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Assessing the key Enablers for Industry 4.0 adoption using MICMAC Analysis: A case study

Abstract

Purpose - The aim of this research is to assess the key enablers of Industry 4.0 (I4.0) in the context of the Indian automobile industry. It is done to apprehend their comparative effect on executing Industry 4.0 concepts and technology in manufacturing industries, in a developing country context. The progression to Industry 4.0 grants the opportunity for manufacturers to harness the benefits of this industry generation.

Design/Methodology/Approach - Literature related to Industry 4.0 has been reviewed for the identification of key enablers of Industry 4.0. The enablers were further verified by academic professionals. Additionally, key executive insights had been revealed by using interpretive structural modelling (ISM) model for the vital enablers unique to the Indian scenario. We have also applied MICMAC analysis, to group the enablers of I4.0.

Findings – The analysis of our data from respondents using ISM provided us with 7 levels of enabler framework. Our study adds to the existing literature on industry 4.0 enablers and findings highlight the specificities of the territories in India context. Our results show that top management is the major enabler to I4.0 implementation. Infact, it occupies the 7th layer of the ISM framework. Subsequently, government policies enable substantial support to develop smart factories in India.

Practical Implication – The findings of our work provides implementers of I4.0 in the automobile industry in the form of a robust framework. This framework can be followed by the automobile sector in enhancing their competency in the competitive market and ultimately provide a positive outcome for the Indian economic development led by these businesses. Furthermore, our work will guide decision-makers in enabling strategic integration of Industry 4.0, opening doors for the development of new business opportunities as well.

Originality/ Value – The study proposes a framework for Indian automobile industries. The automobile sector was chosen for this study as it covers a large percentage of the market share of the manufacturing industry in India. Existing literature does not address the broader picture of I4.0 and most papers do not provide validation of the data collected. Our study thus addresses this research gap.

Keywords - Industry 4.0, Enablers, ISM, Multi-Criteria Decision Making, Automobile Industry, India

1. Introduction

In the current era, Industry 4.0 (I4.0) is directed to design intelligent manufacturing facilities whereby technology is given the push to progress and transform. The execution of I4.0 will bring forth an era where factories will mainly be run by machines that can direct production. It is set to make dream factories where human error is greatly reduced, and production is optimized as the system improves itself. The idea behind I4.0 is to optimize the production process and reduce the cost (Dziurzanski et al., 2018). I4.0 will change the scenario in factory floors as the production process will now be based on the need of consumers, thus removing the wastage that occurs when production is based purely on assumption.

Zezulka et al. (2016) stated that I4.0 is used for three mutually interconnected factors. The first is the digitization as well as the integration of any simple technical-economic relations to complex technical – economical networks. The second is the digitization of completed products or the services offered, and lastly, digitalization of new market models. In the I4.0 environment, technology such as the Internet of Things (IoT), Internet of Services (IoS) and Internet of People (IoP) enable active and effective communication of entities with each other. It also utilizes data from the product owner during the life cycle of these entities (or systems) without restriction between borders of enterprises, and even countries (Rajput & Singh, 2019).

Companies are forced to implement long term sustainable practices into their supply chains to sustain in a competitive market. Integration of I4.0 can be implemented to achieve a highly sustainable supply chain operation (A. Kumar et al., 2019).

The manufacturing sector in India has started reaping the benefits of I4.0 implementation and the concept has started making short inroads in other sectors as well. Though steps have been taken for the adoption of I4.0, there is a lot more that remains to be done. The issue of incapacity is to be addressed and to achieve this, there has to be a major shift in the mind-set of the people. The focus must be on enhancing the existing assets rather than increasing the capital expenditure. Smart manufacturing, IoT and analysis will have an immense impact on industrialization in India. Chanda (2019) revealed that Indian companies adopting I4.0 across their supply chains, especially manufacturing units, have their operating profits enhanced by 40 per cent at less than 10 per cent of the capital expenditure planned. India has been greatly strengthening her position in global manufacturing in recent years. However, manufacturers in the country still lag among their global peers. The study by Kumar & Singh (2018) suggests that the annual manufacturing labour productivity is $ 6,000 per employee in the country, well below $63,400 of the same in China. I4.0 allows India to close this gap with China. The rapid change in technologies is making the demand for labour and skills challenging, however, there is an increase in the hiring of workers under contract in the manufacturing and service sectors in India with the access of social securities (Mehta & Awasthi, 2019). However, over the long term, the impact of automation would demand new forms of skill and work in the future. New technologies only replace existing jobs with new forms and do not diminish them. New technologies brought upon in this generation of I4.0, therefore, creates a market for niche jobs waiting to be tapped upon. With the Indian government's vision of making the country a key automobile manufacturing hub, the opportunity that I4.0 presents are enormous, and needs to be capitalized. Initiatives such as 'Make in India' and 'Green Corridors' by the government reveals that the country stands ready to adopt I4.0.

This study realizes ten enablers that influence the adoption of I4.0 in Indian automobile industries. The categorization of the research theme was done in three fragments. Firstly, enablers were identified through a review of the literature. Discussions with experts in the automobile industry in India and academicians from universities within the country helped authenticate these points. Secondly, Interpretive Structural Modelling (ISM) was used to examine the interrelationship exhibited among the variables in the study. Finally, a MICMAC (Cross- Impact Matrix Multiplication Applied to Classification) evaluation was conducted to derive the ability of the enablers as drivers- and their dependency on each other (Dewangan et al. (2015). To identify these abilities, the outcome of the ISM is incorporated with MICMAC for further analysis. This analysis helps to encourage I4.0 induction in automobile industries.

2. Literature Review

2.1. Impact of I4.0

Kagermann et al. (2013) published the first main notions of I4.0, and since then I4.0 has revolutionized the manufacturing sector and enhanced productivity of manufacturing systems (Liao et al., 2017). A major step towards this industrial era was the use of Cyber-Physical Systems (CPS), which is capable of interacting with the environment using sensors and actuators (Hermann et al., 2016). They enable factories to organize and control themselves autonomously in a decentralized fashion and in real-time (Brettel et al., 2014). These factories are often referred to as “smart factories”. I4.0 does not indicate employee-less production. Human operators are acknowledged as the most flexible components within the production system, being greatly adaptive to the more challenging work environment (Schmitt et al., 2013; Weyer et al., 2015).

Several countries are realizing this new trend in manufacturing and are now more focused on being up-to-date in current technologies. Governments of different nations to encourage the adoption of I4.0 in their manufacturing sectors to be on par with current trends in manufacturing. I4.0 is increasingly becoming important in the development of modern industry and economy. It is considered a key future perspective in both research and application, providing value addition to various products and systems by applying pioneering technologies to conventional products in manufacturing and services (Zhong et al., 2017). In addition to focusing on industrial production, the present or fourth industrial revolution also introduces changes to various fields beyond the conventional interpretation of the concept of I4.0. It virtually embodies a new philosophy, transforming various branches of industry, technical standardization, safety, education, legislation, science, research, the job market, the social system, and other related provinces. The onset of new technology necessitates pressure for greater flexibility in industrial production and increased cyber safety (Kaczmarczyk et al., 2018).

