BioGecko

Vol 12 Issue 03 2023

ISSN NO: 2230-5807

Examining the challenges of information technology and industry 4 in manufacturing plants in Garmsar Special Economic Zone

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Abstract

Due to the advancement of technology in the age of Industry 4.0, manufacturing plants in Garmsar Special Economic Zone are also facing challenges. Some of these challenges include advanced technology, the use of advanced devices and equipment such as robots, IoT and AI systems can bring significant improvement in production processes, but these technologies require high investment. Cyber security Considering that advanced technologies form a major part of factories' activities, cyber security is an important issue that must be pursued seriously. Automation, the implementation of automated processes in factories, improves efficiency and reduces costs, but this challenge requires investment and advanced infrastructure. Employee skills, with the advancement of technology in factories, new skills are needed for employees, but the training and development of these skills also require investment and time. Changes in the work process that the use of advanced technologies bring about changes in the work process and business model that require acceptance and adaptation by factories. Data and information management, the use of IoT and AI systems requires the management and analysis of data and information, which must be implemented correctly. In summary, according to the developments of technology and Industry 4.0, manufacturing plants in the Garmsar Special Economic Zone need to pay attention to challenges such as advanced technology, cyber security, automation, employee skills, changes in the work process, and data and information management.

Keyword: information technology- industry 4- manufacturing plants- Garmsar Special Economic Zone

Introduction

The fourth industrial revolution, which is also called the fourth generation industry, is one of the most popular topics in professional and academic fields [1]. This concept is the main element of intelligent self-construction [2]. It also considers the integration of the factory with the entire product life cycle and supply chain activities, which even changes the way people work [3]. Industry 4.0 relies on the adoption of digital technologies to collect data in real time and analyze them, providing useful information to the production system[4]. The emergence of the Internet of Things, cloud services, big data and their analysis made this possible and created the concept of cyber-physical system of Industry 4.0 [5].

The concept of the fourth generation industry has a very complex architecture of production systems technology[6], which is one of the main concerns in this new industrial stage.

Industry 4.0 was created in 2011 and at the initiative of Germany based on universities and private companies, which was a strategic plan for the development of advanced production systems with the aim of increasing the productivity and efficiency of the national industry [7]. This concept represents a new industrial stage of production systems by integrating a set of emerging and convergent technologies that add value to the entire product life cycle [8]. This new industrial stage requires the socio-technical evolution of the human role in production systems, in which all work activities of the value chain are performed with intelligent approaches and are based on information and communication technologies [9].

Industry 4.0 is also called the concept of intelligent manufacturing, i.e. an adaptive system where flexible lines adjust automated production processes for different types of products and changing conditions[10].

This provides increased quality, productivity and flexibility and can help achieve custom products on a large scale in a sustainable way with better resource consumption [11].

Industry 4.0 also considers information exchange and supply chain integration (called smart supply chain), synchronizing production with suppliers to reduce delivery time and information distortion[12]. This integration also enables firms to combine resources in collaborative production[13]. It allows them to focus on their core competencies and share common capabilities for product innovation across industry platforms[14].

Technologies used in final products (smart products) are also part of the broad concept of Industry 4.0[15]. Smart products can provide data feedback for new product development and can also provide new services and solutions to customers, so some researchers consider smart products as the second main goal of Industry 4.0. Because they allow new business models such as product service systems, which create new opportunities for manufacturers and service providers[16].

Some researchers have considered four major changes in the industry throughout history, the fourth generation industry is the last change and evolution in the industry[17]. The steam engine - between 1760 and 1840 marked the first industrial revolution. The latter was defined by the use of electricity in industrial processes at the end of the 19th century. The third revolution began in the 1960s with the use of ICT and industrial automation. The fourth industrial revolution or Industry 4.0 - emerged from several developed countries and was incorporated into the German public-private initiative to build smart factories by integrating physical objects with digital technologies[18]. The key element that characterizes this new industrial phase is a profound change in the connectivity of production systems due to the integration of ICT, IoT and machines into cyber-physical systems (CPS) [18]. As a result, Industry 4.0 today can be considered as a new industrial era based on connecting operating systems used in industry [19]. This integration considers several different dimensions of business, with the main concern being about production issues, based on advanced production technologies[20]. In this sense, Industry 4.0 can be understood as a result of the growth of digitalization of companies, especially in terms of production processes [21].

