Transforming Indian Engineering Industries through Industry 4.0: An Integrative Conceptual Analysis

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ABSTRACT

The recent innovations in both industrialisation and informatisation technologies have culminated into a new generation of manufacturing paradigm. This manufacturing innovation promises mass customization due to flexibility in manufacturing, improved product quality and safety, new productivity levels, creation of smart products and services. Industry 4.0 is gradually making its presence felt in Indian Industries. Indian Engineering Industries being the largest segment in the Industry, holds immense potential if it embraces Industry 4.0. This research conceptually examines the effect of Industry 4.0 on Indian Engineering Industries on both the heavy and light engineering industries. ABCD framework is used to investigate the effect of Industry 4.0 in these Industries. The study finds that Indian engineering industry can be transformed to produce smart products and services, by the application of Industry 4.0. This is the first study to evaluate the effect of Industry 4.0 on Indian Engineering Industries. It also contributes to the theoretical need for evaluating the effects of Industry 4.0 in the developing world.

Keywords: Industry 4.0, Indian Engineering Industries, Fourth Industrial Revolution, Cyber-Physical Systems

1. INTRODUCTION:

The fourth Industrial revolution is also well-known as Industry 4.0, revolutionise the world of production and network connectivity through the "Cyber-physical systems (CPS)", "Internet of Things (IoT)" and "cloud computing" [1]. The first industrial revolution saw engineering production through the utilisation of steam and water-powers. The second industrial revolution utilised electrical energy for mass production. The third industrial revolution brought in electronic and information technologies to enable production automation [2]. The fourth industrial has brought in a paradigmatic shift through the advances in automation technologies through CPS, Cloud computing and IoT. Industry 4.0 thus marks the transformation from embedded systems to cyber-physical systems [3]. The integration of cyber-space with physical components (e.g. manufacturing machines) has become a reality due to tremendous advancement in the machine to machine communication using semantic technologies, embedded systems, IoT and CPS. These advances are creating a new generation of Manufacturing systems well-known as smart factories. It helps to deal with the intricacy of the production in a new cyber -physical situation. Industry 4.0 is thus a new generation of industrial systems featuring a technological concept called smart factories. One of the advantages of smart factory is that it is helping to deal with the complexity of the cyber-physical situations. The production and network link through IoT and CPS makes Industry 4.0 a reality [4]. Typically, Industry 4.0 is implemented in the organization by three levels of integration. The three types of integration found in Industry 4.0 are (a) "Horizontal integration", (b) the ""vertical integration" ", and (c) "end-to-end integration" [5]. The "vertical integration" is the digital connectivity of all functional department within an organization, that are included in the value chain of producing the product [6]. To cite an example activity such as marketing, design, engineering etc. are all integrated through a technological platform which will enable ease in distributing resources in the company effectively and efficiently to meet the value chain of product or service. “Horizontal integration” occurs when a company is digitally integrated with its partners, suppliers, distributors, and other elements which are external to the organization and are taking part in the value-creation process. In end-to-end integration, the digital integration has been designed around the different phases of product life cycle, such as introduction, growth, maturity, and decline. It begins with the machine to machine integration on the shop floor. The second step is customers are integrated with the organization e.g. manufacturing system and thirdly product to service concept is foreseen based on which the organization can monitor the products resulting in new business models [4, 6, 7]. The modern factory is thus becoming more complex and intelligent due to big data analytics, machine learning and cloud computing with the advent of Industry 4.0 [8]. Besides, the technology enablers such as IoT, CPS, “Industrial internet” etc. makes the modern-day workplace a complex phenomenon [9, 10]. Against this backdrop, it is worthwhile to examine the definition of Industry 4.0 from an implementation perspective to comprehend the strategic significance of Industry 4.0. One of most comprehensive definitions of Industry 4.0 till date has been created by Piccarozzi, Aquilani, and Gatti, 2018 [11] they define “*Industry 4.0 refers to the integration of Internet of Things technologies into industrial value creation enabling manufacturers to harness entirely digitized, connected, smart, and decentralized value chains able to deliver greater flexibility and robustness to firm competitiveness and enable them to build flexible and adaptable business structures, [acquiring] the permanent ability for internal evolutionary developments in order to cope with a changing business environment as the result of a purposely formulated strategy implemented over time*” [12, 13]. Thus, Industry 4.0 can be thought of as an important strategic tool organization can use to achieve a strategic competitive advantage for organizations in the market space [14]. The “United Nations Industrial Development Organization” posits that among the 10 global front runners in Industry 4.0, India is the only middle-income country which is rapidly transforming its production units using “Advanced Digital Production”(ADP) [15]. The growth of the Indian engineering sector has been remarkable, and this is evidenced by increased investment. To be a global superpower Government of India envisioned that be a superpower, exports should be increased. Therefore, it has constituted an entity known as Engineering export promotion council (EEPC). In the Indian Industry, the Indian Engineering Industries represent the largest segment. It is also India’s largest foreign exchange earner, as it contributes to 25% to Indian total exports in goods. It further has 30% weightage in India’s Index of Industrial Production (IIP) as reported by EEPC, (2020) [16]. The Indian Engineering Industries being labour & capital-intensive, the successful application of Industry 4.0, will lead to competitive advantage in both internal and external markets. Thus, the primary research question directing this study is

How can Indian Engineering Industries be transformed through Industry 4.0?