I4.0 has a major impact on the supply chain. The collaboration between the supplier, manufacturer, and customer through smart technologies will create transparency of all steps from manufacturing to dispatch and finally the decline or end of the life cycle of a product. Tjahjono et al. (2017) identified that implementing I4.0 has a major impact on order fulfilment and transport logistics. Tjahjono et al. (2017) reported that 71.43% of opportunities from implementing I4.0 comes within a supply chain. A major benefit of I4.0 adoption is the ability to enable mass customization, enabling organizations to meet the customers' demands. Schroeder et al. (2019) identified that specific firm-level recommendations highlight the need for cultural change across the hierarchies through recruitment and targeted training. Bag et al. (2018) suggested that I4.0 has a link with sustainability. A sustainable supply chain means enhancing the social, economic and environmental benefits with the key developments being a total integrated system and automation. Although I4.0 is often portrayed as a technological challenge, firms need to innovatively upgrade their management practices and business models for optimum benefit.

Upon entering a smarter production process the major benefits realized are the great reduction in the cost per unit and the time saved, as the production is now a faster process (Machado et al., 2019). Digitalization in the present industrial era also poses other benefits in terms of other factors such as the quality of the products, their marketing and delivery, and the sustainability of the unit. To achieve sustainable production, Winroth et al. (2016) suggested that it is essential to measure performance efficiently, calling for an automatic collection and treatment of data. Collection and speedy transfer of data is the core requirement for a smart facility since it is what allows massive Machine Type Communication (mMTC). The state of the art mMTC takes a system design approach by improving existing networks to support the emerging requirements by the customers (Mahmood et al., 2020). The application of Machine Learning (ML) technology has deep roots in production and maintenance in the automobile industry and will dominate this sector in the years to come (Ata et al., 2019; Hung et al., 2019). The automobile sector in India is adopting state of the art I4.0 technologies for tasks such as machine operations, assembly, inspection and logistics. Large manufacturers like Hyundai, Tata Motors, Ford and Honda in India are implementing new technologies (Mehta & Awasthi, 2019). A smart automobile factory has a network of production equipment, cyber-physical systems, conveyors and logistics system. An I4.0 environment allows development from traditional supply chains lines to the digitization, networking and intellectualization (Gong et al., 2019).

2.2. Motivation

In this study, we develop a framework for Indian automobile industries. SIAM (2018) reported a hike in export trends of automobile industries from 2012 to 2018, indicating a positive trend of Indian automotive industries in the competitive global market. This is because of the production of various options of each vehicle produced in the country with varying costing levels- the lowest being the base variant and the highest cost for the higher-end variant of the same model. The automotive industry in India is expected to be an approximate INR 16 trillion by 2026 (IBEF, 2018). The country has an advantage in terms of cost, hence attracting investments even in terms of Foreign Direct Investment in this sector. Because the automobile sector is always the first to adopt the latest that technology has to offer, the research focused on factors enabling the automobile industry (Krasniqi & Hajrizi, 2016). The following subsection elaborates on the enablers that have been identified for further analysis.

2.3. I4.0 Enablers of I 4.0 implementation

This research is focused on the identification of key enablers for I4.0 in the context of the Indian automobile sector through literature review and expert opinion from academia and industry professionals. Since I4.0 is a new concept in that it was first coined in 2011, literature from the year 2000 was reviewed to identify I 4.0 enablers. Research work before 2011 is considered because I 4.0 technologies were available at the beginning of the new millennia. For example, technologies such as AI and ML were available, it was not as widely used as since 2011. The key enablers were then identified with discussions and suggestions from the experts.

From our review, we came across several works resembling our study, however, our work is unique relatively. For instance, Karadayi (2020) and Kamble et al. (2018) studied the challenges/barriers to I4.0 adoption and used this as the basis for forming a hierarchical relationship, whereas our study primarily identifies enablers and based on its analysis form a hierarchical relationship. The strategic approach to finding the results vary significantly simply based on the aforementioned reason. Rajput & Singh (2019) studied the enablers specific to an I4.0 technology, that is IoT. Though the subject matter falls within the I4.0 domain, the study is specific in nature and does not provide a broader picture of I4.0 and its enablers. Similarly, Ghobakhloo (2020) studied on the sustainability dimension of I4.0, leaving behind the scope of another functional impact it has in industries. Luthra et al. (2020) provide another instance of a similar study whereby enablers for I4.0 were identified. Luthra et al. (2020) identified 10 enablers in the context of the manufacturing sector in India. This study however does not provide an industry-specific research and further to that the research depended on only five respondents for their analysis and results. The research fails to justify authenticity either by means of including a larger sample of respondents or by being specific to manufacturing industry.

We note from our review that available literature does not provide a broader analysis of I4.0 enablers, and work that is available does not justify a strong data collection methods. Furthermore, since there is no work on the analysis of the broader picture of I4.0 specific to the Indian automobile industry. We, therefore, saw the gap and gave us the opportunity to initiate this work. Our research pertains specifically to the automobile sector of India. Accordingly, the analysis for the enablers we identified is based on respondents from the automobile industry itself. The questionnaire developed for the same was developed based on discussions with academic experts (professors) who are expertsin the field of manufacturing. The combined experience of the respondents provides a robust analysis of our study.

The academic literature was identified using Google Scholar. Keywords were chosen according to the research topic and the included technologies and methods described in this paper. The keywords include, but not limited to ‘industry 4.0’, ‘cyber-physical systems’, ‘IoT’, ‘industry 4.0 and supply chain’, ‘industry 4.0 and automobile’, ‘smart factory’, ‘ISM’,’MICMAC’. The articles identified using keywords was then validated by their title, their abstract and finally by their content for their relevancy. The enablers identified from the literature are discussed below.

Top management interest in implementing I4.0

Major organizational change has to pass through the eyes of the management, and the management’s willingness is important to its adoption (Kumar et al., 2020). Müller et al. (2018) suggested that the concept of I4.0 is a foremost change in the environment of business and is required to be backed up by the management. The leaders must be committed to the goal of I4.0 and realize its immense potential to maximize the outcomes. They must be willing to re-analyze their organizational structure and maintain an enthusiastic work atmosphere to drive this industrial revolution. Top management interest in implementing I4.0 is the inner or personal qualities that constitute effective leadership.

Future viability of I4.0 adoption

Newmarket entrants may already acquaint themselves with new business models and threaten the existence of the current players (Zhong et al., 2017). Furthermore, it has been noted that I4.0 is closely associated with the word “Future” (Erol, 2016). This era comes with this trend in I4.0 practices and manufacturers have the advantage of future-proofing their firm.

