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MICMAC Analysis of Industry 4.0 in Indian Automobile Industry

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Industrial evolution has taken over as next generation technological breakthrough which is capable of achieving digitalization to ensure enhanced quality, safety and economics. This paper aims to highlight those factors that affect the functioning of the automobile industry. The objective is to find the effect of various factors contributed by Industry 4.0 in the Indian automobile sector through brainstorming with manufacturing experts and literature survey. Ten factors were found relevant. Generated responses were used to measure their influence with each other. Structural Equation Modeling (SEM) analysis was applied for this. Then MICMAC (Matriced'impactscroisés multiplication appliquée á un classment), a cross-impact matrix multiplication is applied to show the dependency of the variables thereby examining the strength of the relationship between Industry 4.0 factors based on their driving and dependence power.The outcome model categorizes the factors in such a way that their impact can be observed by the practitioner and make changes accordingly. Effective mitigation of challenges associated with these factors is envisaged to make it much simpler for the company to enhance their performance and competitive ability. The model reiterates the fact that advancement in technology drives the 4th revolution and other factors such as supply chain management, organizational structure, employment disruption, etc. affect each other at various stages of development.

Keywords: Interpretive structural model, Key enablers, Smart manufacturing, Sustainable development

Introduction

The very first industrial revolution began with the use of machines powered by steam, while the second by the substitution of electricity for steam and water, and the third by the information technology revolution. Industry 4.0 is bringing a new wave of "change" which will include advancement of manufacturing and operation techniques with smart information exchange, thereby creating a huge enterprise that would not only be autonomous and interconnected but also use real-time data to analyze and communicate with technologies that drive physical process more intelligently. It represents the innovative ways in which smart, connected technology would become embedded within people, assets and organizations. The adamant will be caused gradually with the introduction of upcoming fields of science such as analytics, robotics, Internet of Services (IoS), cognitive technologies and artificial intelligence, quantum computing, the Internet of Things (IoT), nanotechnology, advanced materials and additive manufacturing.[1]

Hermann *et al.*[2] in their research defined the concept of Industry 4.0 as: "a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industry 4.0, Cyber Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicates and cooperates with each other and humans in real time. Via the IoS, both internal and cross- organizational services are offered and utilized by participants of the value chain."

While a lot of focus is already on improvements in manufacturing due to the coming of Industry 4.0, there are a lot of transformations going on in other sectors as well.[3] Designing of parts and products, its manufacturing, proper usage and maintenance can also be transformed using new smart and connected technologies. It can also help in transforming organizations and their decision-making abilities of how they act upon different situations to achieve greater excellence in manufacturing, distribution and marketing areas.

Kamble *et al.*[4] identifies there will be many challenges which crucially require the automotive industry to introduce Industry 4.0 within the sector. It is really necessary to study these challenges as to how they will impact the industry and what steps can be

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taken in advance to tackle these challenges. Through this paper we will be going to study some of these challenges that will include both negative and positive changes in the automotive industry.[5] These can be illustrated below.

Employment disruption – As we all know that the introduction of new automated machinery in different sectors will replace the need for manpower on a large scale. But along with that there will be a need for more skilled people for building and managing such machinery. So, extensive manual work will be replaced through digitization and hence people working will lose their jobs. However technical jobs will rise in the service sector particularly at the management level.

Cyber security - Another challenge can be cyber physical attacks on robots especially in self driving cars. The mere possibility of getting hacked and transfer of control poses a threat to security and privacy of the owner. On the other hand, it is necessary to incorporate new technologies for better performance and increased efficiency of tasks.

Investments – The initial cost of infrastructure and services will be very high and right now Return on Investment (ROI) seems to be gradually profitable over a span of 10–15 years. This is also discussed briefly in the next section of this paper.

Aim and Objective

This paper aims to identify and classify various factors of Industry 4.0 that might create an impact on the Indian Automotive Industry. Contextual relationships are developed using Interpretive Structural Modeling (ISM) among various identified factors and then are classified using MICMAC analysis. This method is used to calculate the dependence or driving power of described variables.