In the following section, we review the related works, objectives, Integrative conceptual analysis, Qualitative analysis through ABCD framework, recommendation, and conclusion.

2. RELATED WORKS

The main technological advances driving Industry 4.0 is IoT, CPS, and “Cloud computing” [5, 17]. Industry 4.0 also relies on smart devices and “Business process management BPM”. The fundamental difference between third and fourth industrial revolution is that in the third industrial relied on automation of business systems such as machines, processes, business units or departments Tan et al., 2010 [18]. However, Industry 4.0 relied on end-to-end digitisation as well as trying to find integrated solutions using the integration of digital systems [1]. The benefit of IoT in the production system will enable the creation of a virtual network for the design and operation of smart factory architecture [19]. Another prominent technology supporting Industry 4.0 is cloud-based manufacturing. It is a business model which emphasises to share manufacturing capabilities and resource on a cloud platform. In other words, it uses networked manufacturing resources in a distributed manner. The concept of manufacturing as service (MaaS) is making inroads even in developing countries [20]. The core establishment of Industry 4.0 is CPS. In simple words CPS is defined as system of collaborating computational units, which are connected to the physical world and surrounding other physical processes. Such a system is having both data accessing and data processing powers which enables its use in manufacturing systems. The physical and cyber systems are complexly intertwined in such a manner that higher level of coordination and integration is possible between physical and computational systems [21] in an organization. CPS will, therefore, be able to digitally connect with other machines and thus, forming a decentralised control system which will enable optimum use of manufacturing resources to gain a technological advantage. There are other technologies which have enabled realization of Industry 4.0 such as blockchain, "industrial information integration", "radio frequency identification (RFID)", "Global positioning system", Wifi, "near field communication (NFC)", cellular networks, etc. Smart manufacturing provides, a new opportunity for manufacturing firms to design, produce, source, inventory and maintain business systems using Industrial IoT, data science, analytical algorithms which have the power to analyse live data from several machines, processes and other related systems to attain the manufacturing goals. Many modern-day organizations have applied IoT and Industrial Internet of things (IIoT) in production, transportation, distribution,, service and maintenance [22]. IIoT has been integrated into all stages of product life cycle management. This enables data capabilities which can result in the improved design, manufacturability and the development of new services for the continued product usage [23].To sum up, Industry 4.0 implementation results in complex engineering problems, which needs to jointly optimised by both social and technical systems [24]. The complex problems of Industry 4.0 are solved through strategic collaboration, integration of CPS, analysing big heterogeneous data [25]. From a practical point of view, auto manufacturer used Industry 4.0 and it was fond that there was 10% reduction in capital investments. Besides, it also helped to reduce operating costs. Industry 4.0 implementation in semiconductor company suggested that 15% reduction in cycle time. Besides, it resulted in drastic reduction in equipment idle time. Also, it was further noted that equipment idle times was substantially reduced thereby increasing throughput and asset utilisation [26]. The UNIDO report posits that Industry 4.0 can foster inclusive and sustainable development for the organization, society and environment reported by UNIDO, 2020 [15]. From the Indian manufacturer perspective, Mr N Anbucheziyan, the General Manager(operations) from Caterpillar India, revealed that, "*Rather than just looking at the newer connected technology, we should look for sustainable and smart manufacturing. It has to be scalable in the future. MSMEs should work on four areas namely, smart innovation, smart factory, smart solutions and smart supply chain to ensure sustainable and smart manufacturing*." [27]. Therefore, Industry 4.0 has immense potential to transform Indian Engineering Industries. This study focusses on Indian Engineering industries because (a) In Indian Industry Engineering is the largest segment. It is the highest in terms of foreign exchange earner with India's 25% of total exports. (b) India has 63.4 million MSME units in India. (c) 100% FDI is permitted hence major companies such as Cummins, ABB, Schneider Electric, etc have invested in Engineering sector, (d) with global resentment towards China, India is seen as a next-best manufacturing hub, (e) It is estimated that the R& D market in India's will increase in the year FY22 to US $ 42 billion, (f) Government of India is inspiring organizations for technological upgradation so that manufacturing exports could be boosted, (g) Department of Heavy Industries has done a laudable work to popularise practical Industry 4.0 solutions through "Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH)- Udyog Bharat 4.0". A practical example of Industry 4.0 is noted in Mahindra & Mahindra and Bajaj have started using COBOTS in manufacturing line thereby relieving workers with physically demanding tasks [28]. Industry 4.0 model plant is set up by GE, India at Chakan. The concept of factory is practically demonstrated by smart Henkel Adhesives Technologies in India [29]. (h) Amidst these reports, there is also a concern raised that Industry 4.0 is still in the nascent stages in India and many Industries have not implemented it. Many MSME are still to understand what is smart manufacturing? [27]. (i) Exports are a major focus of Indian Engineering industries, therefore, for the products to be competitive Industry 4.0 implementation cannot be ignored, (j) In a study which explored the awareness of Industry 4.0 in south India, it was found that term " Mass Customization" was not known to 60 % responding citizens and "Industry 4.0" was not known to 49.6%. This suggests general awareness about Industry 4.0 in Indian society is very low towards [30]. Therefore, there is a need for a study which analyses the impact of Industry on Indian Engineering Industries.