Government policies to support smart factories

The Indian government has come up in favour of I4.0, but it lacks aggressiveness and supporting policies. Government and associated bodies need to promote the development of networking agencies that can help promote the adoption of the Industrial Internet of Things in industries and their management. With the onset of new technologies, the government must promote cross-border trades to enhance technology sharing. On the other hand, strict laws regarding liabilities of machines and their usage and privacy protection must be enforced to avoid wrong handling of data. Legal regulations and compliances concerning labour and safety management must be redesigned to aid the adoption of I4.0. The Indian ruling government of 2018 launched the micro, small and medium enterprise Support and Outreach program which provides a 12 point program that includes a 59-minute loan portal for sanction of up to Indian Rupees (INR) 1 Crore which is approximately $140,000 (at the current market exchange rate of about 71.4 INR to the US Dollar). Such initiatives by the government enable the introduction of I4.0 practices. The Indian government through the Ministry of Micro, Small & Medium Enterprises has provided schemes that enable the adoption of new practices financial and other forms of support (MSME, 2018).

Competitive global advantage

Global competitiveness plays an important role in the accomplishment of success in manufacturing sectors in the Indian context. An organization needs to provide the same worth as its competitors but at lower rates, or charge higher rates and provide more value through differentiation. This advantage over the competition can be gained when organizations can expose their core business practices to available technological opportunities. To maintain a global competitive advantage, companies will have to focus on their core competencies through the use of I4.0 technologies. This potentially changes business models of manufacturing companies from offering superior products towards offering a superior manufacturing capability (Brettel et al., 2014).

Ability to address environmental challenges

Manufacturing/production has a severe influence on environmental pollution and global climate warming conditions. Non-renewable resources such as petroleum and coal are consumed at very high rates and are increasing. The industry experiences an ever-shrinking supply of workforce as a result of an ageing population. The latest industrial revolution has recognized the pressing problem areas (e.g. growth of human population, environmental pollution, and decrease in naturally available resources and changes in climate) that modern society faces (Erol, 2016). For industries to minimize their ecological impact, practitioners and managers suggest applying green principles to the supply chain network Preventive action needs to be taken to include the eco-friendly aspects in the business line (Koenig et al., 2019; Kumar & Singh, 2018; Kumar et al., 2019).

Customized customer requirements

Modrak et al. (2019) suggested the significance of the ‘customer is king’ attitude. Providing customers with exactly what they want is the trend amongst manufacturers. It enables manufacturers to be closer to their customers through their customized products. There is an increase in the trend of manufacturers moving from a mass-production business model to a customized customer requirement production model (Vaidya et al., 2018).

Firm’s innovativeness

Shamim et al. (2016) highlighted that I4.0 is characterized by smart manufacturing, implementation of CPS for production, the digital enhancement and reengineering of products, highly differentiated customized products, a well-coordinated combination of products and services, the value-added services with the actual product or service, and efficient supply chains. All of these challenges require continuous innovation. So it can be said that the firm's R&D proves to be very important in effectively implementing I4.0 concept.

Digital and integrated process capabilities

I 4.0 is closely enabled due to digital, and vertically and horizontally integrated processes. Rüßmann et al. (2015) suggested that automation in logistics alone will generate high-cost savings of 50 per cent for the manufacturer. Various packages such as Enterprise Resource Planning (ERP) and MRP (Material Resource Planning) are used to integrate various departments and operations conducted in an organization. This digital integration allows for the transmission of information across various levels of the business. This would, in turn, allow for the smooth functioning of operations leading to a reduction in operating cycle times.

Financial performance

Financial benefits consist of several cost reduction potentials in terms of average units, the operating, personnel and tooling costs. I4.0 implementation is beneficial in terms of enhanced value creation and growing sales volume, resulting in better financial performance (KIEL et al., 2017).

Ability to satisfy the expectation of society

Hasegawa et al. (2007) defined the ability to satisfy the expectation of society as an internalized social norm for individuals and organizations, thus for society as a whole, about what people should do. This is where people with public interests gather to discuss the 'public interest', to carry out social practices, to realize 'publicness' and 'commonality', and to carry out political education. It is important to develop an I4.0 framework or model through research that will support the advancement of the emerging process of civil society.

The key enablers used for analysis and the development of a framework through the study are listed in Table 1 that follows.

“[Insert Table 1 here]”

3. Methodology

In this study, the Interpretive Structural Modelling (ISM) technique has been utilized. The ISM technique is simple, yet an effective method of decision making used by researchers for modelling the relationship between variables of a research study (Shahabadkar et al., 2012). According to Singh & Deshmukh (2007), the ISM technique is an interactive learning process. The method is interpretive in that the group’s judgment decides whether and how items are related; it is structural in that, based on the relationship, and overall structure is extracted from the complex set of items; and it is modelling in that the specific relationships and overall structure are portrayed in a framework model. The ISM methodology helps to impose order and direction on the complexity of relationships among the elements of a system (Qureshi et al., 2007). The overall structure is extracted from the complex set of items, and the relationships between the enablers are modelled to portray in the framework developed. The development of the ISM model follows the basic steps:

I.	Identifying the variables through a review of literature;
II.	Examination of the contextual relationship between the variables;
III.	Constructing the self-structural interaction matrix indicating the interrelationships among the variables of the system;
IV.	Deriving an initial reachability matrix from the developed SSIM. It is assumed in this methodology that the collected empirical data is transitive. The Identity matrix is added to the collected data matrix to create the reachability matrix.

V.	Level Partitioning of the developed reachability matrix;
VI.	Developing the ISM framework;
VII.	Reviewing the ISM model.

Thakkar et al. (2008) list the advantages of adopting the ISM method. One of which is that this method systematically incorporates the experts' subjective verdicts and their knowledge base. The ISM technique does not require much effort in computation especially for factors ranging in numbers between 10 and 15. Furthermore, this technique is a handy method to derive speedy managerial insights (Thakkar et al., 2005).

The Self-Structural Interaction Matrix (SSIM):

A contextual association is established by SSIM. Four symbols are used for the type of the relationship that exists between two sub-variables under consideration: 'V' for the relation from i to j but not in both directions; 'A' for the relation from j to i but not in both directions; 'X' for both direction relations from i to j and j to i; and 'O' if the relation between the variables does not appear valid (Thakkar et al., 2008). The statements tabulated in Table 3 guides the use of codes V, A, X and O in SSIM.

Data Collection

To analyze the key enablers of I4.0 adoption in Indian automobile industries, ten enablers were considered. The input for SSIM was done based on discussions with experts from automobile industries in India. These experts comprise senior managers, junior managers and also executives in the design, production, quality and procurement departments in automobile industries in India. Furthermore, academicians were also consulted. Meetings with these experts and academicians were done personally after explaining the objective of this research over the phone. A questionnaire was then developed and distributed to a total of 43 automobile industry experts, out of which 32 filled responses were received. These 43 experts were first or second contacts of the researchers, which made it simpler to communicate the purpose of research and further collect data. The questionnaire was designed to facilitate data collection to help develop the SSIM matrix (Jharkharia & Shankar, 2004). Table 2 summarizes the profiles of the experts contacted.