Factors Affecting Automobile Industry

The most important component in inculcating Industry 4.0 is linking the architecture of digital technology with the framework laid from physical assets.[6] The target for such integration is to develop and build communication within the business processes.[7] The execution of high-end technologies like IoT, Cloud Computing and Cyber Physical Systems (CPS) in the domain of manufacturing industry, the companies looks for several factors which determine whether a company can incorporate them. These factors consist of profitable trade, strategic alignment, business processes, operation model changes, capability upliftment and end to end security. All of them are necessary to support the successful growth of the company.

This research uses articles and research papers for literature review obtained from several journals, discussing the impact of Industry 4.0 in the manufacturing industry (with function related or similar to automobile production) so that later they can be applied in the automotive sector in India.

Any new technology requires a skill set for which training is provided. The accessibility of necessary skills and competencies in a country's youth will have a substantial impact on the effective integration of Industry 4.0 at both the micro and macro levels. Maisiri *et al.*[8] mentions that the workforce's skills and capabilities will play a significant role in fostering organizational innovation and competitiveness. This shift towards introduction of technology must be a gradual one which will then be able to sustain in the society. This is further categorized into the levels of implementation, where each level has a unique phase of development requiring the workforce to improve their skill set. Some examples of professions and the associated skill development required are also mentioned by Benešová & Tupa[9]. In this context, Yet Schallock *et al.*[10] describes that Industry 4.0 should provide an outlet of human resource development, where people develop technological skills which are more future oriented.

Because of its fast (and often unanticipated) effects on the global economy, technological development is becoming increasingly difficult to quantify. This has generated competition among interested business players which in turn affects hiring priorities. Fareri *et al.*[11] emphasizes the effect of incorporating technology on work profiles and concluded that management jobs are the most affected. Another reason for employment disruption is that current research or studies carry information generically, which is not useful to apply in hiring in professional profiles, thereby reducing the essential integration of current talents.

Increased automation is being used in India's automobile sector. While most OEMs' plant-level mechanization remains around 30%, the degree of automation in the body shop has surpassed 95%. Automobile manufacturers are progressively implementing AI-enabled smart robots that can interfere and amend the designs by communicating, and interacting with one another and with people.

Now given the fact that India has the largest number of young workforce in the world, where 2/3rd of population comes under working age (15–59) and the unemployment rate fluctuating from 6–10% reiterates the question whether we as a country are ready or not. This implies that both skill development and employability act as a major obstacle with the advent of exponential technologies.[12]

Bernard Marr[13] has provided some light on a list of jobs which might seem to be threatened in reference to rise of efforts in advancement of upcoming scientific endeavours. These job profiles are: Healthcare, Insurance, Architecture, Finance, Journalism, Education, Human Resources, Marketing and Advertising, and some aspects of Judicial Services.

The future of jobs will depend how the country reacts to the 12 megatrends such as rising nationalism, quick adoption of digital innovation, expanding/shrinking global employment market for Indian labor, and degree of FDI flows. Companies must contend with shorter product life cycles, shorter commute time with the market and lowering costs as a result of ongoing globalization. As a result, traditional company methods are being surpassed and must be substituted with customer-centric and service-oriented business models. This entails redesigning organizational forms, adapting working techniques and hence personnel qualification, as well as management comprehension. Fettig *et al.*[14] mentions that companies will have notable challenges in terms of flexibility, agility, and inventive capability as a result of this digital transition. Workplaces will alter in compliance with the reorientation of business models along with corporate strategies resulting in shifting of work duties. This results in new interfaces, as well as the gradual disintegration of structural constraints in the organization causing hierarchies to change. Therefore, organizational structures will change and working culture must evolve to keep in line with the pace of technology advancements.[15]