3. OBJECTIVE OF THE STUDY:

This paper emulates a research-based prediction model to conceptually analyse and identify the suitable model in the form of a Theory to answer a question on *How can Indian Engineering Industries be transformed through Industry 4.0?* It tries to identify

1. To conceptually analyse the implementation Industry 4.0 in Indian Engineering Industries
2. To qualitatively analyse the implementation of Industry 4.0 using ABCD framework

4. INTEGRATIVE CONCEPTUAL ANALYSIS:

Indian Engineering Industry has been broadly divided into two segments heavy and light engineering goods. Heavy engineering industry consists of capital goods and consumer durables. Some of the examples of heavy engineering products are power generation equipment, industrial machinery or capital goods, aircraft building, transport equipment, rail equipment, and ship building [31]. The light engineering goods assembly parts that form a vital part of various types of machineries used in engineering, automobile, saddlery, and other industries. It includes air-brakes, drum, LPG cylinders, switch gears, electric motors, exhausters manufacturing of barrels, lamps, containers, cables machine tools components & instruments, teleprinters, watches, telephones, tractors, etc [32]. Thus, an integrative analysis is carried out to investigate the impact of Industry 4.0 on Indian Engineering Industries by carrying out a thematic analysis of prior literature for conceptual understanding.

4.1 Strategic competitive advantage for Indian Engineering Industries

It will be a tough time for the traditional manufacturers in the new era, as Industry 4.0 implementation will result in the creation of smart products and services [11]. IT will be an integral part of every product, as such, it creates unique business opportunity in every stage of the product life cycle [33, 34]. The big data which would be at the disposal will create an opportunity of product servitization [35]. Thus, now manufacturers will have an opportunity to extend services for the products they sell creating new business models. Moreover, Industry 4.0 firms will now compete vigorously to create customer segmentation, product differentiation, value-added services, dynamic price setting and closer customer relationships [36]. Heavy industries which constitute 80% of the total industry in India will now facilitate the creation of smart capital goods and consumer durables. Light industries will also profit from Industry 4.0 in terms of product differentiation of goods such as smart diagnostic medical equipment. The early birds will have a competitive advantage and will set the market standards. Therefore, Industry 4.0 implementation will create a strategic competitive advantage for Indian engineering firms in both domestic and international markets.

4.2 Indian Engineering Industries will be efficient and effective

Effectiveness of an organization is the ability of an organization to meet its objectives or goals and efficiency is the amount of output for an input. Industries due to the implementation of Industry 4.0 will be able to build a reconfigurable flexible manufacturing system [10]. This will create a new industrial ecosystem which will result in organizations to integrate, appropriate, adapt, both internal physical & information subsystems, in addition, to utilise the external organizational competence, to reduce losses in resources and improve organizational efficiency [37]. Additionally, it will create an efficient handling of supply chains [38]. The "product-centric value creation" would be achieved in all stages of the product life cycle [39]. Implementing Industry 4.0 will establish a competitive advantage in terms of producing high quality products and services, dynamic pricing ability due to use of big data, producing customised products and services [11] Such a strategy may result in increased market share for Indian Engineering Industries in both internal and external markets. Consequently, the slump in demand experienced by Indian Engineering Industries due to COVID -19 pandemic or any similar incidences would be negated in the long run due to the efficiency and effectiveness of the organization.

4.3 Improving Indian Engineering Industries Agility

Organizational agility is well-defined as the ability of an organization to respond to uncertainty in the market place, through rapid response, to transform this into an opportunity, by creating innovative products and services [40]. Therefore, organizational agility has two components quickness and innovativeness. Industry 4.0 enactment would result in networked manufacturing systems. It therefore warrants hierarchical levels of value- creation in an organization through the integration of aggregation. The networking of manufacturing systems with other functional departments within the organization such as production, sales or marketing and will create a unique opportunity to quickly respond to customer needs. The big data generated due to the networking will enable organizations to understand and innovate to create innovative products and services [35]. The digitalization of supply chain in Industry 4.0, thus will enable manufacturing and delivery of the customised products through unique delivery channels [39]. The heavy engineering industries can, therefore, use Industry 4.0 to be agile and deliver products & services to meet customer needs. This feature of Industry 4.0 will enable organizations to deal with uncertainty during this pandemic, as Indian engineering industries will be able to bring out capital goods, consumer durables quickly and innovatively.

4.4 Manufacturing Innovation through Industry 4.0 for Indian Engineering Industries

Industry 4.0 implementation entails an introduction of innovative technologies such as IoT, CPS, Cloud manufacturing, additive manufacturing etc creating a new manufacturing paradigm which was unheard in traditional manufacturing. The ability to deal with high mix and low volumes is one such ability, which traditional manufacturers would have never conceived [34, 41, 42]. This capability will enable Indian engineering industries, to innovate and expand the market segment catered by the traditional organization [27]. Furthermore, they would be able to compete on various dimensions in international and national markets in both heavy and light engineering segments.