"[Insert Table 2 here]"

The Reachability Matrix:

The developed SSIM - Table 5 has been converted into an *initial reachability matrix* (IRM) - Table 6. It is a matrix of binary entries that replace X, A, V, and O with 1 and 0. The substitution rules of 0s and 1s are summarized in Table 3.

"[Insert Table 3 here]"

The initial reachability matrix obtained for I4.0 key enablers is shown in Table 6. The development follows the rules as summarised in Table 3. After incorporating the transitivity, the final reachability matrix is derived - Table 7. In Table 7, the driving and dependency power of each variable is also calculated. The driving power for each variable is the total number of variables (including itself), which may help to drive. The dependence power, on the other hand, indicates the extent to which a variable is dependent on other variables. These driving power and dependencies will be used later in the classification of variables into the four groups: autonomous, dependent, linkage and drivers (Singh et al., 2007).

The Level Partitioning:

The development of the reachability set and the antecedent set for every variable is done by referring to the final reachability matrix. The intersection of the reachability (horizontal factors) and antecedent (vertical factors) set is derived for all elements. The topmost level variable in the ISM layers is the one with common variables in the reachability set and the intersection set.

The top-level element of the hierarchy would not help achieve any other element above its own. Once the top-level element is identified, it is separated from the other elements. Then by the same process, the next level of elements is found. These identified levels help in building the final model. In the present case, the competitive factors along with their reachability set, antecedent set, intersection set and the levels are shown in Tables 8 – 14.

The Classification of the enablers:

Different enablers are classified based on their nature as autonomous, dependent, linkage or driver. They are classified based on their power as a driver and their dependencies. Each quadrant characteristics are given in Table 4. The driving power and dependency diagram of the enablers - Figure 1 is developed and further explained in section 3.3.

“[Insert Table 4 here]”

3.1. Interpretive Structural Modelling

“[Insert Table 5 here]”

“[Insert Table 6 here]”

The level partitioning of the enablers is done through seven iterations (Table 8- Table 14).

“[Insert Table 7 here]”

“[Insert Table 8 here]”

“[Insert Table 9 here]”

“[Insert Table 10 here]”

“[Insert Table 11 here]”

“[Insert Table 12 here]”

“[Insert Table 13 here]”

"[Insert Table 14 here]"

The developed ISM segregates the factors in a hierarchy of seven different levels as performed. The levels are listed in Table 15.

"[Insert Table 15 here]"

3.2. MICMAC analysis

The last step of ISM methodology is the MICMAC analysis. A driving and dependence diagram of the enablers of I4.0 is then developed that categorizes the variables based on them being autonomous, dependent, linkages or driver in nature. This enables a simpler analysis of these factors. Enablers occupying autonomous typically are fragile drivers. They exhibit fragility as dependents as well. They are comparatively incoherent within the system. Variables of this nature do not have a severe influence on the rest of the identified variables in the system (Khaba & Bhar, 2018).

Linkage variables represent strong driving power along with solid dependency. These variables exhibit unsteady characteristics.

Variables in the driver quadrant represent solid driver characteristics and fragile dependency power and so are independent.

Dependent variables represent solid dependencies with fragile driving characteristics. Their characteristics stay influenced by the drivers or independent variables.

Table 16 shows the driving and dependency powers established from Table 7 of the SSIM process. Furthermore, Figure 1 illustrates MIMAC analysis, which is developed and the result explained.

"[Insert Table 16 here]"

"[Insert Figure 1 here]"

Analyzing the attained driving, as well as the dependency of these key enablers, is the main aim behind the classification of key enablers of I4.0. Figure 1 indicates that none of the factors that represent autonomous characteristics lies in the first quadrant. This quadrant represents a fragility in dependency as well as fragility in driving characteristics; variables in this quadrant have no or least connection with the developed system. These variables exhibit autonomous characteristics. Those variables that exist in the third that is a quadrant in the northeast corner (competitive global advantage - E4 and firms' innovativeness - E7) exhibit linkage characteristics with strong driver powers and strong dependent powers. An action taken on these variables will upset the others and will reflect their effect on themselves. The second quadrant comprises of the future viability of I4.0 adoption (E2), ability to address environmental challenges (E5), customized customer requirements (E6) and ability to satisfy the expectation of the society (E10). Variables falling in this quadrant exhibit fragile power as drivers but are highly dependent on others. Their nature shows a relative disengagement from the system leading influencers. Variables of this nature are known as dependent variables. The northwest quadrant includes Top management interest towards implementing I4.0 (E1), Government policies to support smart factories (E3), Digital and Integrated Process capabilities (E8), and financial performance (E9). This is the fourth quadrant that includes variables that are independent and are drivers with weakness as dependents.

4. Results & Discussion

The framework model for the enablers of I4.0 has been developed and represented in

Figure 2.

"[Insert

Figure 2 here]"

It can be inferred from the developed ISM framework represented in

Figure 2 that the Level 7 enabler consisting of ***top management interest towards implementing I4.0*** is the major driving factor for the I4.0 era in the study. The management is responsible for verdicts made in the organization and is a key enabler to implementing a smart industry model. Top management interest towards implementing I4.0 fall at the bottom level as their driving power is highest among the identified enablers. The management with the help of government and their policies support the implementation of newer frameworks.

Governments who are unable to develop far-sighted policies will find crumbling economies, drop in revenue, and increase in expenditure. India under the current government is grabbing pace to the direction of the present industrial era. With initiatives such as 'Make in India', technology up-gradation and quality certification scheme, entrepreneurship and skill development programme, and infrastructure development programme, the government is enabling industries especially small and medium scale enterprises, to advance through assisting in form of finance and guidance (MSME, 2018). Hence **government policies to support smart factories** are a high influencer when it comes to implementation of I4.0 concepts and technologies. With a high driving power, this enabler falls in the following level to top management interest towards implementing I4.0 - at the 6^{th} level.

The 5^{th}level consisting of the **financial performance** of the company is crucial as infrastructure, skilled labour and initial implementation of smart systems can incur a large cost to the company. It can be seen from the framework that such a decision is made by the management and their willingness to adopt such a model and further backed by the government. A financially sound enterprise is capable of implementing digitally connected systems and processes. Furthermore, Schönborn et al. (2019) identified that the loyalty and of the employees with their company is a significant, and positive predictor of corporate financial success.

Complex systems can be put in place based on the financial status of the firm. For this reason, the **Digital and Integrated Process capabilities** are placed in level 4. Implementing I4.0 concepts isn't a small task and require enough finance for initial setup. In the case of manufacturers in India, they require more complex integrated systems that help facilitate operations under this concept of I4.0.

