Sustainable value addition to Micro, Small, and Medium Enterprises (MSMEs) in India: A review of Industry 4.0

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Abstract - **Rising Energy cost and ecological awareness driving enterprises to put energy efficient production processes as their top priorities. Energy is the main driver for enhancing economical growth of nations. Numerous concepts are emerging with rapid progress in industry, technology and applications in manufacturing sector among them digital transformation is one of it. Digitization accelerating the enterprises and the governments to instigate an evolutionary journey toward the fourth industrial revolution called Industry 4.0. A numbers of manufacturing enterprise in India are still in Industry 2.0 stage regarding innovation and technology capabilities. A systematic review analyzes endeavours taken by Indian government to address the challenges in adopting industry 4.0 in MSMEs. This paper reviews potential of current manufacturing trends in MSMEs and main drivers for improving sustainability, productivity, and lower energy intensity in enterprises.**

Keywords: MSME. Digitization. Industry4.0. Energy Intensity. Productivity. Sustainability

I. INTRODUCTION

Energy is the effective strength to every nation for enhancing economic growth. Energy is the major inputs to any MSMEs. Nowadays competitiveness enhancing among enterprises for business at national as well as global levels. Enterprises fostering self- improvement which will leads to their advancement in the long-run also it facilitates improvement at all the steps of value addition in the manufacturing activity.

Most of the MSMEs in India are failing in achieving energy targets due to poor management, high energy intensity, traditional manufacturing practices and the energy efficiency is well lower that of other industrialized countries. MSMEs should overcome barriers by implementing Energy management techniques, adopting advanced technologies that decline their energy intensity overall and enhance economic growth. Energy management incorporates energy efficiency exercises, techniques and management of related procedures leads to lower operation and production energy cost. Enhancing energy management leads to increased productivity as well as sustainability.

Industry 4.0 is known as fourth industrial revolution is the main driver for achieving high economical benefits in manufacturing sector in future. It is the strict integration of human in the manufacturing process so as to have steady improvement and mainly focus on value adding activities and avoiding wastes. It modifies the regular machines to self-aware and self- learning machines to improve their overall execution and maintenance management with the surrounding interaction.

Industry 4.0 provides immense opportunities for the realization of sustainable, eco-friendly and resource saving manufacturing (Stock & Seliger 2016). The main purpose of this work is to analyze the potential of sustainable manufacturing and gearing Indian MSMEs towards Industry 4.0. This paper shall reduce the gap of knowledge by gathering and analysing current manufacturing methods in MSMEs, which the limited research on this topic has identified so far.

II. REVIEW OF MSMES AND INDUSTY 4.0

A.MSMEs:

MSMEs are pivotal in the times when policies like Make in India and Start-up India are boost manufacturing and young entrepreneurship in India. MSMEs are usually reliant on the locally endowed natural resources, and are therefore environmentally cognizant. For most MSMEs, short-term profits are usually preferred over long-term gains. This makes it difficult to sell the 'business' argument that greater efficiency and

higher material recovery leads to improved profits in the long run.

The energy intensity per enterprise of production is higher in industrial MSME segments that of the comparing large enterprises partly due to the use of obsolete technologies and poor management practices, and partly because many of the enterprises escape regulatory ambit. Most of the MSMEs initiate renovation and modernisations to upgrade their firms to be competitive and eco friendly. Many of firms are facing barriers pertaining to innovations in small and medium enterprises also technology information and information on markets in India (Pachouri & Sharma, 2016). They are many obstacles in adopting technological capabilities and up gradation are not an end in itself. A recent report by the National Skill Development Council of India forecasts that there could be an incremental shortfall of 240-250 million people by 2022, in 20 high growth sectors of the Indian economy, and in the unorganised segment. The government has to take efforts to reduce skill gaps amongst MSMEs to promote the concept of inclusive growth. (CII, 2011). One of major barrier to small and medium firms to be innovative is unavailability of skilled workers (Pachouri & Sharma, 2016). As reported by BRICS India 2016, 30 Employees who were rendered jobless due to elimination of low skilled jobs need to be re-skilled or upgrade their skills to make them in adopting and facing new opportunities.

MSMEs capacity to adapt to the new innovative change is constrained by several factors like lack of technical expertise, shortage of funds and poor access to skilled manpower. The advancement of technology through evolution of Industry 4.0(Fourth Industrial Revolution) further adds to the already existing obstacles of MSMEs. The barriers faced in adopting these technologies have been distinguished and an analysis has been done of the various techniques and policy options available in promoting Industry 4.0.

Cluster development approach is the key strategy for enhancing the productivity and competitiveness in Micro, Small, and Medium Enterprises (MSMEs), one of the best practices adopted by Government of India (GOI). The GOI has been taking several measures to promote the adoption of Industry 4.0. The adoption of industry 4.0 is expected to play a very important role in the development process. Many case studies of Industry 4.0 have to be studied clearly in greater depth rather than blindly following the foot prints of some of the developed nations.

The GOI review at small and medium enterprises (SMEs) under the Micro, Small and Medium Enterprises Development Act 2006, to improve competitiveness of MSMEs as a whole. In the act, for the first time, the concept of "enterprise" has been made to include both manufacturing and services firms. Also described in the act, for the first time, is the concept of "medium" enterprises.

The high costs involved in meeting a large number of regulatory requirements tend to negatively affect the innovation capacity of the firms. For ensuring better targeting of enterprises at the bottom of the pyramid in economy, it is crucial for India to consider these concerns in new definition of MSMEs.