4.5 Long-run profitability through Industry 4.0 for Indian Engineering Industries

The implementation of Industry 4.0 entails the implementation of vertical, horizontal, and end-to-end integration of organizations. This philosophy is actuated using various architecture for the development of CPS. One of the popular architecture is 8C which include connection, cyber, cognition, conversion, configuration, coalition, content and customer [43, 44]. The connection component deals with the connection of machines through sensors for acquiring various parameters of machines for accurate data. The conversion component of architecture relies on converting this data to information. The cyber component is a massive hub of the integrated cyber system. It is basically used for analysing, prediction, monitor the performance of machines connected in the cyber system. AI algorithms are used to further refine the information for decision making in cognition component. The configuration part is configuring the physical systems to actuate the decision made in cognition component. The coalition component integrates the product value chain and designs an integration mechanism for linking production process to value chains. The content part is used for storing product information which can be used for storing, extracting, and enabling product traceability. The customer part is linking the customer to the organization. The product usage data, customer needs and preferences are relayed back to the organization. To design such a mechanism a huge initial investment is required. These are fixed costs and will not vary with the quantity of units of products produced. Besides, there would also be operating cost which will vary with the quantity of units of products produced. By implementing Industry 4.0 the operating cost component will be lower than traditional manufacturers. In the long run, the fixed costs will break even as there would be less number of defects, less material waste, optimum allocation of resources, reduced operating personnel, reduced human errors, etc [37, 45]. Over the long term, the Indian engineering industries implementing Industry 4.0 will be break even the costs and be monetarily successful. The initial investment must be managed by the industries. The Government of India along with various banking and non-banking financial institution provides support for Industries through various programs. Besides technical know-how is provided through Department of science and technology and the Department of Heavy Industries [27]. The Government of India has thrown open a leading programme through the ministry of skill development and entrepreneurship called “Pradhan Mantri Kaushal Vikas Yojana (PMKVY)” to promote skills in Industry 4.0 PMKVY, 2016 [46]. The Indian Engineering Industries both light and heavy in the long run due to the increased customer base, extended markets will find implementing Industry 4.0 profitable.

4.6 Improving Indian Engineering Industries Product Quality & Safety

Product quality is an important dimension customer consider while purchasing a product or service [47]. Implementing Industry 4.0 will entail organizations to manufacture products and services with close dimensional tolerance and that too without defects [48]. The concept of quality will be built into the product at every stage, as through sensors vital parameters will be monitored [49], therefore the likelihood that defective items going to next stage would be minimised. The data from products usage such as quality failure incidences, product recall data, monitoring dimensional tolerances and quality characterises throughout all the phases of the product life cycle will further improve the product safety in Industry 4.0 era [50]. Product quality and safety is an important dimension, which enables organizations to enter into export markets [51]. Indian engineering industries will, therefore, benefit from Industry 4.0, as the new improved manufacturing quality and product safety, will improve the image of the organization in both domestic and international markets. Besides, the new standards of quality & safety will benefit the heavy engineering industries to compete in European Union and US markets vigorously with other competitors because product quality and safety are one of the main dimensions for entering into export markets. The light engineering industries will also benefit from it, as most of them are suppliers to heavy industries, and it will help them to pass the heavy industries quality and safety requirements. Besides, manufacturers of medical diagnostic equipment's will benefit immensely to enter markets which are at present dominated by other Asian counterparts.

4.7 Indian Engineering Industries improving customer experience through Industry 4.0
Consumption of product or service entails an experience for the customer. An encounter of customer with product or company or any constituent elements authorised by the company will instil in customer a set of experience who warrants a reaction. The experience is subjective and it involves various constituent such as physical, rational, emotional, spiritual and sensorial [52]. Satisfied customer experience is vital for organizations to maintain a competitive advantage. The technology is the base component for customer experience, in a classical pyramid model, where other components being (a) company-employee, (b) company-customer, and (c) employee-customer interactions [53]. The application of Industry 4.0 in Indian Engineering Industries will enable the organization to use technology component to maximum advantage to make the interactions between customer and product or company a satisfying experience. In terms of customer-product relationship, there will be customer supports at their fingertips, smart digital assistants to help them to understand the various features of products. In terms of the customer–company interaction, there will be sea change as organizations will be able to customise the service experience based on customer need, as product usage data will be at the disposal of organizations.

4.8 Indian Engineering Industries improved operations
Industry 4.0 implementation will result in organizations taking lesser time to bring a product into the market. This is because design, production, marketing, finance, sales and other departments are interconnected through a cyber system [54]. All forms of resource waste are now accounted for digitally at every stage, this gives the organization a continuous improvement tool which is data-driven and hence the operations are immensely improved. Smart product manufacturing through intelligent manufacturing systems reduce wastes, reduced scrap rates, fewer quality defects, reliable production systems and improved production efficiency [55]. Manufacturing cost is a sizeable component in the heavy engineering industry. Indian Engineering Industries will, therefore, benefit from improved operations and efficient production. This will help heavy engineering industries to decrease the manufacturing charge and shorter throughput time. Heavy industries will thus be cost-efficient and compete on cost dimensions in the international market to improve the market share.

4.9 Environmental and Social Benefits for Indian Engineering Industries
The carbon footprints are monitored and well managed in Industry 4.0 because data regarding emissions are digitally monitored and appropriate control actions are taken using intelligent algorithms through [56]. "Additive manufacturing" is the procedure of joining materials using 3D model data in layer by layer. "Additive manufacturing" is production cost is lower and the time taken to produce is also less to make the product. The advantages of this type of manufacturing is reduced energy use, occupational health, waste, reduced environmental life cycle impact [57]. The new-age production process with ROBOTS and COBOTS will help to carry out manually challenging tasks. Besides the monotonous jobs will also be carried out by these intelligent machines thus socio technically improving the quality of work [24, 58]. The Indian engineering industries following the implementation of Industry 4.0 will see a reduction in emission levels thereby performing well on the environmental dimension. Besides, occupational stress and hazards in heavy engineering industries will be mitigated through the implementation of Industry 4.0.