A vast range of difficulties and profit margins are observed when the domain of Supply network is analyzed. Ghadge *et al.*[16] highlighted various impediments and proposed a framework for the efficient adoption and transfer of the industry 4.0 concept into supply chains. According to Wu *et al.*[17], digitalization is essential for Supply Chain (SC) systems to survive in today's highly dynamic and competitive corporate environment. The impact of wide range of technologies can be seen in this development of SC systems. They offer more accountability (being totally transparent in nature), enhance efficiency of tasks, adjust to adverse situations (high adaptability) and have robust built quality. The effects of Industry 4.0 can also be seen in SC Management (SCM) strategies. These strategies optimize and improve the precision of forecasting by increasing traceability of materials and products. Planning is more effective in nature and performance of supplier is enhanced by ensuring connectivity throughout the chain. It uses real-time data sharing to carry out processes like vehicular routing and intelligent warehousing.

Luthra & Mangla[18] inferred that SC parameters like material and equipment real time monitoring when coupled with Industry 4.0 enabled capabilities can help in improving the overall performance of the supply chain with the benefit of reduced risks. There are huge numbers of articles describing the practical deployment of these Industry 4.0 technologies, but there is relatively little information about their costs and other cost-related aspects.

This raises the need to analyze the ROI and its reliability calculation for sustainability ensuring large profits of Industry 4.0. Every organization must analyze and determine where the greatest opportunity for ROI exists and what may be the best techniques for achieving it.[19] As an example, the ROI for IoT can be derived from efficiency gains realized through useful insights offered by data collected from machines throughout the value chain. These real-time insights must be applied in a way that allows them to revolutionize corporate processes and business models. A majority of software companies require fast solutions provided by upcoming technologies and hence need to be cost effective.

Alami & ElMaraghy[20] demonstrated a brief cost-benefit analysis which highlights the finances incurred within the supply chain network in a production system. The cost analysis must include a discussion of sustainability. More and more businesses are aiming to lessen their environmental impact. Certain technical solutions may be beneficial to the company's performance and profitability, but can produce excessive environmental pollution (such as, 3D printed parts) throughout the manufacturing process. An overview of some cost influencing factors specified with respective technology is mentioned in Table 1.[(21)]

Table 1 — Cost influencing factors of different technologies

Technology	Important Cost influencers
IoT	Specific Hardware (Smart sensors and executors, Signal Processing systems), Software deployment and system integration(network expansion and security costs), Maintenance
Big Data	Data collection systems, Data storage and distribution system, Maintenance and support
Cloud Computing	External Service Provider, Cloud service (software, platform or infrastructure service), total capacity used (storage space), Location of Cloud, Full/Part time usage, future capacity trend (reduction or expansion)
Augmented Reality	Display Platform (Smart devices and Headset displays), Library packages, Development environment, Maintenance
3D printing	Machine Cost, Raw Material, Additional Equipment (customization), Product compactness, Maintenance

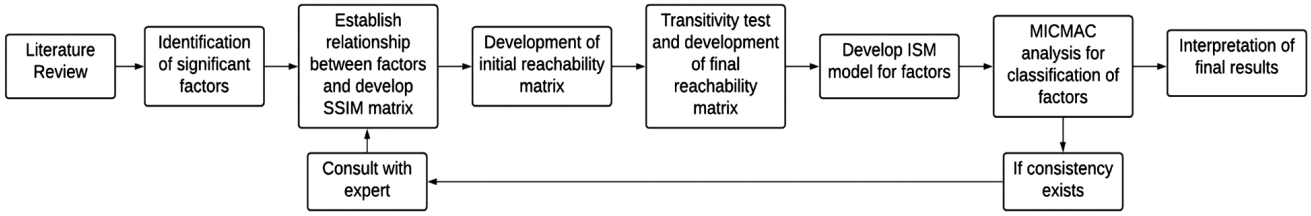

Fig. 1 — Step wise methodology depicting research process

The high availability of IT systems is a critical feature of every manufacturing firm. Various hardware and software businesses go to great lengths to guarantee that their products include security and authentication features[22], but each Industry 4.0 technology must keep security in mind.[23] There are many cases of security breach involved with software companies, even the tech giants like Microsoft and Google are attacked, so we can only imagine what threat we invite by digitalization of processes. In a technologically driven environment, cybersecurity plays a key role in protecting organizations from losing their competitive edge. The exposure to different types of cyber-attacks, which differ both in nature and degree of influence, may be able to disrupt the working of whole business model.[24]

