Human Empowerment by Industry 5.0 in Digital Era: Analysis of Enablers

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Abstract In modern digital era, technology has dominated in all sectors of society. In manufacturing sectors, technology development has been divided into different time zones (Industry 1.0–4.0). These industrial upheavals have highly focused on technology applications. But modern challenges of customization, personalization and technology upgrading can only be done by human involvement. These modern challenges have led to new industrial revolution called "Industry 5.0," which emphasizes on technology advancement with human empowerment. In this research paper, authors have studied the enablers, which help in execution of Industry 5.0 in Indian manufacturing sector. Eight enablers have been distinguished by literature review and specialist's supposition. By using total interpretative structural modeling (TISM) technique, authors have studied the relationship between these enablers. Authors have developed a diagraph to show structural relationship between different enablers influencing implementation of Industry 5.0 in Indian manufacturing sector.

Keywords Industry 5.0 · Human empowerment · Enablers · TISM

1 Introduction

The term "Industry 5.0" was initially coined by Michael Rada in 2015 in his article "From Virtual to Physical." Industry 5.0 emphasis on empowering the human being specially the customers through fulfilling their personalizing and customized needs [19]. This technology stresses on automation with co-existence of human [4]. Chronologically, Industry 5.0 has followed Industry 4.0, all technologies of later will be an asset for I5.0 (Table 1). After going through four revolutions over a period of more than two centuries, these revolutions made a significant technical development (Fig. 1). Latest running industrial revolution, "Industry 4.0" incorporates various technologies such as "Big data analytics," "autonomous robotics," "the industrial

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Table 1 Chronology of industrial revolutions

Industrial revolutions	Description
Industry 1.0	The methodology of industry 5.0 evolved from the late eighteenth century when water and steam-powered machines were made for mass production of goods thereby removing the barrier of serving limited number of customers and lead to the expansion of business and was referred as the era of industry 1.0
Industry 2.0	The starting of the twentieth century gave rise to the next industrial upheaval, which came into limelight because of the production of machines running on electricity. These machines not only reduced the human effort but they were also easy to operate and were better than machines operated on steam and water as they were not resource hungry
Industry 3.0	With the more advancements in the electronic industry, automation in production and manufacturing sector promoted to a new level as many new electrical devices came into existence such as transistors, PLC's and integrated circuits automated the machines which substantially reduced human labor, increased pace, improved accuracy and in fact full substitution of human body. This level of automation was referred to as Industry 3.0
Industry 4.0	The blast in the web and media transmission industry in the late 1990s took the automation to a new level when the connection and exchange of information were done in totally different ways as compared with earlier ones. Cyber Physical System was one property that enabled us to merge the physical world with the virtual one where machines became smarter enough to communicate with each other without any physical or geographical barrier and is known as Industry 4.0
Industry 5.0	This era of industrial upheaval attempts to take the Industry 4.0 to a new milestone by integrating humans and machines in the smart factory. It will also enable the implementation of critical factors such as mass customization and personalization. It will also enhance the skills of the workers and improve their knowledge about the manufacturing processes

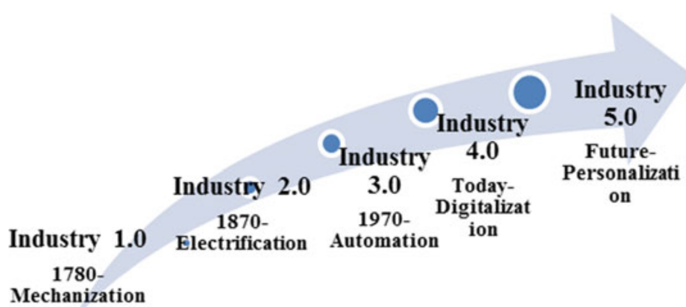

Fig. 1 Industrial development phases (Industry 1.0–Industry 5.0)

internet of things," "simulation," "system integration," "cyber security," "cyber physical system," "the cloud," "additive manufacturing" and "augmented reality" [11, 12]. But there are many issues with these technologies like loss of job, issues of autonomy and investment scarcity. Industry 5.0 works with all these technologies with human involvement. Industry 5.0 allows staying competitive in global market because it can provide higher efficiency, cost reduction, mass individualization, and safe factories with more human empowerment. Section 2 discusses the related literature. Section 3 discusses the research methodology and its discussion. Section 4 is Discussion and conclusion.

2 Literature Review

Industry 4.0 implementation investment with different other challenges push it to a slow implementation [5]. Industry 5.0 is the totality of the circles of economy wherein the completely programmed creation process depends on the counterfeit keenness and the web make new machines without the human support [1]. Sanders et al. [22] stated that Industry 5.0 essentially impacts the creation condition with radical changes in the execution of tasks. Industry 5.0 empowers ongoing arranging of creation plans, alongside unique self-enhancement. Demir et al. [4] discussed the issues of human–robot coworking from organizational and human perspective. There are various issues in coworking of human and robots like legal, regulatory, psychological, social, and ethical. Various enablers of Industry 5.0 have been summarized with related references in Table 2.