4.10 Challenges for Indian Engineering Industries for Implementing Industry 4.0
The internet connectivity in India is a challenge, especially in rural areas. If the industry is in rural areas, the large amount of data which needs to be transmitted over industrial ethernet, due to Industry 4.0 implementation will be a challenge. In 2019, India was ranked 79th in the "network readiness index" [59]. However, this is set to change with "India's trillion dollar digital opportunity" an initiative of

"Ministry of Electronics and Information technology" is set to address the connectivity challenges so that India can transform into a digital economy [60]. The huge initial investment is a challenge for Indian Engineering Industries. In the year 2019-20, the exports dropped by 6% from India. In addition, the performance in March 2020, has been dismal due to Covid-19 pandemic [16]. During these challenging times finding the initial investment for implementing Industry 4.0 would be a challenge. Firms usually invest in technology when the competition is scarce in the market space Rodrigues at al., 2010 [61]. When the market is very competitive due to globalisation in engineering exports, it will be a challenge to motivate engineering industries to go for structural changes in products while implementing Industry 4.0. Another challenge for the engineering firms would be changing the existing business model to incorporate Industry 4.0 implementation. This further warrants changing the existing business models for traditional organizations, to derive maximum benefits from the fourth industrial revolution [62]. Indian Engineering Industries have at present well tested business models and business capabilities. Motivating them to change the business model may sometimes need a lot of rethinking and strategizing which needs immense top management support. Therefore, it could be a challenge for organizations to convince the stakeholders. Trade union are quite strong in India to protect the interest of workers [63]. Implementation of Industry 4.0 will warrant taking into confidence the trade unions as existing workforce may feel threatened by automation suggested in Industry 4.0. Organizations must strategically deal with trade union to convince them of its socio-technical benefits [64]. Cybersecurity is another aspect organization fear because Industry 4.0 implementation will put sensitive information about the organizations products and services online [65]. Miscreants can hack the information to create an undue advantage for some firms or create the loss to host firm. "Data Security Council of India (DSCI)" is setup by "NASSCOM" and the industry authority on data protection and data safety in India. It is committed to making the cyberspace safe [66]. Also, the Government has set up the cybercrime police stations in every state of India, therefore instilling confidence in Industries about cyber safety [67]. Finding skilled workforce to implement Industry 4.0 is a major challenge most organizations face around the world [68]. The skill requirement in Industry 4.0 is more polarised towards ICT and traditional engineering disciplines will have to orient core engineering skills towards ICT [69]. However, the "Government of India" has launched the "Pradhan Mantri Kaushal Vikas Yogana" [46], and the primary aim is to skill the youths to make them employable. Such initiatives of Government will naturally help engineering industries with talent acquisitions.

5. QUALITATIVE ANALYSIS OF INDUSTRY 4.0 IMPLEMENTATION IN INDIAN ENGINEERING INDUSTRY THROUGH ABCD FRAMEWORK:

ABCD framework stands for the acronym Advantages, Benefits, Constraints, and Disadvantages is developed by Aithal et al., (2015) [70]. It is well-known model for analysing various business and engineering decision. It is evidenced by a host of research publications using the ABCD framework [70–74]. This study uses the framework to analyse Industry 4.0 implementation in Indian Engineering Industry.

5.1 Advantages

1. It gives a strategic competitive advantage in terms of producing high quality, low cost, high variety of smart products & services
2. Improves organizational efficiency and makes it effective to meet organizational goals
3. The organization will be able to respond to uncertainty in the marketplace through swift response strategy
4. Smart manufacturing will make an organization innovative
5. Long-run profitability of the organization

5.2 Benefits

1. The organization will be able to produce high quality products and services
2. Customers will experience satisfied product and service consumption
3. New standards of operational excellence through integrated automation
4. The organization will meet environmental standards
5. The organization will be sustainable in social dimension such as improving quality of work life

5.3 Constraints

1. Internet connectivity is a challenge as India is ranked 79th in World Network Index
2. Huge initial investment
3. Technology Acquisition & Management
4. The requirement of ICT skilled workforce
5. The trade union must be strategically managed else it may create unrest

5.4 Disadvantages

1. Some workers may be unemployed because they will not be able to learn ICT polarised skills.
2. Threats of cyber-attacks on Industries sensitive data
3. Small scale manufacturers might find technology acquisition for Industry 4.0 a herculean challenge
4. Radical change initiative and hence workers may sometime resist Industry 4.0 implementation
5. Training & retraining of workers may be costly