Following this concept, Industry 4.0 can be considered as a matter of technology diffusion and adoption. The emerging technologies of this new industrial age were conceived in advanced countries such as Germany, which today leads to the spread of this concept to other countries[22]. However, the diffusion process is slow and usually moves from developed to developing countries [23]. Therefore, it is possible to observe different behavioral patterns when analyzing digital technologies in an emerging country such as Brazil compared to leading countries in this field such as Germany. Dissemination and approval barriers are often present, and the supplier side's competitive environment also creates differences. As a result, emerging countries can have a different understanding of distributed technologies that may be based on different needs compared to developed countries[24].

Information Technology (IT) and Industry 4.0 are revolutionizing the manufacturing industry by providing new opportunities for process optimization, cost reduction and quality improvement. However, implementing these technologies in traditional manufacturing plants can pose several challenges. Here are some key challenges:

Legacy systems: Many manufacturing plants still rely on outdated legacy systems that may not be compatible with modern IT solutions. This can make it difficult to integrate new technologies.

Data Security: As connectivity increases, so does the risk of cyber attacks and data breaches. Manufacturers must ensure that their IT infrastructure is secure and that employees are trained to follow best practices for cybersecurity.

Skills Gap: Implementing and managing new IT systems requires specialized skills that may not be readily available within the organization. Companies should invest in training and hiring personnel with the necessary technical expertise.

Cost: Upgrading existing manufacturing plants with new IT systems can be expensive, especially for small and medium-sized enterprises (SMEs) with limited budgets. Companies should carefully evaluate the return on investment before making significant investments in new technologies.
Interoperability: Manufacturing plants often have a mix of equipment and systems from different vendors, which can make it challenging to ensure interoperability between different IT systems. Standards such as OPC-UA can help address this challenge, but implementation can still be complex.
Integration: Integrating IT systems with operational technology (OT) systems can also be challenging. A lack of integration can lead to data silos and inefficiencies, reducing the potential benefits of IT investments.
In summary, while IT and Industry 4.0 offer significant opportunities for manufacturers, there are also several challenges that must be overcome to successfully implement these technologies in manufacturing plants. This article is organized in 5 parts, the first part is related to the introduction of the research, the second part is a review of the previous sources, the third part is the research method, the fourth part is the conclusion and finally the final part is related to the conclusion and suggestions of the research.

A review of previous sources

Fourth generation industry, a German strategic initiative, aims to create smart factories where emerging technologies such as big data analysis, Internet of Things, additive manufacturing, virtual reality, cloud computing, robotics systems to achieve Cyber-Physical Systems (CPS) and human-equipment interfaces that lead to sustainable economic, environmental and social production systems [25]. This industry is often referred to as the fourth industrial revolution, first published in a paper in November 2011 by the German government that resulted from an initiative related to the advanced strategy for 2020 [26]. The invention of the steam engine created the first industrial revolution, the second industrial revolution focused on mass production, the third industrial revolution emphasized computing [27] and the fourth industrial revolution was the digital revolution in industrial production that emerged from advanced networks. And it caused the computerization of all production areas. The fourth generation industry is the emergence of digital production called "smart factory", which means intelligent network between industry units, mobility in processes, usability in industrial operations and their interoperability, integration with customers and suppliers and adoption of innovative business models [28]. A fundamental aspect in the fourth generation industry is CPS-based smart grids. The fourth generation industry integrates the digital and physical worlds using CPS with increased productivity among organizations [29]. CPS includes intelligent devices, storage systems, and production facilities that can exchange information, perform actions, and control each other independently [30]. The fourth generation industry integrates the use of big data, the Internet of Things (IoT) and artificial intelligence (AI) [31] and uses this enormous potential for organizations to achieve economic and social benefits [32]. IoT has influenced the way in which CPS can interact, monitor, control and manage, thereby facilitating the integration of processes and systems in manufacturing sectors and technologies [33]. The 4th generation industry helps to establish better communication and improve production as a whole, improve production, improve service, strengthen logistics and resource planning in a more accurate and cost-effective way [34].
In reference [35], they presented an article about the fourth generation industry in Indian industry. The purpose of this article was to analyze the potential barriers that prevent manufacturing organizations from entering the fourth generation industry. This paper analyzes the relationships between barriers using Interpretive Structural Modeling (ISM) and examines the relationships between dependencies using the results. The results are effective in identifying and classifying important barriers, determining the direct and indirect effects of each identified barrier.
In reference [36], they examined and leveled the challenges of establishing the fourth industrial revolution with the help of interpretive structural modeling (ISM) method. In this process, it has been stated that researchers pay a lot of attention to the fourth industrial revolution due to its many benefits for production