Despite the innumerous benefits of Industry 4.0, there exist a lot of unsustainable practices associated with it because of increase in consumption of resources, information and energy. Such practices have made it difficult for the society to be ecologically viable, which in turn makes public sector to worry about environmental dangers. According to Burritt & Christ,[25] Industry 4.0 adds a beneficial influence towards environment through extensive digitalization, which enables accurate and quality rich management along with updated process management for the external side of environment.

Frédéric *et al.*[26] suggested a multi-functional model for decision-making process that describes levels of autonomy. Their extensive work shows that inter-related applications of Industry 4.0 are bound to increase the autonomy in production systems, including operators and production equipment. This is important to the notion of intelligent factories, and it's not unexpected that a number of experimental projects have focused on decision-making from database management in manufacturing across a wide range of topics including design, scheduling, planning, and processing.[27] This will result in faster and effective results without compromising quality of the product or service. Lucas *et al.*[28] provides a substructure for the division of Industry 4.0 into Decision Making (DM) and Quality Management (QM). The study extensively shows the different views of researchers and shows that decision making will be enhanced in the future with a sustainable practice of integration with upcoming trends.

Experimental Details

The methodology adopted to predict the effect of industry 4.0 on automotive industry by generation of ISM model is shown in Fig. 1.

Identification of Significant Factors Influencing Automobile Industry

From extensive literature work mentioned above, a list with 25 factors was selected. These factors were consulted and discussed upon with some industry experts. Through brainstorming from these experts, total of 10 final factors were selected suitable for this research:

1. Supply Chain Management[29]
2. Skilling and training[30]
3. Employment disruption[31]
4. Organisational structure [32]

5. Resource ranagement[33]
6. Environmental sustainability[34]
7. Advancement in technology[35]
8. Cost effectiveness[36]
9. Decision Making[37]
10. Security and privacy[38]

Interpretive Structural Model

In this research, ISM technique is utilized to investigate and describe the links between the identified factors that affect Industry 4.0. ISM is a well-established interactive method for organizing directly or indirectly connected variables into a unified framework. For this research we have used online software called Smart Interpretive Structural Modeling.[39] Following are the steps of methodology adopted in the ISM model.

- Identification and listing of factors affecting the system under consideration (Industry 4.0).
- Development of Structural Self-Interacting Matrix (SSIM) for the identified factors to show pair wise relationship among factors.
- Development of the initial Reachability matrix from SSIM.
- The Reachability matrix developed in 5 steps is partitioned into different levels.
- Finally, the hierarchies of the chosen factors are formed.
- Directed graphs are obtained by linking up the vertices or nodes and the resulting graph is converted to an ISM model.

Development of Structural Self-Interacting Matrix (SSIM)

As shown in Table 2, SSIM is built using contextual linkages formed amongst the factors after considering expert comments (using symbols V, A, X and O). After defining the link between two factors (i and j) and the direction of the relationship, we engaged to confirm the influence that had been identified. The associated orientation of the relationship between two factors is denoted by four symbols mentioned below.

Symbols to define relationships:

V → Row variable influences corresponding column variable

A → Row variable is influenced by corresponding column variable

X → Row and corresponding column variable influence each other

O → Row and corresponding column variable have no relationship

Formation of Initial Reachability Matrix (IRM)

In this step, the 4 symbols used in the SSIM namely V, O, A and X were replaced by binary values '1' and '0' (Table 3). The following rules were used for the substitution:

Table 2 — Structural self-interacting matrix SSIM

	Variables	1	2	3	4	5	6	7	8	9	10
1	Supply Chain Management		A	O	O	V	O	A	V	A	O
2	Skilling and Training			O	A	O	V	A	V	V	V
3	Employment disruption				A	A	O	A	O	A	O
4	Organisational Structure					O	O	A	O	A	O
5	Resource Management						V	A	V	A	V
6	Environmental Sustainability							A	O	A	O
7	Advancement in technology								V	V	V
8	Cost effectiveness									A	O
9	Decision Making										V
10	Security and Privacy										

Table 3 — Initial Reachability Matrix

	Variables	1	2	3	4	5	6	7	8	9	10
1	Supply Chain Management	1	0	0	0	1	0	0	1	0	0
2	Skilling and Training	1	1	0	0	0	1	0	1	1	1
3	Employment disruption	0	0	1	0	0	0	0	0	0	0
4	Organisational Structure	0	1	1	1	0	0	0	0	0	0
5	Resource Management	0	0	1	0	1	1	0	1	0	1
6	Environmental Sustainability	0	0	0	0	0	1	0	0	0	0
7	Advancement in technology	1	1	1	1	1	1	1	1	1	1
8	Cost effectiveness	0	0	0	0	0	0	0	1	0	0
9	Decision Making	1	0	1	1	1	1	0	1	1	1
10	Security and Privacy	0	0	0	0	0	0	0	0	0	1

Table 4 — Final Reachability Matrix

	Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
1	Supply Chain Management	1	0	1*	0	1	1*	0	1	0	1*	6
2	Skilling and Training	1	1	1*	1*	1*	1	0	1	1	1	9
3	Employment disruption	0	0	1	0	0	0	0	0	0	0	1
4	Organisational Structure	1*	1	1	1	1*	1*	0	1*	1*	1*	9
5	Resource Management	0	0	1	0	1	1	0	1	0	1	5
6	Environmental Sustainability	0	0	0	0	0	1	0	0	0	0	1
7	Advancement in technology	1	1	1	1	1	1	1	1	1	1	10
8	Cost effectiveness	0	0	0	0	0	0	0	1	0	0	1
9	Decision Making	1	1*	1	1	1	1	0	1	1	1	9
10	Security and Privacy	0	0	0	0	0	0	0	0	0	1	1
	Dependence Power	5	4	7	4	6	7	1	7	4	7	

1* denotes the change in value of the element from 0 to 1 by incorporating transitivity

- V, If 'i' is predictor of 'j', then (i, j) is 1 and (j, i) is 0
- A, If 'j' is predictor of 'i' then (j, i) is 1 and (ij)is 0
- X, If 'i' and 'j' predict each other then (i, j) is 1 and (j, i) is 1
- O, If no predict each other then (i, j) is 0 and (j, i) is 0

where,

- 'i' is row element
- 'j' is column element

Formation of Final Reachability Matrix (FRM)

Transitivity was applied in the initial reachability matrix as per the rule that if variable "a" is related to variable "b" and variable "b" is related to variable "c" then variable "a" will be necessarily related to variable "c". After performing transitivity, final reachability matrix was deduced by mentioning the transitive element as "1" instead of "0" (Table 4).

Level of Variables (Level Partitioning)

The Reachability set and Antecedent set were created (Table 5). Reachability set is the set of factors which a single factor influences or has influence upon. Antecedent set consists of the factor itself and the factors on which it depends. Out of these two sets, the common element is determined and placed in the intersection set. Level partition is now carried on this.

In level partitioning, the process of eliminating factors is done. For the first level, a factor in the reachability set is chosen which has the same elements as the intersection set. This factor or factors are then placed on 1st level and cancelled out from all the sets. Then this process is repeated for the second level ignoring all the first level factors and so on. Finally, all the level partitioning is done and now our model is ready.

MICMAC Analysis

MICMAC analysis is performed of the above mentioned 10 factors on the basis of driving and dependence power. Both powers are calculated by adding up the units in the respective rows for driving power and in respective columns for dependence power. In order to obtain the results, the components were classified to validate the interpretive structural model factors. The values hence obtained are plotted on a graph via the SmartISM[39] software as shown in Fig. 2.