6. IMPLICATIONS FOR THE INDIAN ENGINEERING INDUSTRIES:

During the times of pandemic when the exports are dwindling and the demand for heavy and light engineering products are taking a downturn, Industries may find it difficult to embark on the implementation of Industry 4.0. However, the pandemic may be a blessing in disguise as many advanced countries such as the US and UK wants to take away the manufacturing base from China [75], this creates a huge opportunity for Indian Engineering Industries. Therefore, implementation of Industry 4.0 will be big motivation for these countries to invest in India. The "Government of India" is doing their part by allowing 100% FDI in Indian Engineering Industries [16] and also promoting Industry 4.0 through Department of Heavy Industries, Department of Science & Technology and others. It is now up to the Indian Engineering Industries to capitalise on this opportunity and implement Industry 4.0. This study has reviewed previous literature to conceptually analyse the application of Industry 4.0 in Indian Engineering Industries. The study finds a lot of merits for these organization to implement Industry 4.0 in terms of gaining strategic advantage in the dimensions of cost, quality, customization, reliability, etc. Besides, it will make Indian Engineering Industries more efficient and effective to produce heavy and light engineering goods. The organization agility will also be improved drastically with the implementation of Industry 4.0 and this facet will help the organization to deal with uncertainty in the marketplace. The operational excellence after implementation of Industry 4.0 will attain new levels standards unimagined in traditional manufacturing organizations because of implementation of the smart manufacturing. The organizations will contribute to a reduction in environmental emissions as Industry 4.0 will monitor the emission levels and proactively self -regulate through cyber-physical systems to reduce the environmental impacts. The hazards and ergonomically unsafe activities would be automated and therefore, the health of workers would be preserved. A point Indian engineering Industries should consider is that the issue of the initial investment. The investment must be strategically managed with both banking and other financial institutions as in the long run the operating cost would be substantially reduced, and it will break even. Indian Engineering Industry should consider that change in inevitable and the pandemic has brought in new opportunity for doing business digitally. Therefore, it is up to the organizations to strategically implement Industry 4.0 to gain long term financial and non-financial rewards.

7. CONCLUSIONS:

Industry 4.0 is a buzzword in both academic and industrial circles. It is making its presence gradually in developing countries, as it warrants huge initial investments. Indian Engineering Industries is the biggest segment in the Indian Industry and is also the largest foreign exchange earner. It contributes to 25% of total goods exports, therefore the implementation of Industry 4.0 in both heavy and light engineering industries will have a sizeable impact on the Indian Economy. This study has conceptually evaluated the implementation of Industry 4.0. Besides, ABCD framework was used to further analysis the feasibility of Industry 4.0. The study finds that Indian Engineering Industries will strategically benefit with this initiative and will help to capture new markets.

REFERENCES:

[1] Xu, L. Da, Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962.

[2] Ziaei Nafchi, M., & Mohelská, H. (2020). Organizational Culture as an Indication of Readiness to Implement Industry 4.0. *Information*, *11*(3), 174.

[3] Khan, A., & Turowski, K. (2016). A survey of current challenges in manufacturing industry and preparation for industry 4.0. In *Proceedings of the First International Scientific Conference "Intelligent Information Technologies for Industry"(IITI'16)* (pp. 15–26). Springer.

[4] Sony, M., & Naik, S. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An International Journal*. https://doi.org/https://doi.org/10.1108/ BIJ-09-2018-0284

[5] Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*. Forschungsunion.

[6] Chen, Y. (2017). Integrated and intelligent manufacturing: Perspectives and enablers. *Engineering*, *3*(5), 588–595.

[7] Sony, M. (2018). Industry 4.0 and lean management: a proposed integration model and research propositions. *Production & Manufacturing Research*, *6*(1), 416–432.

[8] Saldivar, A. A. F., Li, Y., Chen, W., Zhan, Z., Zhang, J., & Chen, L. Y. (2015). Industry 4.0 with cyber-physical integration: A design and manufacture perspective. In *Automation and computing (icac), 2015 21st international conference on* (pp. 1–6). IEEE.

[9] Cheng, G.-J., Liu, L.-T., Qiang, X.-J., & Liu, Y. (2016). Industry 4.0 development and application of intelligent manufacturing. In *Information System and Artificial Intelligence (ISAI), 2016 International Conference on* (pp. 407–410). IEEE.

[10] Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination. *Computer Networks*, *101*, 158–168.

[11] Piccarozzi, M., Aquilani, B., & Gatti, C. (2018). Industry 4.0 in Management Studies: A Systematic Literature Review. *Sustainability*, *10*(10), 3821.

[12] Prause, G. (2015). Sustainable business models and structures for Industry 4.0. *Journal of Security & Sustainability Issues*, *5*(2), 159–169.

[13] Koether, R. (2018). *Taschenbuch der Logistik*. Carl Hanser Verlag GmbH Co KG.

[14] Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard business review*, *93*(10), 96–114.

[15] UNIDO. (2020). *Industrial Development Report 2020. Industrializing in the digital age*. Retrieved from https://www.unido.org/resources-publications-flagship-publications-industrial-development-report-series/idr2020

[16] EEPC. (2020). *Indian Engineering Electrifying Growth*. Retrieved from http://www.eepcindia.org/download/IndianEngineeringBrochure-200819124444.pdf

[17] Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, *6*(4), 239–242.

[18] Tan, W., Xu, Y., Xu, W., Xu, L., Zhao, X., Wang, L., & Fu, L. (2010). A methodology toward manufacturing grid-based virtual enterprise operation platform. *Enterprise Information Systems*, *4*(3), 283–309.

[19] Peruzzini, M., & Stjepandic, J. (2017). Editorial to the special issue -Enterprise modelling and system integration for smart manufacturing. *Journal of Industrial Information Integration*, 1-3.