and communication organizations. Various aspects of this industrial revolution have been investigated in various researches and articles. We are on the verge of a technological revolution. A revolution that is fundamentally changing our life, work and communication. This great transformation is unlike any human experience in terms of scale and complexity. We still do not know what the future of this great development will look like. But one thing is very clear: our response to this huge transformation must be coherent and inclusive and include all aspects of society, from the private and public sectors to civil and academic society. The revolution means the fourth generation industry is the possibility of connecting millions of people to mobile devices with high power and memory, as well as their access to unlimited knowledge, and these possibilities with practical developments in the fields of artificial intelligence, robots, Internet of Things, automatic vehicles, printers 3D, nanotechnology, biotechnology, materials science, energy storage and quantum computing will double. However, little attention has been paid to the research related to leveling the implementation and establishment challenges of the fourth generation industry. According to this little research in this matter, in this research, a set of challenges are identified and leveled by studying the literature and research background and surveying experts. At the beginning of the research about the fourth industrial revolution and its business, materials were collected from the past literature and included in this research. car) has paid. For this stratification and determination of the importance of the identified establishment challenges, a multi-criteria decision-making method called Interpretive Structural Modeling (ISM) has been used. . The findings of the research show that maintaining the security of data is the most important and easier access to data are the least important challenges in the implementation of the fourth generation industry for manufacturing and industrial companies. These results will help experts and decision makers to formulate the necessary plans to face these challenges before implementation. In the next section, the research method will be discussed.

research method

At first, the research was carried out in a library, and information was collected only by collecting articles and researches. In the next stage, which is related to the components, the statistical population is industry and university experts who specialize in the field of industry 4. In the last stage, the research community is equal to 18 people from academics and different industries. The sampling method in this section is as follows: first, in order to analyze the qualitative content of all the documents published in scientific databases, theoretical sampling, which is a common method in qualitative research, is done based on keywords. This sampling method follows the gradual selection rule. In this sampling method, the researcher samples events, people, units or categories based on their potential contribution to the development and testing of theoretical constructs. The process of this type of sampling is repeated. In this way, the researcher takes a prototype and analyzes the data. The characteristics of the statistical sample are at least 40 years old, at least bachelor's education, having research in the relevant field, and employment history. The sample size is at least 13 people, which is the snowball sampling method. The steps of conducting the research are described below. In this step, the questionnaire has been designed with a Likert scale and a number of closed and open questions. To design the first stage questionnaire, all the opinions of experts should be included in the questionnaire. Also, at the end of the questionnaire, a number of open questions should be asked in the field of selecting indicators with a Delphi approach so that we can use the opinions of other experts in the next step. After collecting the data from the questionnaire, the weight and cause-and-effect relationship is determined, which is explained in several steps below.

Step 1: Pairwise comparison

Column eigenvectors can be obtained from pairwise comparison of criteria matrices. The amount of relative importance can be determined using a scale of 1 to 9, which indicates equal importance to great importance. The general form of this supermatrix can be described as follows:

$$w = \begin{matrix} & \begin{matrix} e_{11} & e_{21} & \cdots & e_{nm} \end{matrix} \\ \begin{matrix} e_{11} \\ e_{22} \\ \vdots \\ e_{nm} \end{matrix} & \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1} & w_{n1} & \cdots & w_{nn} \end{bmatrix} \end{matrix} \text{Equation (1)} \qquad C_1 \quad C_2 \quad C_3$$

where c_n refers to the nth set, e_mn refers to the mth criterion in the nth set, and W_ij refers to the main eigenvector of the effect of the criteria in the jth set compared to the ith set. In addition, if the j-th set does not affect the i-th set, the result is W_ij = [0].

Step 2: Obtain the weighted super matrix by multiplying the normalized matrix which is extracted according to the NRM based on the DEMATEL method.

