	0.086	0.052	10
High power consumption (B8)	0.013	0.016	0.086	0.033	0.047	0.015	0.033	0.012	0.022	0.011	0.029	13
High operating and maintenance costs (B9)	0.026	0.034	0.086	0.086	0.109	0.063	0.072	0.021	0.022	0.039	0.056	8
Cybersecurity and privacy concerns (B10)	0.188	0.078	0.086	0.033	0.021	0.063	0.016	0.202	0.101	0.178	0.097	4
Poor data storage and device management (B11)	0.054	0.034	0.086	0.016	0.021	0.063	0.072	0.021	0.012	0.019	0.040	12
Adaptation to organizational process changes (B12)	0.188	0.173	0.086	0.195	0.021	0.164	0.266	0.097	0.227	0.178	0.159	1
Legal and regulatory compliance issues (B13)	0.026	0.034	0.029	0.086	0.021	0.026	0.016	0.097	0.045	0.086	0.046	11

Weights calculated by TOPSIS gives a slightly different result. The first barrier is "Poor network coverage and technological facilities" which is in the thirds position according to AHP. In the second position there is "Poor flexibility in the existing system" same as AHP. "High implementation cost" is on the third position but it is in seventh calculated by AHP. A comparison between the ranks of the barriers are shown in the figure 2 below.

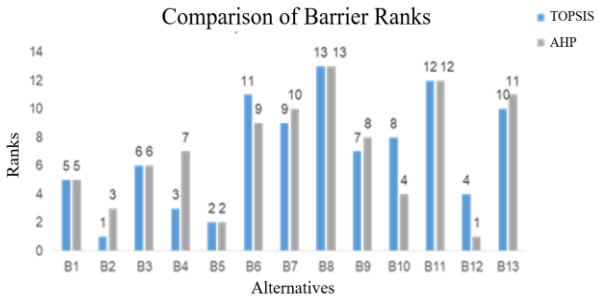

Fig. 2 Comparison of barrier ranks

5. Discussion on findings

According to the AHP methodology analysis for potential barrier identification behind successful IoT implementation in the manufacturing industries of Bangladesh, "Adaptation to organizational and process changes" has secured the first position weighting 0.159. Most of the Bangladeshi industry follows traditional rules where resistance to change has an enormous effect on decision making. Also, there is no effective change management in the industries. "Poor flexibility in the existing system" holds the second position in the list. Applying new technology needs an environment where the whole environment can adapt to the technological changes that have been made. But unfortunately, this type of flexibility was of little consideration while designing the existing manufacturing systems in Bangladesh. "Poor network coverage and technological facilities" is at the third position followed by "Cybersecurity and privacy concerns" at fourth and "Substandard infrastructural facilities" at fifth. As many Bangladeshi industries are situated in remote areas for taking advantage of lower infrastructural development costs, infrastructure facilities are substandard and network coverages are poor. Again lack of cybersecurity experts in this country creates a fear of losing data if IoT is implemented in the manufacturing industry. In the sixth position, there is "Scarcity in talented and expert personnel". Brain drain has always been a huge concern for Bangladesh and to eradicate this problem the industries should offer attractive packages for talented and expert people. Arranging related competition in technical and engineering universities can help in finding talented personnel from relevant areas. "High implementation cost" which is at the seventh position followed by "High operating and maintenance costs" at the eighth position is also a concern for industries in a developing country like Bangladesh as a high return period is associated with IoT implementation. For any investment, the return period plays a vital role. So, the government can offer incentive packages and tax waivers for organizations to implement IoT to boost up productivity and efficiency. "Lack of standards and reference architecture" holds the ninth position and "Employment disruption and redundant human resources" comes at the tenth. IoT implementation will result in lower demand for unskilled and non-technical workers in the industries. On the other hand, there will be a higher demand for expert human resources from relevant fields of technology. But in the context of Bangladesh, availability of these two (unskilled non-technical workers and expert technical human resources) are just opposite. At the eleventh position, there is "Legal and regulatory compliance issues". The government can play a significant role in making legislative policies easier and convenient for the industries. "Insufficient data storage and poor device management" is at the second last position and "Energy efficiency and power consumption" is at the last. Investment in the power sector in recent years has increased electricity production considerably. So, these are the sequences of potential barriers behind successful IoT implementation in the manufacturing industries considering their significance and impacts on the perspective of Bangladesh.

6. Conclusion

IoT implementation in the manufacturing industries is considered a challenge due to the existence of many difficulties and potential barriers. In this paper, we identified and analyzed the challenges and barriers behind successful IoT implementation in the manufacturing industries of Bangladesh. Analysis using AHP methodology was performed for thirteen potential barriers behind successful IoT implementation and ranking was done according to their significance. Adaptation to organizational process changes, poor flexibility in the existing system, poor network coverage, and cybersecurity with data privacy concerns have been identified and ranked as the most significant potential

barriers behind successful IoT implementation in the manufacturing industries. Policymakers and related professionals should take the necessary steps accordingly to eradicate these hurdles for successful IoT implementation.

7. Limitations and scope for future works

This study is a preliminary endeavor to analyze the challenges and barriers behind successful IoT implementation in the manufacturing industry of Bangladesh. Therefore, identified potential barriers in this study are not be the only barriers for implementing IoT. In upcoming researches, some more barriers may appear. Our research incorporated professionals' opinions during data collection to investigate the challenges behind successful IoT implementation. Our research used AHP methodology and this possesses some limitations. Another significant limitation of this study is that, the results may be influenced due to the selection of domain specified experts for data collection. In future studies, fuzzy AHP, ISM or, other MCDM techniques may be used apart from AHP and TOPSIS approaches to avoid biases.

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