Table 5 — Level Partitioning

Elements	Reachability Set	Antecedant Set	Intersection Set	Level
1	1	1, 2, 4, 7, 9	1	3
2	2, 4, 9	2, 4, 7, 9	2, 4, 9	4
3	3	1, 2, 3, 4, 5, 7, 9	3	1
4	2, 4, 9	2, 4, 7, 9	2, 4, 9	4
5	5	1, 2, 4, 5, 7, 9	5	2
6	6	1, 2, 4, 5, 6, 7, 9	6	1
7	7	7	7	5
8	8	1, 2, 4, 5, 7, 8, 9	8	1
9	2, 4, 9	2, 4, 7, 9	2, 4, 9	4
10	10	1, 2, 4, 5, 7, 9, 10	10	1

Results and Discussion

The data analysis provides a sense of how the factors are influencing this paradigm shift of Industry 4.0 in the Indian automobile industry. The model generated (from SmartISM[39]) has 5 levels of hierarchy (Fig. 3). The factor which influences the most is "advancement in technology" and hence it takes the bottom position at level 1. All the other factors are affected by it and any change in technology will result in changes in other factors. This is quite appropriate in considering that industry 4.0 is basically bringing more automation towards all the aspects of the auto-chain.

The 2nd level consists of 3 factors: skilling and training, organizational structure and decision making. These factors are equally likely to affect each other and the factors on level 3–5. With the onset of

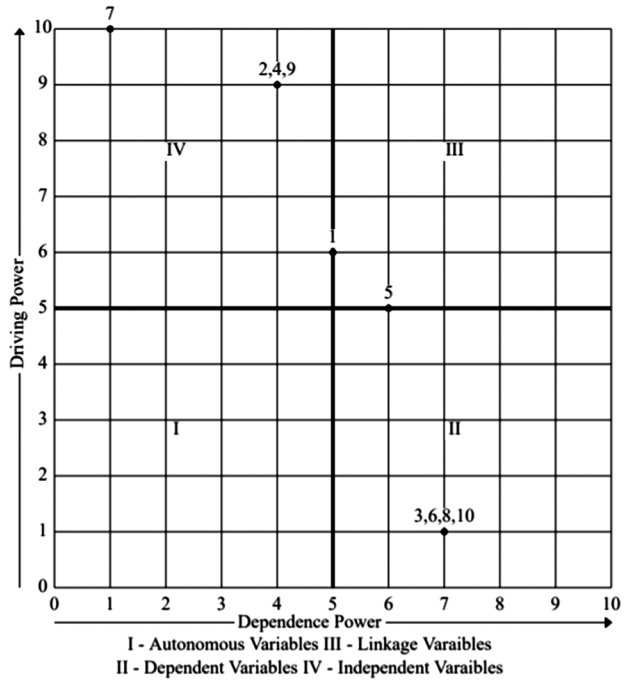

Fig. 2 — MICMAC analysis of factors affecting automobile industry

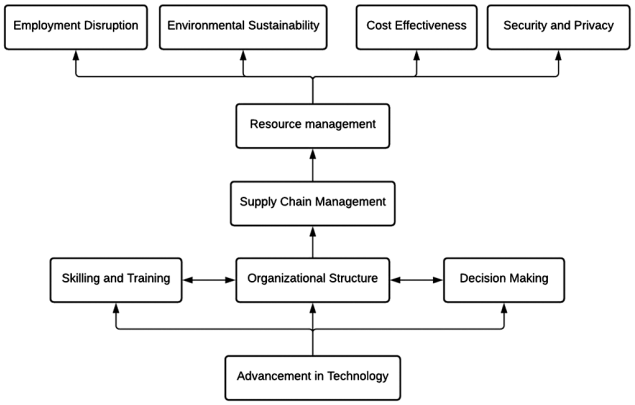

Fig. 3 — Final model generated-ISM based hierarchical model

an adamant technological revolution, a more skilled workforce has become a necessity. Enhanced skills for operation of machines and executive training are required to ensure the quality and reap benefits of Industry 4.0 technologies. Existing organizational structure will change with the introduction of robots or automated machines as employee's engagement with the product or services are impacted. Also, for every company, decision making is a very crucial and delicate matter as it helps in making thoughtful decisions through classifying and identifying useful information and defining alternatives.