Following this level is the 3rd level where **competitive global advantage** and the **firm's innovativeness** lies. Based on the complexity of the level 4 enabler, the firm will be able to innovate through its R&D. It is not enough to just innovate theoretically. The more complex the systems available in the plant, the more opportunities the R&D department will have to innovate and develop their manufacturing practices. Furthermore, level 4 enabler also is associated with a competitive global advantage whereby the ability to provide for the customer with a product of better quality at market price or less is dependent upon. A more complex manufacturing system, well-integrated digitally, is a major driver for the production of competitively priced products. Further, a relation between the level 3 enablers is feasible. The firms' innovativeness is driven by its R&D. R&D is an important determinant corporate strategic performance relative to competition in a broad range of industries. Relative R&D intensity is thus an important driving force and predictor of corporate growth. Corporate R&D intensity also emerges as a principal means of gaining market share in a global competition.

The level 3 variables are followed by level 2 enabler - **Ability to satisfy the expectation of society.** A financially sound firm with strong R&D capabilities enabling their innovativeness will endure high expectations from the society. Firm's innovativeness and Ability to satisfy the expectation of society enables fulfilling the requirements of the customers being targeted. The needs of the customer are always being updated based on trends in the market. To stay in the market, the firm's management must develop a tactful strategy to compete in the market. For that reason, the framework shows the association of Ability to satisfy the expectation of the society with the firm's innovativeness. Furthermore, an association with a competitive global advantage is also seen. An article by (Porter & Kramer, 2006) explained that "integrating business and social needs takes more than good intentions and strong leadership. It requires adjustments in organization, reporting relationships, and incentives." However social responsibility has been made mandatory in India after an amendment to The Company Act of

2013 in 2014. Based on data last updated on 11th January 2017, the Companies Act promotes that companies with a net worth of about Indian Rupee (INR) 4 billion or over, or an annual turnover of about Indian Rupee 9 billion or over, or an approximate net profit of Indian 50 million or more during a financial year, must allocate two per cent of average net profits of 3 years towards Corporate Social Responsibility (Associates, 2020).

Level 1 enablers are **Future viability of I4.0 adoption, the ability to address environmental challenges and customized customer requirements**. These enablers occupy the topmost position in the framework as they have relatively low driving strength and high dependency on other variables. These enablers do not have much influence on the other enablers of the system. The current scenario in Indian cities where manufacturing is dominant face issues like air pollution and water pollution. This affects the livelihood of neighbouring residents. Several initiatives have been taken to lessen dangerous levels of pollution present in the urban city's ambient air. A major initiative was to move public transport vehicles to use CNG. This implementation has been in the capital city of India – Delhi, since April 2001 and has shown visible positive results. Any business model must have set goals that have a reasonable chance of success. The future viability of I4.0 adoption is a way of seeing that the firm is future-proofed, which is a fundamental objective of any organization. Finally, the environment is a major consideration of industries and for this smart manufacturing or green manufacturing is the rising trend among manufacturers for the viability of their service or product in the future. Though several treaties such as the Paris peace treaty have been signed, the world is at risk of global climate changes due to human influence. Wastes and exhausts from industries and products influence the natural environment and for this reason, a greener manufacturing system needs to be put in place. Thus, implementing I4.0 is more of a necessity than just an upgrade in the industrial era for the sustainability of the environment.

5. Validation of Research

Digital and Integrated Process capabilities in India are enabled by the use of SAP (Systems, Applications, and Products in data processing) for business management. Furthermore, big data and IoT are playing major roles in automotive Industries as most modern vehicles already have this advanced technology through the use of sensors, control panels, and processing modules. The above variables are enabled majorly by the financial performance of the firm. The current government has been key in enabling the boom in the automotive sector and its encouragement to the use of I4.0 practices. The government has also come up with reforms such as the Goods and Service Tax (GST) to boost the automotive sector. As mentioned earlier, the Indian government is ambitious and has targeted the use of only electric vehicles in the country. Under the FAME scheme by the government, a mammoth increase in electric vehicle units manufactured from 2015 to 2018 has been witnessed (IBEF, 2018).

On top of all the enablers, the management comes above all in decision making and holds the main responsibility in introducing new, improved and feasible practices for not only automotive but all manufacturing sectors in the country. The automotive industry provides jobs for a large fraction of the workforce in India and so a strong team lead by strong tech-savvy management is necessary. Strategic planning and production in the automotive industries is essential and is the sole reason for the ever-continuing growth in this sector. And since the management and their attributes are responsible for setting organizational goals and enabling them through the adoption of various technologies and current practices, they are considered the most important enabler of I4.0.

Several firms lose a huge amount of money through unguided use of I4.0 technologies, impacting operations in the supply chain and losing face value (Bag et al., 2018). This paper is, therefore, valid research conducted to identify and scientifically verify I4.0 enablers that may lead to achieving smooth business operations and sustainability.

6. Managerial Implications

The study provides the significance of the I4.0 key enablers for industries, the environment, and society. I4.0 can have a great effect on the way manufacturers conduct their production processes by reducing long term costs, reduce wastes produced and increase safety for workers in the firm. The factors identified in the paper provide essential revelations to the decision-makers in the consideration of the design of a smarter automobile/manufacturing plant. The enabler in Level 7 is given the highest preference by practitioners to implement the I4.0 concept in the industry. This paper theoretically identified ten enablers, whereby top management interest towards implementing I4.0 come to be of highest driving power for I4.0 and the lowest being the level 1 enablers of ability to address environmental challenges, Future viability of I4.0 adoption and customized customer requirements having a high dependency on the previous levels.

Technologies will affect every industry in India. There is a great drive for the adoption of these technologies and a revamping of business. Individual companies and industry associations can work to achieve an ecosystem to create collaborative learning in their respective sectors and academia to skill the workforce and students on the next generation of technologies (Mashelkar, 2018). However, implementation of state of the art technologies is not enough. Top-level management should seek collaborations globally to achieve a sustainable I4.0 environment. They also need to collaborate with educational institutes. They need to realize that the Universities of the future which we can now call "University 4.0', are giving importance to reasoning capabilities and logical thinking. A new trait of creative thinking may be inculcated into young minds using technologies like artificial intelligence and their practical usage by bridging the gap between industry and academia. The shortening of this gap would lead to students being industry ready and not just ready to be trained. This would help satisfy the job market crisis the country is currently facing. This, in turn, would bring in the sustainable nature of implementing I4.0 technologies and also allow for the suitability of the country to seamlessly enter into future Industry generations.

The framework presented in this paper provides adopters of I4.0 technology and concepts a guide to adopting a smarter firm through the new industrial era concepts. Decision-makers can use this research as a reference to the development of their organization through the most suitable management strategy of I4.0 implementation that helps in attaining positive development outcomes.