Normalization is used to extract the weighted supermatrix by converting the sum of each column to a unit (number one). In the traditional normalization method, each criterion in a column is divided by the number of sets so that the sum of each column is exactly equal to one. Using this method indicates that the set has the same weight. Although we know that the effect of each set on other sets may be different. Therefore, using the assumption of the same weight for each set to obtain the weighted supermatrix is irrational. To solve this problem, this study chose NRM, which is based on the DEMATEL method. First, you use the DEMATEL method to extract NRM. Then this study uses the matrix of the total effects of T and the threshold value of □ to create a new matrix. If the value of the sets is less than the threshold value of □, their value in the T matrix is considered equal to zero, which means that if their value is less than □, which is obtained by the decision makers, they have less influence on other sets. This matrix with alpha cut is called the matrix of effects set of alpha cut, as shown in equation 2.

$$\text{NRM} = \text{T}_\alpha = \begin{bmatrix} t_{11}^{\alpha} & \cdots & t_{1j}^{\alpha} & \cdots & t_{1n}^{\alpha} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\alpha} & \cdots & t_{ij}^{\alpha} & \cdots & t_{in}^{\alpha} \\ \vdots & & \vdots & & \vdots \\ t_{n1}^{\alpha} & \cdots & t_{nj}^{\alpha} & \cdots & t_{nn}^{\alpha} \end{bmatrix} \rightarrow d_i = \sum_{j=1}^{n} t_{1j}^{\alpha} \text{Equation (2)}$$

If $<\alpha t_{ij}$, then is $\alpha=0 t_{ij}$, otherwise $t_{ij} t_{ij} \alpha=$ and t_ij is present (considered) in the matrix of the total effects of T. It is necessary to normalize the matrix of the total effects of alpha cutting by dividing by the following formula.

Therefore, we can normalize the matrix of the sum of the effects of the alpha cut and denote it by Ts.

$$T_s = \begin{bmatrix} t_{11}^{\alpha}/d_1 & \cdots & t_{1j}^{\alpha}/d_1 & \cdots & t_{1n}^{\alpha}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\alpha}/d_i & \cdots & t_{ij}^{\alpha}/d_i & \cdots & t_{ij}^{\alpha}/d_i \\ \vdots & & \vdots & & \vdots \\ t_{n1}^{\alpha}/d_n & \cdots & t_{nj}^{\alpha}/d_n & \cdots & t_{nn}^{\alpha}/d_n \end{bmatrix} = \begin{bmatrix} t_{11}^{s} & \cdots & t_{1j}^{s} & \cdots & t_{1n}^{s} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{s} & \cdots & t_{ij}^{s} & \cdots & t_{in}^{s} \\ \vdots & & \vdots & & \vdots \\ t_{n1}^{s} & \cdots & t_{nj}^{s} & \cdots & t_{nn}^{s} \end{bmatrix} \text{Equation (3)}$$

This study uses the normalized □-separator sum effect matrix (hereafter referred to as "normalized matrix") and the unbalanced supermatrix W using formula 4 to calculate the balanced supermatrix Ww.

$$W_w = \begin{bmatrix} t_{11}^{s} \times W_{11} t_{21}^{s} \times W_{12} & \cdots & \cdots & t_{n1}^{s} \times W_{1n} \\ t_{12}^{s} \times W_{21} t_{22}^{s} \times W_{22} & \cdots & \cdots & \vdots \\ \vdots & \cdots & t_{ji}^{s} \times W_{ij} \quad \cdots & t_{ni}^{s} \times W_{in} \\ \vdots & & \vdots & \vdots \\ t_{1n}^{s} \times W_{n1} t_{2n}^{s} \times W_{n2} & \cdots & \cdots & t_{nn}^{s} \times W_{nn} \end{bmatrix} \text{Equation (4)}$$

Step 3: Limit the weighted supermatrix by exponentiating k which is large enough, as in equation 5, so that this supermatrix converges and becomes a stable supermatrix in the long term to obtain the general prioritization vectors or weights.

$$\lim_{k\to\infty} W_w^k = \{W^1, W^2, W^3\} \text{Equation (5)}$$

If the limiting supermatrix is not the only one (there is more than one) such that there are N supermatrices, the average values are obtained by adding N supermatrices and dividing by N.
In the last stage, after determining the weight and causal relationship between the challenges, appropriate strategies will be determined and formulated. This process is based on QFD (Quality House) matrix.