The 3rd level comprises of Supply Chain Management. Given the importance of this factor, it has taken an optimal central place among all the factors. The only thing separating it from Resource Management at level 4 is the fact that SC has more driving power. It can be inferred that Supply Chain is the backbone of automobile market and various processes of SC affect the working of entire industry; from acquiring raw materials for manufacturing to product retail. Also, both these factors come under linkage variables (Fig 2), as they form a link between dependent (Level 5) and independent variables (Level 1 & 2).

The 5th level has 4 factors: Environmental sustainability, cost effectiveness, employment disruption and security and privacy. They have no influence on any other factor and changes in these factors will not impact others, but they have very important roles as they are most likely to predict the impact of Industry 4.0 on automobile industry. Any technological advancement results in indirectly affecting the environment. Among other environmental factors, most important concern is the waste disposal system. We are not yet capable of disposing off E-waste. Moreover, rise in population will cause resources to deplete fast and if we do not find a way to balance our needs and recycle products the results can be catastrophic. This calls for sustainable practices to ensure environment is not impacted with development.

The overall cost of manufacturing and machines is reduced if profits are analyzed for long term investment. Also, with current cyber threats highlighted with the digitalization, they have raised a high concern among the masses. In Industry 4.0 era, the command of the product or service ultimately remains with the authorized code personnel. Any compromise on security will affect the whole business operation, and in some cases safety of consumer will be affected. Secondly, the question of reliability raises that if something goes wrong with the product or service which party will be held accountable or who will be responsible for damage. On the other hand, job profiles in cybersecurity will be in high demand. The Indian Auto-market consists of massive capital and it provides a base for large amounts of employment opportunities. With the onset of digitalization and automation it is set to have an impact on these job platforms extensively. If changes in technology are

not adapted by any organization they might be outmatched by others in competitiveness.

The results conclude that advancement in technology will customize the Indian Automobile industry in every aspect of its structure. The influence degree of Industry 4.0 will be massive and transformational in nature. This calls for preparations so that India can grow in a sustained and economically efficient manner. There are various challenges associated with Industry 4.0 which needs to be addressed.

The MICMAC analysis allowed us to classify the factors into 4 quadrants with varying degrees of dependence and driving power. Factors 7, 2, 4 and 9 have a high percentage of driving power (7 being with the highest), whereas the factors with high percentage of dependence power are 3, 6, 8, and 10. Factors no. 1 and 5 are linkage factors which form a connection between the dependent and driving factors. Such classification allows us to clearly see which areas or factors should be focused upon and prioritized for improvement.

For Indian automobile industry, this model provides a better understanding of impact created by industry 4.0 by studying different factors of industry 4.0. Also, this study will help in taking preventive measures in order to lower the challenges and also to prepare for a new era of industry where many things will be automated. We have listed some factors like employment disruption & security and privacy. These factors will portray a negative impact on society. Having knowledge about these factors will help to determine their effect and then there can be multiple actions taken to improve the condition.

Conclusions

The objective of this study is achieved with the analysis of various factors of Industry 4.0 which will impact the automobile industry in India. Biasing of expert's opinions may be the limitation of this study. Findings may help the organizations to understand the impact of Industry 4.0 and will further aid in optimizing their strategies with the market accordingly. The study recommends that along with private players the government also needs to put initiatives for the smooth transitioning of Industry 4.0 and acts as a base for researchers to look into its effects.

In the future, SEM might be utilized to evaluate and validate this study's model. It is also suggested that researchers undertake a large-scale survey by expanding the data collection and increasing the number of facilitators in order to acquire better findings. More such research will greatly assist practitioners and industry personnel in improving organizational performance and more effectively achieving the intended organizational goals.

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