7. Conclusions & Future Scope

The primary objective of this paper is to provide decision-makers of automobile industries a framework that allows improvement in business operations by establishing a hierarchy of the enablers and categorizing them based on their driving and dependency powers. Decision-makers can then focus on specific enablers based on the effects of changes to those enablers. Successful execution of I 4.0 concepts requires the consideration of the key enablers studied in this paper. The enablers considered in this paper are identified and verified with academicians from the University. The hierarchal levelling of the enablers using ISM technique is used, enabling the development of a framework that enables the application of I4.0 practices. A MICMAC analysis is conducted to define the enablers as dependent and independent variables. It is ascertained from the MICMAC analysis that Top management interest towards implementing I4.0 is of the highest importance in the process of executing I4.0 techniques in a firm. The management and their capability being tested, and the result is seen based on their attributes. It occupies the 4^{th} quadrant in the dependency driver power diagram and occupies a point of highest driver power amongst the various key enablers in the study. The other driver enablers - Government policies to support smart factories, financial performance, and Digital and Integrated Process capabilities along with the management's verdict play a key function within the fulfilment of initiating I4.0 practices in a factory. Though it is evident that the enablers such as 'financial performance', 'Government policies to support smart factories' and 'Top management interest towards implementing I4.0' are well-known enablers, and that these enablers will always be driving ones, the application of a scientific approach was required to verify this in literature. This verification was done in this research work through the ISM methodology and the MICMAC analysis. An important observation to be made from this analysis is that no variable falls under the autonomous quadrant which implies that all the enablers in the study are important in implementing I4.0 standards.

This research is quite generalized for implementing I4.0 concept as a whole and is not the same as the enablers of implementing the various I4.0 technologies. Meaning, the enablers of additive manufacturing implementation would be different from that IoT or Augmented Reality in an organization. This is, in fact, a limitation that this research faces. Another limitation of this research is that it lacks the usage of empirical data to verify the outcomes presented.

The future research directions are seen by amplifying the enablers identified in this paper by conducting fuzzy ISM or a hybrid approach can be to further verify the viability of the study. Further to this, SEM (Structural Equation Modelling), MCDM or Multi-Criteria-Decision-Making techniques can also be adopted to figure out the causal relationships among the enablers and to validate the developed hypothetical model statistically. Any extended research from this study may consider the use of larger data sets from the industry and consider the use of I 4.0 technologies such as ML to develop an algorithm for decision making. This paper considers the study of ten enablers and the addition of more enablers would develop the framework further.

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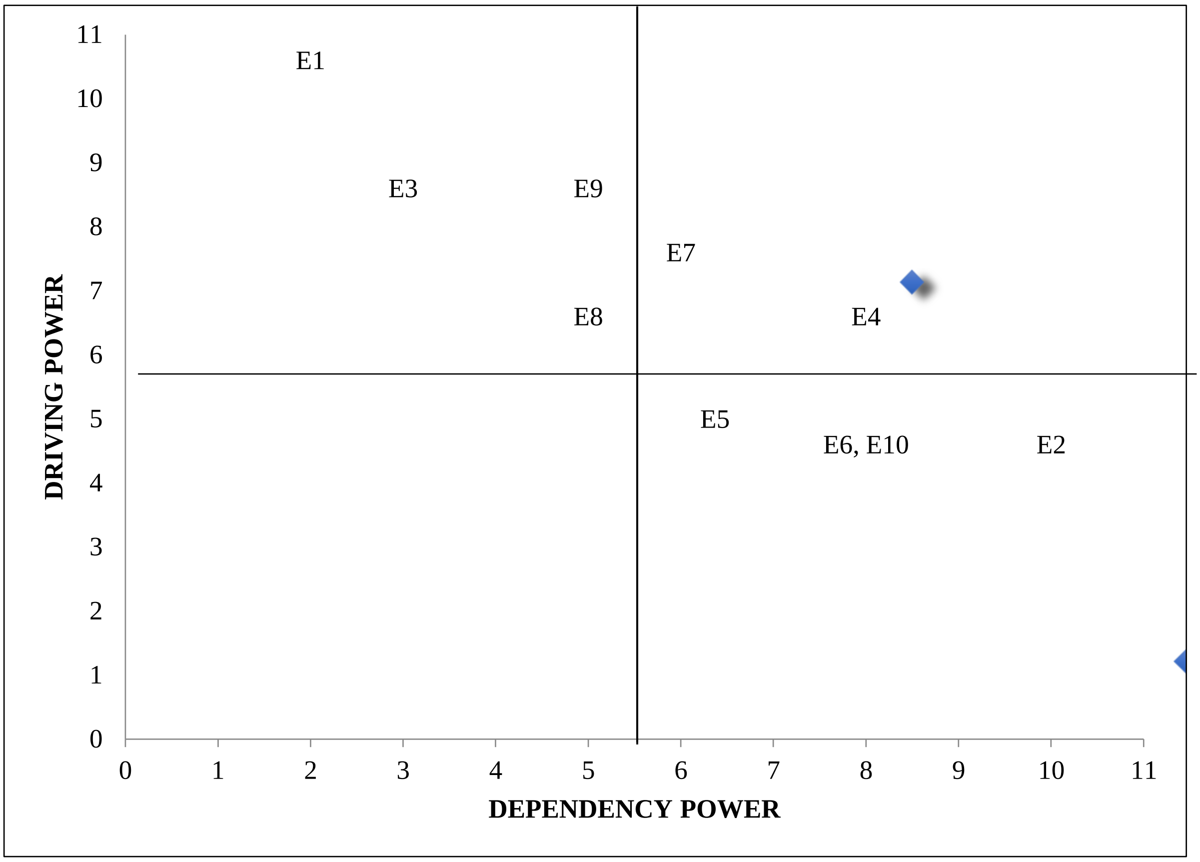