3 Research Methodology and Application

Total Interpretative structural Modeling Technique (TISM) is the procedure that changes indistinct and ineffectively verbalized models of system, which is into unmistakable, very much characterized models, which is helpful for some research purposes. Khurana et al. [9] used TISM for analyzing the critical factors of sustainable-oriented innovation for Indian manufacturing MSMEs. TISM is an interactive management technique, which helps look into research groups as well as research scholars in dealing with complex issues. It is also used for distinguishing and condensing relationship among explicit factors, which characterize a problem or an issue. Research methodology has been graphically summarized in Fig. 2. The application of TISM has been discussed from Tables 3, 4, 5, 6, 7, 8, 9 and 10.

"A": Connection from section i to section j but not segment j to segment i

"V": Connection from section j to section i but not segment i to segment j

Table 2 Enablers of Industry 5.0

Enablers of Industry 5.0	Description	References
Exoskeleton	These are the devices and equipment human can wear on body to overcome fatigue and exhaust. Some exoskeletons may be driven by motor and actuators to reduce human efforts	[18, 24–26]
Block chain-enabled Fog computing	Blockchain technology provides extreme security feature. Information saves in blocks and blocks are connected to each other by unique id number (UID)	[16, 17, 21]
IOT Data Interoperability	From Industry 4.0 we found that big data analysis helps in data analysis received from various IoT devices to achieve the mass customization faster	[11, 12, 14, 15, 23]
Intelligent autonomation	Robots that can directly interact to human by using safety features assured by human in them	[2, 28, 29]
Personalized delivery system	Drones are devices used in sudden inspection. These devices can also be used to transfer low weight material from one palace to another palace	[3, 6, 7]
Manufacturing traceability	Shop floor trackers are devices used to track the real-time production. They help to link the sales and production department along with buffer with efficient use of resources and reduced wastage	[13, 27]
Mixed reality	Mixed reality is the outcome that is received when we integrate the physical world with the digital world. It is the evolution that will involve the role of human, environment and computer interaction	[8, 10, 20]

"X": Connection between both direction, section i to section j and section j to section i

"0" (zero): No connection in both direction.

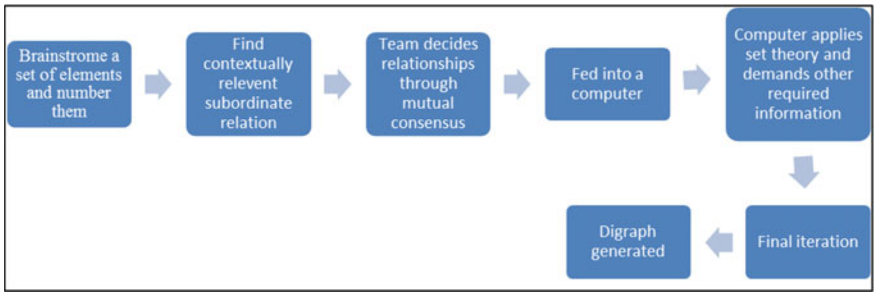

Fig. 2 The steps of research methodology of TISM

Table 3 Symbols and assigned values

Symbol	'V'	'A'	'X'	'O'
For (*i*, *j*) cell	1	0	1	0
For (*j*, *i*) cell	0	1	1	0

Table 4 Structural self-interaction matrix (SSIM) of critical factors

Variable	EL.8	EL.7	EL.6	EL.5	EL.4	EL.3	EL.2	EL.1
EL.1	V	V	X	V	V	V	X	X
EL.2	V	0	A	X	A	0	X	
EL.3	0	0	0	0	X	X		
EL.4	X	V	A	V	X			
EL.5	A	V	A	X				
EL.6	V	V	X					
EL.7	A	X						
EL.8	X							

EL.1—Virtual training, **EL.2**—Exoskeleton, **EL.3**—Block chain enabled Fog computing, **EL.4**—IOT Data Interoperability, **EL.5**—Intelligent autonomation, **EL.6**—Mixed reality technologies, **EL.7**—Personalized delivery system, **EL.8**—Manufacturing traceability, **EL.**—Enabler

Table 5 Initial reachability matrix

Enablers code	EL.8	EL.7	EL.6	EL.5	EL.4	EL.3	EL.2	EL.1
EL.1	1	1	1	1	1	1	1	1
EL.2	1	1	0	0	1	0	0	1
EL.3	0	0	1	1	0	0	0	0
EL.4	0	1	1	1	1	0	1	1
EL.5	0	1	0	0	1	0	1	0
EL.6	1	1	0	1	1	1	1	1
EL.7	0	0	0	0	0	0	1	0
EL.8	0	0	0	1	1	0	1	1

Table 6 Final reachability matrix

Enablers code	EL.8	EL.7	EL.6	EL.5	EL.4	EL.3	EL.2	EL.1
EL.1	1	1	1	1	1	1	1	1
EL.2	1	1	1*	1*	1	1*	1*	1
EL.3	0	1*	1	1	1*	0	1*	1*
EL.4	1*	1	1	1	1	0	1	1
EL.5	1*	1	0	0	1	0	1	1*
EL.6	1	1	1*	1	1	1	1	1
EL.7	0	0	0	0	0	0	1	0
EL.8	0	1*	1*	1	1	0	1	1