[20] Li, B.-H., Zhang, L., Wang, S.-L., Tao, F., Cao, J. W., Jiang, X. D., … Chai, X. D. (2010). Cloud manufacturing: a new service-oriented networked manufacturing model. *Computer integrated manufacturing systems*, *16*(1), 1–7.

[21] Lee, Bagheri, B., & Kao, H.-A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters*, *3*, 18–23.

[22] Tao, F., Wang, Y., Zuo, Y., Yang, H., & Zhang, M. (2016). Internet of Things in product life-cycle energy management. *Journal of Industrial Information Integration*, *1*, 26–39.

[23] Cai, H., Da Xu, L., Xu, B., Xie, C., Qin, S., & Jiang, L. (2014). IoT-based configurable information service platform for product lifecycle management. *IEEE Transactions on Industrial Informatics*, *10*(2), 1558–1567.

[24] Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technology in Society*, 101248.

[25] Schuh, G., Potente, T., Wesch-Potente, C., Weber, A. R., & Prote, J.-P. (2014). Collaboration Mechanisms to increase Productivity in the Context of Industrie 4.0. *Procedia Cirp*, *19*, 51–56.

[26] Arm, I. B. M. (2017). The Internet of Things Business Index 2017, Transformation In Motion. *The Economist, Intelligence Unit Limited*, 1–22.

[27] Molly, R. (2020). Industry 4.0: A great future. *Manufacturing Today India*. Retrieved from https://www.manufacturingtodayindia.com/sectors/6089-industry-40-a-great-future

[28] René Van Berkel. (2020, August 22). India well-poised for digital transformation of manufacturing. *The Economic Times*. Retrieved from https://economictimes.indiatimes.com/small-biz/sme-sector/india-well-poised-for-digital-transformation-of-manufacturing/printarticle/77428990.cms

[29] Geeta Nair. (2020). Industry 4.0: Pune can be epicentre of fourth industrial revolution. *financial express*. Retrieved from https://www.financialexpress.com/industry/industry-4-0-pune-can-be-epicentre-of-fourth-industrial-revolution/1865006/

[30] Safar, L., Sopko, J., Dancakova, D., & Woschank, M. (2020). Industry 4.0—Awareness in South India. *Sustainability*, *12*(8), 3207.

[31] IBEF. (2020). Indian Engineering Industry Analysis. *India Brand Equity Foundation*. Retrieved from https://www.ibef.org/industry/indian-engineering-industry-analysis-presentation

[32] DPE. (2014). Medium and Light Engineering Enterprise. *Department of Public enterprise*. Retrieved from https://dpe.gov.in/sites/default/files/6-Vol2_medium%26lightengineering_11_0.pdf

[33] Sony, M., & Naik, S. (2019). Ten Lessons for managers while implementing Industry 4.0. *IEEE Engineering Management Review*.

[34] Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., … Schroter, M. (2015). Industrie 4.0-Readiness. *Impuls-Stiftung des VDMA Aachen-Köln*, *52*(1), 1–77.

[35] Ennis, C., Barnett, N., De Cesare, S., Lander, R., & Pilkington, A. (2018). A Conceptual Framework for Servitization in Industry 4.0: Distilling Directions for Future Research. In *The Advance Services Group Spring Servitization Conference 2018*. Aston University and Higher Education Academy.

[36] Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard business review*, *92*(11), 64–88.

[37] Sony, M. (2020). Pros and cons of implementing Industry 4.0 for the organizations: a review and synthesis of evidence. *Production & Manufacturing Research*, *8*(1), 244–272.

[38] Rajnai, Z., & Kocsis, I. (2018). Assessing industry 4.0 readiness of enterprises. In *2018 IEEE 16th World Symposium on Applied Machine Intelligence and Informatics (SAMI)* (pp. 225–230). IEEE.

[39] Cimini, C., Pezzotta, G., Pinto, R., & Cavalieri, S. (2018). Industry 4.0 Technologies Impacts in the Manufacturing and Supply Chain Landscape: An Overview. In *International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing* (pp. 109–120). Springer.

[40] Carvalho, A., Sampaio, P., Rebentisch, E., Carvalho, J. Á., & Saraiva, P. (2017). Operational excellence, organisational culture and agility: the missing link? *Total Quality Management & Business Excellence*, 1–20.

[41] Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*(1), 54–89.

[42] Wan, J., Yi, M., Li, D., Zhang, C., Wang, S., & Zhou, K. (2016). Mobile services for customization manufacturing systems: an example of industry 4.0. *IEEE Access*, *4*, 8977–8986.

[43] Jiang, J.-R. (2018). An improved cyber-physical systems architecture for Industry 4.0 smart factories. *Advances in Mechanical Engineering*, *10*(6), 1–15.

[44] Saldivar, A. A. F., Goh, C., Chen, W., & Li, Y. (2016). Self-organizing tool for smart design with predictive customer needs and wants to realize Industry 4.0. In *2016 IEEE Congress on Evolutionary Computation (CEC)* (pp. 5317–5324). IEEE.

[45] Rubmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*.

[46] PMKVY. (2016). Pradhan Mantri Kaushal Vikas Yojana (PMKVY). Retrieved from http://pmkvyofficial.org/

[47] Herrmann, A., Huber, F., & Braunstein, C. (2000). Market-driven product and service design: Bridging the gap between customer needs, quality management, and customer satisfaction. *International Journal of production economics*, *66*(1), 77–96.