Figure 1. Driving power and dependency diagram of the enablers

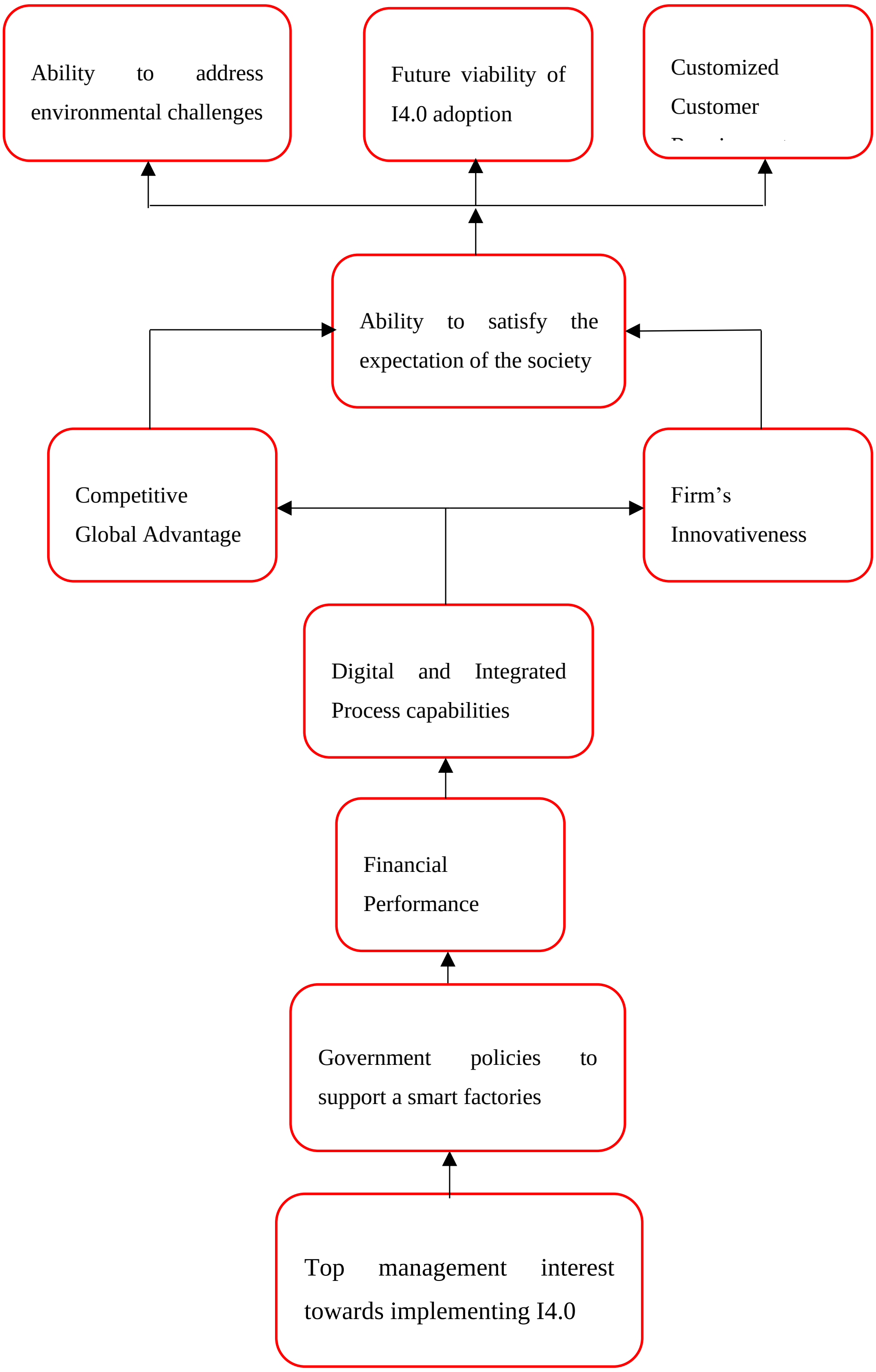
Ability to address environmental challenges
Future viability of I4.0 adoption
Customized Customer
Ability to satisfy the expectation of the society
Competitive Global Advantage
Firm’s Innovativeness
Digital and Integrated Process capabilities
Financial Performance
Government policies to support a smart factories
Top management interest towards implementing I4.0

Figure 2. ISM Framework developed

Table 1. Identified Enablers of Industry 4.0

Enabler Identified	Source	Definition
Top management interest towards implementing I 4.0 (E1)	(Müller et al., 2018)	Adopting the latest technologies and concepts require the makers' interest towards achieving customer satisfaction
Future viability of I 4.0 adoption of I 4.0 adoption (E2)	(Selim Erol, Jäger, Hold, Ott, & Sihn, 2016)	Industry 4.0 can be a calculated risk. However, Its adoption has long term benefits for the adopters.
Government policies to support smart factories (E3)	(MSME, 2018)	The policies set by the government not only influences customers, but also the means in which businesses can develop to introduce smart manufacturing.
Competitive Global Advantage (E4)	(Brettel et al., 2014)	The business strives to have an edge in their target market over competing businesses. Adopting newer technologies and concepts enable more penetration into the target market.
Ability to address Ability to address environmental challenges (E5)	(Erol et al., 2016; Kumar & Singh, 2018; Kumar et al., 2019)	With the depletion of natural resources and the population increase in India, environment faces a threat with needs to

		be rectified through smarter manufacturing facilities.
Customized Customer Requirements (E6)	(Modrak et al., 2019)	Customers wish to acquire products and services that are individualized and meant for them alone. They want their own ideas to be addressed.
Firm's Innovativeness (E7)	(Shamim et al., 2016)	In the manufacturing sector, innovative designs and products need to introduce into the market regularly otherwise the product may undergo a short life cycle.
Digital and Integrated Process capabilities (E8)	(Rüßmann et al., 2015)	Manufacturing facilities should be able to visualize and develop mathematical models and algorithms. That is, the technical requirements will be needed to integrate the required Industry 4.0 core components.
Financial Performance (E9)	(KIEL et al., 2017)	The financial standing of the firm will play an important role in the ability of the organization to promote smarter a production
Ability to satisfy the expectation of the society (E10)	(Hasegawa et al., 2007; Schönborn et al., 2019)	Smarter production should benefit society through various channels such as Corporate Social Responsibility.

Table 2. Profile of the respondents in various Indian Automobile Industry

Profile	Total	Percentage
Senior Managers	2	6.25
Junior Managers	4	12.5
Design Dept. executives	9	28.125
Production Dept. executives	8	25
Quality Dept. executives	5	15.625
Procurement Dept. executives	4	12.5
Total	32	100

Table 3. Code for ISM model

i, j record in SSIM	V	A	X	O
i, j record in Initial reachability matrix	1	0	1	0
j,i record in final reachability matrix	0	1	1	0

Table 4. Table for MICMAC quadrant – explanation

Quadrant	1st	2nd	3rd	4th
Nature of Variables	Autonomous variables	Dependent variables	Linkage variables	Driver variables

Description/ characteristics	1.Weak dependent 2.Weak driving	1.Weak driver 2.Strong dependency	1.Strong driver 2.Strong dependency 3.Unstable variables	1.Strong driver 2.Weak dependency

Table 5. SSIM Matrix.

	ABILITY TO SATISFY THE EXPECTATION OF THE SOCIETY (E10)	FINANCIAL PERFORMANCE (E9)	DIGITAL AND INTEGRATED PROCESS CAPABILITIES (E8)	FIRM'S INNOVATIVENESS (E7)	CUSTOMIZED CUSTOMER REQUIREMENTS (E6)	ABILITY TO ADDRESS ENVIRONMENTAL CHALLENGES (E5)	COMPETITIVE GLOBAL ADVANTAGE (E4)	GOVERNMENT POLICIES TO SUPPORT SMART FACTORIES (E3)	FUTURE VIABILITY OF I 4.0 ADOPTION (E2)	TOP MANAGEMENT INTEREST TOWARDS IMPLEMENTING I 4.0 (E1)
(E1)	V	X	V	V	V	V	V	V	V	

(E2)	A	O	A	A	X	X	X	A		
(E3)	V	V	V	V	O	X	V			
(E4)	V	X	A	X	X	O				
(E5)	X	O	X	A	O					
(E6)	X	A	A	A						
(E7)	V	X	A							
(E8)	O	A								
(E9)	V									
(E10)										

Table 6. Initial Reachability Matrix.