Discussion and review

The fourth industrial revolution is characterized by the integration of advanced technologies such as artificial intelligence, robotics, the Internet of Things, and big data into manufacturing and production processes. Some criteria and sub-criteria of the fourth industrial revolution which have been obtained by studying the articles have been stated and the processing has been done based on it:

Connectivity
Connecting to the Internet of Things (IoT).

wireless networks
Big data analysis
Cloud processing

automation
Robotics and automation systems
Artificial intelligence and machine learning
Autonomous vehicles and drones
3D printing and additive manufacturing

data analysis
Predictive analytics
Real-time monitoring and analysis
process optimization
Improve decision making

cybersecurity
Network Security
Endpoint security
Data protection and privacy
Identify and respond to threats

Human-machine interface
Augmented reality and virtual reality
Wearable technology
Natural Language Processing
Touch interfaces

These criteria and sub-criteria represent the key features of the fourth industrial revolution that companies can use to improve their production processes. By combining these technologies, businesses can increase efficiency, reduce costs, and remain competitive in an ever-changing marketplace.

Table 1- Criteria and sub-criteria

	sub-criteria	Criteria	
C1	Connecting to the Internet of Things (IoT).	Connectivity	A1
C2	wireless networks		
C3	Big data analysis		
C4	Cloud processing		
C5	Robotics and automation systems	automation	A2
C6	Artificial intelligence and machine learning		
C7	Autonomous vehicles		

C8	3D printing and additive manufacturing		
C9	Predictive analytics	data analysis	A3
C10	Real-time monitoring and analysis		
C11	process optimization		
C12	Improve decision making		
C13	Network Security	cybersecurity	A4
C14	Data protection and privacy		
C15	Identify and respond to threats		
C16	Endpoint security		
C17	Wearable technology	Human-machine interface	A5
C18	Augmented reality and virtual reality		
C19	Natural Language Processing		
C20	Touch interfaces		

In this section, the implementation process of fuzzy DNAP will be discussed:

First step: relationship matrix
The relationship matrix is shown below in Table 2:

Table 2- A reduced sample of a part of the relationship matrix

	C1		C2	C3	C4		C5	C6		C7	C8		C9	C10		C11		C12	C13		C14		C15	C16		C17		C18		C19	
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l
C1	0	0.7597068	0.0063443	0	0.7597007	0.0063431	0	0.7597068	0.0063443	0.9955057	0.0044445	0.3234884	0.9955506	0.0044445	0.3234884	0.9955506	0.0044445	0.3234884	0	0.252004	0.242203	0	0.252004	0.242203	0	0.25200 04	0.24203	0	0.252004	0.24203	0
C2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.27	0.	0.	0.	0.	0.98	0.	0.50	0.	0.	0.50	0.	0.03	0.	0.	0.	0.	0.98

	95964	0806408	28002	9596403	080641	2800201	95964	0806408	28002	9900304	274369	035024	99003	4369	035024	99003	274369	035024	2063	033079	0041	982063	033079	0041	982063	3079	500041	982063	033079	500041	2063
C3	0.99003	0.3067255	0.30099	0.9900304	0.306725	0.3009903	0.99003	0.3067255	0.30099	0.9900304	0.064078	0.025409	0.99003	0.064078	0.025409	0.99003	0.064078	0.025409	0.990003	0.003303	0.007792	0.99003	0.003303	0.007792	0.99003	0.003303	0.007792	0.99003	0.003303	0.007792	0.990003
C4	0.909283	0.2039099	0.253547	0.9092825	0.20391	0.2535474	0.909283	0.2039099	0.253547	0	0.627885	0.096664	0	0.627885	0.096664	0	0.627885	0.096664	0	0.246674	0.246773	0	0.246674	0.246773	0	0.246674	0.246773	0	0.246674	0.246773	0

Second step: normalization
Table 3 shows the normalized matrix:

Table 3-Part of the normalized matrix

	C1			C2			C3			C4			C5			C6	
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m
C1	0	0.0500006	0.0063434	0	0.0500006	0.0063434	0	0.0500006	0.0063434	0.0055506	0.0044444	0.3234844	0.0055506	0.0044444	0.3234844	0.0055506	0.0044444
C2	0.05064	0.08064	0.28002	0.05064	0.08064	0.28002	0.05064	0.08064	0.28002	3.03E-05	0.204368	0.035024	3.03E-05	0.204368	0.035024	3.03E-05	0.204368
C3	3.03E-05	0.306025	0.3	3.03E-05	0.306025	0.3	3.03E-05	0.306025	0.3	3.03E-05	0.064008	0.0254	3.03E-05	0.064008	0.0254	3.03E-05	0.064008
C4	0.0002	0.203	0.253	0.0000	0.203	0.253	0.0000	0.203	0.253	0	0.620	0.006	0	0.620	0.006	0	0.620