[48] Schmidt, R., Möhring, M., Härting, R.-C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015). Industry 4.0-potentials for creating smart products: empirical research results. In *International Conference on Business Information Systems* (pp. 16–27). Springer.

[49] Chiarini, A. (2020). Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research. *The TQM Journal*, 32(4), 603-616.

[50] Li, C. H., & Lau, H. K. (2017). A critical review of product safety in Industry 4.0 applications. In *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 1661–1665). IEEE.

[51] Howells, G. G. (2018). *Consumer product safety*. Routledge.

[52] Gentile, C., Spiller, N., & Noci, G. (2007). How to sustain the customer experience:: An overview of experience components that co-create value with the customer. *European management journal*, *25*(5), 395–410.

[53] Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans*, *30*(3), 286–297.

[54] Rudtsch, V., Gausemeier, J., Gesing, J., Mittag, T., & Peter, S. (2014). Pattern-based business model development for cyber-physical production systems. *Procedia CIRP*, *25*, 313–319.

[55] Meyer, G. G., Wortmann, J. C., & Szirbik, N. B. (2011). Production monitoring and control with intelligent products. *International Journal of Production Research*, *49*(5), 1303–1317.

[56] Peukert, B., Benecke, S., Clavell, J., Neugebauer, S., Nissen, N. F., Uhlmann, E., … Finkbeiner, M. (2015). Addressing sustainability and flexibility in manufacturing via smart modular machine tool frames to support sustainable value creation. *Procedia CIRP*, *29*, 514–519.

[57] Rejeski, D., Zhao, F., & Huang, Y. (2018). Research needs and recommendations on environmental implications of additive manufacturing. *Additive Manufacturing*, *19*, 21–28.

[58] Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In *Management of permanent change* (pp. 23–45). Springer.

[59] NRI. (2019). Network Readiness Index. *Portuland Institute*. Retrieved from https://networkreadinessindex.org/

[60] MEiTy. (2020). *India's Trillion Dollar Digital Oppurtunity*. Retrieved from https://www.meity.gov.in/writereaddata/files/india_trillion-dollar_digital_opportunity.pdf

[61] Rodríguez-Ardura, I., & Meseguer-Artola, A. (2010). Toward a longitudinal model of e-commerce: Environmental, Technological, and Organizational Drivers of B2C Adoption. *The Information Society*, *26*(3), 209–227.

[62] Weking, J., Stöcker, M., Kowalkiewicz, M., Böhm, M., & Krcmar, H. (2020). Leveraging industry 4.0–A business model pattern framework. *International Journal of Production Economics*, *225*, 107588, 1-17.

[63] Singh, J., Das, D. K., Abhishek, K., & Kukreja, P. (2019). Exploring the pattern of trade union activity in the indian manufacturing sector. In *Globalization, labour market institutions, processes and policies in India* (pp. 87–107). Springer.

[64] Davies, R., Coole, T., & Smith, A. (2017). Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *Procedia Manufacturing*, *11*, 1288–1295.

[65] Dawson, M. (2018). Cyber Security in Industry 4.0: The Pitfalls of Having Hyperconnected Systems. *Journal of Strategic Management Studies*, *10*(1), 19–28.

[66] Kesharwani, S., Sarkar, M. P., & Oberoi, S. (2019). Cyber Security in India: Threats and Challenges. *CYBERNOMICS*, *1*(2), 32–34.

[67] Kethineni, S. (2020). Cybercrime in India: Laws, Regulations, and Enforcement Mechanisms. *The Palgrave Handbook of International Cybercrime and Cyberdeviance*, 305–326.

[68] Pinzone, M., Fantini, P., Perini, S., Garavaglia, S., Taisch, M., & Miragliotta, G. (2017). Jobs and Skills in Industry 4.0: An Exploratory Research. In *IFIP International Conference on Advances in Production Management Systems* (pp. 282–288). Springer.

[69] Frey, C. B., & Osborne, M. A. (2017). The future of employment: how susceptible are jobs to computerisation? *Technological forecasting and social change*, *114*, 254–280.

[70] Aithal, P. S., Shailashree, V., & Kumar, P. M. (2015). A new ABCD technique to analyze business models & concepts. *International Journal of Management, IT and Engineering*, *5*(4), 409–423.

[71] Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). ABCD analysis of Stage Model in Higher Education. *International Journal of Management, IT and Engineering*, *6*(1), 11–24.

[72] Aithal, P. S., Shailashree, V., & Kumar, P. M. (2016). Application of ABCD Analysis Framework on Private University System in India. *International Journal of Management Sciences and Business Research*, *5*(4), 159–170.

[73] Aithal, P. S. (2017). ABCD Analysis as Research Methodology in Company Case Studies. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *2*(2), 40–54.

[74] Aithal, P. S., & Kumar, P. M. (2016). CCE Approach through ABCD Analysis of 'Theory A'on Organizational Performance. *International Journal of Current Research and Modern Education (IJCRME)*, 1(2), 169-185.

[75] Kumar, N. (2020). Tie up with US, UK firms planning exit from China over coronavirus: Gadkari to industry captains. *Business Today*. Retrieved from https://www.businesstoday.in/current/corporate/tie-up-with-us-uk-firms-planning-exit-from-china-over-coronavirus-gadkari-to-industry-captains/story/401961.html