*To develop the final reachability matrix, transitivity check is applied on the initial reachability matrix following the transitivity rule as mentioned in methodology. In this final reachability matrix dependence power and driving power are obtained for each challenge represented by row and column respectively

Table 7 Level partitioning level 1

S. No.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 4, 5, 6	1, 2, 4, 5, 6	
2	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 5, 6, 8	1, 2, 3, 4, 5, 6, 8	
3	2, 3, 4, 5, 7, 8	1, 2, 3, 4, 6, 8	2, 3, 4, 8	
4	1, 2, 3, 4, 5, 7, 8	1, 2, 3, 4, 6, 8	1, 2, 3, 4, 8	
5	1, 2, 5, 7, 8	1, 2, 3, 4, 5, 6, 8	1, 2, 5, 8	
6	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 6	1, 2, 6	
7	7	1, 2, 3, 4, 5, 6, 7, 8	7	One
8	2, 3, 4, 5, 7, 8	1, 2, 3, 4, 5, 6, 8	2, 3, 4, 5, 8	

Table 8 Level partitioning level 2

S. No.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 8	1, 2, 4, 5, 6	1, 2, 4, 5, 6	
2	1, 2, 3, 4, 5, 6, 8	1, 2, 3, 4, 5, 6, 8	1, 2, 3, 4, 5, 6, 8	Second
3	2, 3, 4, 5, 8	1, 2, 3, 4, 6, 8	2, 3, 4, 8	
4	1, 2, 3, 4, 5, 8	1, 2, 3, 4, 6, 8	1, 2, 3, 4, 8	
5	1, 2, 5, 8	1, 2, 3, 4, 5, 6, 8	1, 2, 5, 8	Second
6	1, 2, 3, 4, 5, 6, 8	1, 2, 6	1, 2, 6	
8	2, 3, 4, 5, 8	1, 2, 3, 4, 5, 6, 8	2, 3, 4, 5, 8	Second

Table 9 Level partitioning level 3

S. No.	Reachability set	Antecedent set	Intersection set	Level
1	1, 3, 4, 6	1, 4, 6	1, 4, 6	
3	3, 4	1, 3, 4, 6	3, 4	Third
4	1, 3, 4	1, 3, 4, 6	1, 3, 4	Third
6	1, 3, 4, 6	1, 6	1, 6	

Table 10 Level partitioning level 4

S. No.	Reachability set	Antecedent set	Intersection set	Level
1	1, 6	1, 6	1, 6	Fourth
6	1, 6	1, 6	1, 6	Fourth

4 Discussion and Conclusion

In the current research paper, authors have identified eight enablers, which help in implementing Industry 5.0 in the manufacturing sector, from literature review and expert opinions. Further authors have used TISM technique for establishing the structural relationship between these enablers. From the TISM analysis, authors observed the interrelationship between the enablers of Industry 5.0. Virtual training (EL1) and mixed reality technologies (EL6) train the manpower and helps to improve the efficiency of block chain enabled fog computing (EL3) and IOT data interoperability (EL4). By Block chain-enabled Fog computing (EL3), the data gathered by different IOT devices can be analyzed and stored more securely. These enablers further connect and enable exoskeleton (EL2), intelligent autonomation (EL5) and manufacturing traceability (EL8). These enablers ultimately help in meeting modern challenge of personalized product development and customized delivery system (EL7) (Fig. 3). This will empower future manufacturing organizations in improving delivery, logistic, individualization, customization and human involvement.

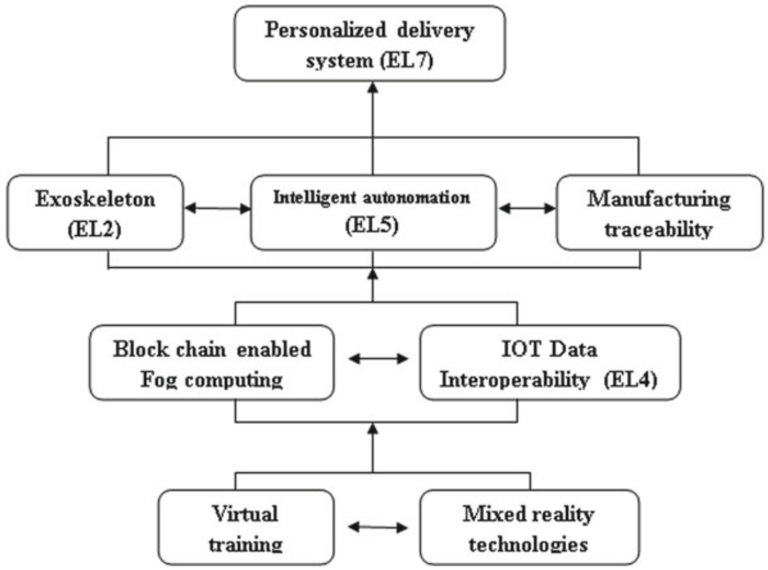

Fig. 3 TISM diagraph

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