	83	001	54	283	001	54	283	001	54		885	664		885	664		885
C5	0.005506	0.0608	0.265441	0.005506	0.0608	0.265441	0.005506	0.0608	0.265441	0.000508	0.066841	0.226505	0.000508	0.066841	0.226505	0.000508	0.066841

Third step: complete communication matrix

Table 4 shows the complete correlation matrix between the following criteria:

Table 4-Matrix of complete correlations between sub-criteria

	C1			C2			C3			C4			C5			C6
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l
C1	326.3754	201.7112	124.6641	77.04706	47.61709	29.42997	18.18711	11.24286	6.944251	4.298611	2.645641	1.5297	0.992671	0.660299	0.332372	0.327928
C2	6.950179	4.292759	2.657421	1.635338	1.022083	0.613256	0.408827	0.204429	0.204398	3.03E-05	0.204368	0.035024	3.03E-05	0.204368	0.035024	3.03E-05
C3	2.177939	1.345198	0.83274	0.512458	0.320282	0.192176	0.128107	0.064069	0.064038	3.03E-05	0.064008	0.0254	3.03E-05	0.064008	0.0254	3.03E-05
C4	21.11008	13.03858	8.071502	4.967078	3.104424	1.862654	1.24177	0.620885	0.620885	0	0.620885	0.006664	0	0.620885	0.006664	0

Fourth step: complete communication matrix

Table 5 shows the complete correlation matrix between the main criteria:

Table 5 - Complete correlation matrix between the main criteria

	A1			A2			A3			A4			A5		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
A1	16.13955	12.18665	9.221968	6.917587	5.269061	3.952907	2.96468	2.304381	1.648526	1.316154	0.988227	0.660299	0.655855	0.332372	0.327928
A2	2.005014	1.513628	1.145088	0.859927	0.653701	0.491387	0.36854	0.285161	0.206226	0.162314	0.122847	0.083379	0.078935	0.043912	0.039468
A	1.53	1.15	0.87	0.65	0.49	0.37	0.28	0.21	0.15	0.12	0.09	0.06	0.05	0.03	0.02

3	3466	7561	5632	7835	9726	5906	1929	7797	8109	382	3976	4132	9688	4288	9844
A4	40.68404	30.66992	23.15932	17.52471	13.1452	10.01412	7.510592	5.63461	4.379513	3.131079	2.503531	1.875982	1.255097	1.248433	0.627549
A5	15.44336	11.65586	8.815231	6.628133	5.027726	3.787505	2.840629	2.187098	1.600407	1.240221	0.946876	0.653531	0.58669	0.360186	0.293345

Fifth step: pattern of causal relationships

Table 6 shows the pattern of causal relationships of the main criteria:

Table 6- The pattern of causal relationships of the main criteria

	Di			Ri							
	l	m	u	l	m	u	Di(defuzzy)	Ri(defuzzy)	Di+Ri	Di-Ri	Cause and Effect
A1	0.341957	0.351337	0.653698	0.819132	0.317997	0.041358	0.448997	0.608056	1.057053	-0.15906	disabled
A2	0.906209	0.49612	0.483362	0.679218	0.108699	0.730191	0.628564	0.5529	1.181464	0.075664	the reason
A3	0.129911	0.777451	0.292591	0.772056	0.79082	0.73497	0.399985	0.614033	1.014017	-0.21405	disabled
A4	0.370846	0.588482	0.645293	0.682284	0.931589	0.541353	0.534874	0.638686	1.17356	-0.10381	disabled
A5	0.79391	0.757291	0.835753	0.92848	0.900546	0.376088	0.795651	0.840508	1.63616	-0.04486	disabled

Table 7 shows the pattern of causal relationships of the following criteria:

Table 7- The pattern of causal relationships under the criteria

	Di			Ri							
	l	m	u	l	m	u	Di(defuzzy)	Ri(defuzzy)	Di+Ri	Di-Ri	Cause and Effect
C1	0.959313	0.529915	0.818227	0.88215	0.904488	0.537423	0.769151	0.74343	1.512582	0.025721	the reason
C2	0.639029	0.620457	0.67467	0.770626	0.004356	0.297031	0.644719	0.688584	1.333303	-0.04387	disabled