	ABILITY TO SATISFY THE EXPECTATION OF THE SOCIE	FINANCIAL PERFORMANCE (E9)	DIGITAL AND INTEGRATED PROCESS CAPABILITI	FIRM'S INNOVATIVENESS (E7)	CUSTOMIZED CUSTOMER REQUIREMENTS (E6)	ABILITY TO ADDRESS ENVIRONMENTAL CHALLENG	COMPETITIVE GLOBAL ADVANTAGE (E4)	GOVERNMENT POLICIES TO SUPPORT SMART FACT	FUTURE VIABILITY OF I 4.0 ADOPTION (E2)	TOP MANAGEMENT INTEREST TOWARDS IMPLEMENT

	TY (E10)		ES (E8)			ES (E5)		ORIES (E3)		ING I 4.0 (E1)
(E1)	1	1	1	1	1	1	1	1	1	1
(E2)	0	1	0	1	1	1	0	0	0	0
(E3)	0	1	1	1	1	0	1	1	1	1
(E4)	0	1	0	1	0	1	1	0	1	1
(E5)	0	1	1	0	1	0	0	1	0	1
(E6)	0	1	0	1	0	1	0	0	0	1
(E7)	0	1	0	1	1	1	1	0	1	1
(E8)	0	1	0	1	1	1	1	1	0	0
(E9)	1	1	0	1	0	1	1	1	1	1
(E10)	0	1	0	0	1	1	0	0	0	1

Table 7. Final Reachability Matrix

	TOP MAN AGE MEN T	FUTU RE VIAB ILITY OF I	GOV ERN MEN T POLI	COM PETIT IVE GLOB AL	ABILI TY TO ADD RESS	CUST OMIZ ED CUST OME	FIRM 'S INNO VATI VENE	DIGIT AL AND INTE GRAT	FINA NCIA L PERF ORM	ABILI TY TO SATI SFY	DRIV INGP OWE R

	INTEREST TOWARDS IMPLEMENTING I 4.0 (E1)	4.0 ADOPTION (E2)	CIES TO SUPPORT SMART FACTORIES (E3)	ADVANTAGE (E4)	ENVIRONMENTAL CHALLENGES (E5)	R REQUIREMENTS (E6)	SS (E7)	ED PROCESS CAPABILITIES (E8)	ANCE (E9)	THE EXPECTATION OF THE SOCIETY (E10)	
(E1)	1	1	1	1	1	1	1	1	1	1	10
(E2)	0	1	0	1	1	1	0	0	0	0	4
(E3)	0	1	1	1	1	0	1	1	1	1	8
(E4)	0	1	0	1	0	1	1	0	1	1	6
(E5)	0	1	1	0	1	0	0	1	0	1	5
(E6)	0	1	0	1	0	1	0	0	0	1	4
(E7)	0	1	0	1	1	1	1	0	1	1	7
(E8)	0	1	0	1	1	1	1	1	0	0	6
(E9)	1	1	0	1	0	1	1	1	1	1	8
(E10)	0	1	0	0	1	1	0	0	0	1	4
DEPENDE	2	10	3	8	7	8	6	5	5	8	62

NCY POWER											

Table 8. Iteration I

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E2,E3,E4,E5,E6,E7,E8,E9,E10	E1,E9	E1,E9	
(E2)	E2,E4,E5,E6	E1,E2,E3,E4,E5,E6,E7,E8,E9,E10	E2,E4,E5,E6	1
(E3)	E2,E3,E4,E5,E7,E8,E9,E10	E1,E3,E5	E3,E5	
(E4)	E2,E4,E6,E7,E9,E10	E1,E2,E3,E4,E6,E7,E8,E9	E2,E4,E6,E7,E9	
(E5)	E2,E3,E5,E8,E10	E1,E2,E3,E5,E7,E8,10	E2,E3,E5,E8,E10	1
(E6)	E2,E4,E6,E10	E1,E2,E4,E6,E7,E8,E9,E10	E2,E4,E6,E10	1
(E7)	E2,E4,E5,E6,E7,E9,E10	E1,E3,E4,E7,E8,E9	E4,E7,E9	
(E8)	E2,E4,E5,E6,E7,E8	E1,E3,E5,E8,E9	E5,E8	
(E9)	E1,E2,E4,E6,E7,E8,E9,E10	E1,E3,E4,E7,E9	E1,E4,E7,E9	
(E10)	E2,E5,E6,E10	E1,E3,E4,E5,E6,E7,E9,E10	E5,E6,E10	

Table 9. Iteration II

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3,E4,E7,E8,E9,E10	E1,E9	E1,E9	
(E3)	E3,E4,E7,E8,E9,E10	E1,E3	E3	
(E4)	E4,E7,E9,E10	E1,E3,E4,E7,E8,E9	E4,E7,E9	
(E7)	E4,E7,E9,E10	E1,E3,E4,E7,E8,E9	E4,E7,E9	
(E8)	E4,E7,E8	E1,E3,E8,E9	E8	
(E9)	E1,E4,E7,E8,E9,E10	E1,E3,E4,E7,E9	E1,E4,E7,E9	
(E10)	E10	E1,E3,E4,E7,E9,E10	E10	2

Table 10. Iteration III

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3,E4,E7,E8,E9	E1,E9	E1,E9	
(E3)	E3,E4,E7,E8,E9	E1,E3	E3	
(E4)	E4,E7,E9	E1,E3,E4,E7,E8,E9	E4,E7,E9	3
(E7)	E4,E7,E9	E1,E3,E4,E7,E8,E9	E4,E7,E9	3

(E8)	E4,E7,E8	E1,E3,E8,E9	E8	
(E9)	E1,E4,E7,E8,E9	E1,E3,E4,E7,E9	E1,E4,E7,E9	

Table 11. Iteration IV

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3,E8,E9	E1,E9	E1,E9	
(E3)	E3,E8,E9	E1,E3	E3	
(E8)	E8	E1,E3,E8,E9	E8	4
(E9)	E1,E8,E9	E1,E3,E9	E1,E9	

Table 12. Iteration V

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3,E9	E1,E9	E1,E9	
(E3)	E3,E9	E1,E3	E3	
(E9)	E1,E9	E1,E3,E9	E1,E9	5

Table 13. Iteration VI

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3	E1	E1	
(E3)	E3	E1,E3	E3	6

Table 14. Iteration VII

ENABLER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
(E1)	E1,E3	E1	E1	7

Table 15. Level Constituents

Level 1 include:	Future viability of I 4.0 adoption (E2); Ability to address environmental challenges (E5) and customized customer requirements (E6).
Level 2 include:	Ability to satisfy the expectation of the society (E10).
Level 3 include:	Competitive global advantage (E4) and firm's innovativeness (E7).
Level 4 include:	Digital and Integrated Process capabilities (E8).
Level 5 include:	Financial performance (E9).
Level 6 include:	Government policies to support smart factories (E3).

Level 7 include:	Top management interest towards implementing I 4.0 (E1).

Table 16. Driver and dependency power of enablers identified

Factor	Driving Power	Dependency power
(E1)	10	2
(E2)	4	10
(E3)	8	3
(E4)	6	8
(E5)	5	7
(E6)	4	8
(E7)	7	6
(E8)	6	5
(E9)	8	5
(E10)	4	8