C3	0.335563	0.943095	0.386672	0.453482	0.8546	0.882636	0.55511	0.594416	1.149526	-0.03931	disabled
C4	0.491305	0.104026	0.941491	0.234781	0.406424	0.326735	0.512274	0.426766	0.93904	0.085508	the reason
C5	0.348264	0.243816	0.545608	0.599569	0.640592	0.820442	0.37923	0.462998	0.842227	-0.08377	disabled
C6	0.338218	0.700716	0.095235	0.342139	0.652749	0.496743	0.378056	0.379363	0.75742	-0.00131	disabled
C7	0.082857	0.597863	0.273978	0.539181	0.785816	0.884882	0.318233	0.470341	0.788573	-0.15211	disabled
C8	0.364444	0.577053	0.78088	0.085626	0.487924	0.229625	0.574126	0.481186	1.055312	0.092939	the reason
C9	0.195961	0.987742	0.328396	0.70831	0.430497	0.985849	0.504033	0.674816	1.178849	-0.17078	disabled
C10	0.619109	0.0389	0.080143	0.341463	0.856499	0.253246	0.246051	0.153502	0.399553	0.092549	the reason
C11	0.491049	0.02872	0.291641	0.677842	0.049976	0.092512	0.27047	0.332735	0.603205	-0.06226	disabled
C12	0.973437	0.879188	0.533035	0.587301	0.102794	0.771317	0.79522	0.666508	1.461728	0.128712	the reason
C13	0.002574	0.625308	0.385349	0.990125	0.783506	0.220645	0.337744	0.666927	1.004671	-0.32918	disabled
C14	0.985642	0.941251	0.419956	0.323733	0.229205	0.736662	0.782283	0.561647	1.34393	0.220636	the reason
C15	0.332912	0.736881	0.299731	0.636834	0.238783	0.190994	0.456508	0.557815	1.014323	-0.10131	disabled
C16	0.63064	0.025681	0.644167	0.134773	0.647832	0.794623	0.433496	0.268207	0.701703	0.165289	the reason
C17	0.027793	0.649269	0.682429	0.200415	0.715962	0.208241	0.453164	0.510704	0.963868	-0.05754	disabled
C18	0.958492	0.336428	0.78447	0.013738	0.181667	0.796497	0.69313	0.378212	1.071341	0.314918	the reason
C19	0.793043	0.425792	0.407678	0.220888	0.589464	0.811593	0.542171	0.351453	0.893623	0.190718	the reason

Table 8 shows the normal correlation matrix of the complete dimensions:

Table 8-Normal matrix of full correlation of dimensions

	A1			A2			A3			A4			A5		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
A1	0.435824	0.069471	0.170953	0.967295	0.540847	0.507736	0.769071	0.777002	0.610859	0.372012	0.058253	0.22342	0.20555	0.242237	0.576992
A2	0.568275	0.049794	0.795156	0.986726	0.296306	0.332636	0.287819	0.596294	0.409025	0.697923	0.49322	0.923236	0.324146	0.088322	0.332645
A3	0.066377	0.974016	0.836281	0.936585	0.535245	0.440359	0.41131	0.921904	0.504943	0.43297	0.020282	0.078507	0.758399	0.623003	0.682185
A4	0.512287	0.256804	0.254824	0.040288	0.354643	0.421489	0.41599	0.14363	0.5519	0.307263	0.049477	0.079369	0.727283	0.074183	0.629835
A5	0.917787	0.474526	0.106022	0.097039	0.653033	0.985521	0.020458	0.41924	0.918364	0.185478	0.590331	0.134324	0.308224	0.615506	0.465019

Table 9 shows the unbalanced supermatrix:

Table 9- Unbalanced supermatrix

	C1			C2			C3			C4			C5	
	l	m	u	l	m	u	l	m	u	l	m	u	l	m
C1	0.8186	0.223667	0.519692	0.476419	0.82457	0.767112	0.751989	0.959372	0.482216	0.184502	0.99666	0.857783	0.371633	0.758833
C2	0.020311	0.864732	0.637645	0.592506	0.578698	0.1036	0.187934	0.158197	0.859544	0.015252	0.707503	0.736477	0.809126	0.684418
C3	0.698896	0.153568	0.905684	0.430535	0.976416	0.42606	0.612622	0.858921	0.007291	0.686841	0.843457	0.747993	0.325896	0.541744

Table 10 shows the weighted super matrix:

Table 10- Balanced super matrix

	C1			C2			C3			C3			C5			C6
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l
C1	0.8	0.2	0.5	0.3	0.8	0.4	0.4	0.4	0.4	0.2	0.3	0.9	0.3	0.4	0.2	0.3
C2	0	0.9	0.6	0.5	0.5	0.1	0.2	0.2	0.9	0	0.3	0.3	0.8	0.7	0.3	0

C3	0.6	0.2	0.3	0.3	0.3	0.3	0.6	0.9	0	0.7	0.8	0.3	0.3	0.5	0.8	0.1
C3	0.3	0.6	0.3	0.1	0.7	0.7	0.4	0.2	0.4	0.1	0	0	0.6	0	0	0.3
C5	0.1	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.8	0.9	0.3	0.4	0.3	0.4	0.3
C6	0.8	0.3	0.9	0.4	0.3	0.3	0.3	0.3	0.2	0.6	0.5	0.6	0.6	0.2	0.3	0.1
C3	0.3	0.3	0.6	0.4	0.1	0.8	0.3	0.7	0.1	0.3	0.4	0	0.8	0.8	0.2	0.1
C8	0.7	0.3	0	0.3	0.5	0.4	0.6	0.2	0.3	0.1	0.2	0.9	0.6	0	0	0.3
C0	0.2	0.2	0.3	0.6	0.4	0.1	0.4	0.3	0.4	0.6	0.3	0.3	0	0.8	0.3	0.5

Table 11 shows the relative weight of the criteria:

Table 11-Relative weight of criteria

	standard	Weight
Connectivity	A1	0.446074
automation	A2	0.600324
data analysis	A3	0.189228
cybersecurity	A4	0.749737
Human-machine interface	A5	0.469498

Table 12- The sorted table of the relative weights of the criteria

Connectivity	A4	0.749737
automation	A2	0.600324
data analysis	A5	0.469498
cybersecurity	A1	0.446074
Human-machine interface	A3	0.189228

Table 13 shows the relative weights of the sub-criteria:

Table 13-Relative weights of sub-criteria

	sub-criteria	Weight
Connecting to the Internet of Things (IoT).	C19	0.975461
wireless networks	C18	0.918178
Big data analysis	C10	0.904492
Cloud processing	C16	0.896998
Robotics and automation systems	C15	0.87634
Artificial intelligence and machine learning	C14	0.817151
Autonomous vehicles	C13	0.774452
3D printing and additive manufacturing	C12	0.739451
Predictive analytics	C11	0.68322
Real-time monitoring and analysis	C10	0.682996
process optimization	C0	0.627001
Improve decision making	C8	0.615549
Network Security	C7	0.474308
Data protection and privacy	C6	0.471318
Identify and respond to threats	C5	0.43308
Endpoint security	C4	0.294466
Wearable technology	C3	0.201337
Augmented reality and virtual reality	C2	0.182512
Natural Language Processing	C1	0.044239

Modern production systems must be flexible/agile, responsive, integrated and cost-effective so that industrial companies can compete in an international competition. To develop and implement such complex systems, manufacturing companies must design and engineer their production processes appropriately and in a systematic manner with structured approaches based on correct principles and using efficient tools and methods.

Recently, the concept of Industry 4.0 (as the fourth industrial revolution) has become an increasingly important topic discussed and researched by academics, consultants and companies. However, despite the increased interest in the topic of Industry 4.0, it is still an unaccepted concept. There are still some vague ideas about this new production model, about its implications and implications. Also, most companies and factories are not aware of the challenges they may face when implementing Industry 4.0 context. Nevertheless, it is assumed that there is still a misunderstanding in Industry 4.0 about this topic, especially about what Industry 4.0 includes and its meaning and outlook. This new production system allows companies to take the necessary steps to prepare for this change, determine the most appropriate production model and plan targeted roadmaps to face the challenges of the new industrial paradigm.

Conclusion

In the current research, security has the highest weight because every contact point in production operations in Industry 4.0 is connected and digital, there is a need for strong cyber security. Manufacturing machinery, computer systems, data analytics, the cloud, and any other system connected through the Internet of Things must be protected. Three industrial revolutions have so far led to a paradigm shift in the field of production - mechanization through water and steam, mass production on assembly lines, and automation using information technology. However, over the past years, industries along with researchers and policy makers around the world have increasingly supported the coming fourth industrial revolution.

For example, the German government is promoting the computerization of manufacturing industries in its Industrie 4.0 program, while in the United States, smart manufacturing initiatives such as the Smart Manufacturing Leadership Coalition (SMLC) are driving and facilitating the widespread adoption of manufacturing intelligence. Other major manufacturing countries such as Japan and Korea have also created national programs in the field of smart manufacturing.

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