On February 2018, Ministry of MSMEs revised the definition of MSMEs in India and categorize enterprises on the basis of their annual turnover, as against the earlier classification based on investment in plant and machinery for goods companies, and in equipment for services firms. The new definition is definitely a step forward towards using the criteria that is more commonly used at a global level to define MSMEs – Annual Turnover. This act boosted entrepreneurs to upgrade their firms to improve economic growth and productivity of firms.

Table 1:

Classification of enterprises as Micro, Small and Medium (Currency in Indian Rupees)

Type of Enterprises	2006 Act		2018 Act
	Manufacturing	Services	All Enterprises
	Investment in Plant and Machinery	Investment in Equipment	Annual Turnover
Micro	25 Lakh	10 Lakh	5 Crore
Small	25 Lakh to 5 Crore	10 Lakh to 2 Crore	5to75 crore
Medium	5 to 10 Crore	2 to 5 Crore	75 to 250 crore

(Govt. of India Micro, Small and Medium Enterprises Development (Amendment) Bill, 2018)

B. Role of energy in MSMEs:

Energy is essential to all sectors of economic growth and development of nation. It is essential to accomplish economic, social, and environmental objectives of sustainable human development (Kumar and Vimala, 2016). Energy management will enhance competitiveness among enterprises (Posch et al., 2015). For developed and developing countries main driving forces if economic growth is the relationship between use of energy and economic growth (Pokharel, 2006). A review reported by Schulze et al. Stated that energy management leads to large energy consumption which remains untapped in industries. Energy

management is considered as a combination of energy efficiency activities, techniques, and management of related processes which result in lower energy costs and CO 2 emission (Kannan and Boie, 2003). Most of MSMEs pay little attention about their energy usage and potential to save it. Improvement of energy efficiency will have not only micro but also macro benefits. At the firm level, it will decrease the expense of production of individual MSMEs enterprises and at the total dimension it will cut down or diminish the growth of demand for energy from the MSMEs part sector as a whole. This is agreeable, as the previous will add the cost benefits to Small Scale Industries (SSI) while the latter will call for less energy related investments at the national level (Bala Subrahmanya, 2006).

C. Journey of Industrial revolution:

The first industrial revolution depends on coal, metallurgy, textile in this way mechanics production with the steam machines. It begins in Great Britain at the end of the eighteenth 18th century.

The second industrial revolution began at the end of the eighteenth 19th century, discovers its establishments in the power, mechanics, the oil and the chemistry that is mass production with the arrival of electricity.

The third revolution is the automated production with the programmable logic controllers (PLC) and robots. It produced amidst the twentieth century whose dynamic originated from electronics, telecommunications, computing. On account of the miniaturized materials production, robots and automation the production turns out to be progressively better and the improvement of advances is continual. It started in the United States, then Japan and the European Union, the third industrial revolution has seen rise also Internet, in the twilight of the twentieth 20th century.

Industry 4.0 or the fourth industrial revolution is taking shape before our eyes at the beginning of the 21st century. It is the current trend of automation and data exchange in manufacturing technologies.

Fig.1 History of Industrial revolutions

Currently, the industrial value creation inside the early industrialized countries is shaped by the improvement in the direction of the fourth stage of industrialization, the so-called Industry 4.0. Industry 4.0 refers to the collaboration of Internet of Things (IoT) technologies into industrial value creation enabling manufacturers to harness absolutely digitized, connected, smart, and decentralized value chains (Hartmann & Halecker, 2015; Kiel et al., 2016). Industry 4.0 is a technological evolution from embedded systems to cyber-physical production systems.

The principles of Industry 4.0 are the horizontal and vertical integration of production systems driven by real-time data interchange and flexible manufacturing to enable customised production (Thoben et al., 2017). The most significant components of Industry 4.0 are cyber-physical systems (Drath and Horch, 2014), the internet of things, cloud manufacturing, and additive manufacturing (Kang et al., 2016).

The integration of shop floor and top floor via suitable cloud services which might be more promising for SMEs. The efforts which have to be taken to get this kind of seamless integration between the two different world's top-floor and shop-floor also have to be taken into consideration. It will support a holistic problem-based learning environment. The Industrial Internet of Things (IIoT) poses several implications on manufacturers in terms of economic, ecological, and social aspects referring to the Triple Bottom Line (TBL) of sustainable value creation. An area where IoT will play a major role is in smart meters, thus enabling energy consumption data collection in real time (e.g. at machine, production line and facility level). In order to improve energy efficiency, this data will then have to be integrated in the production management practices and decisions. These data can be used to improve product functionality and performance (Stock & Seliger 2016).

D. Components of Industry 4.0:

Cyber-Physical Systems (CPS), which involves sensors, data processing units, and actuators, establish the technological core of the Industrial Internet of Things (IIoT). Due to their reconciliation into industrial manufacturing, they are also labelled as Cyber-Physical Production Systems (Schlechtendahl et al., 2015), which encourage condition monitoring, predictive maintenance, remote diagnosis and control of production facilities (Lee et al., 2013). Cyber-physical systems are technological systems which integrate cyberspace with physical processes and objects in order to transform machines and devices of production lines and cells into a network, so that

real-time data is available for making decisions such as the prioritisation of production orders, optimisation of tasks, maintenance requirements, etc. (Lee et al., 2015). Sensors and actuators are employed to gather and distribute this data in real-time. These information can be utilized to enhance product functionality and execution (Stock & Seliger 2016).

The internet of things is an information technology infrastructure which enables the collection and transmission of data between devices, resulting in identification, localization, tracking, and monitoring of objects (Li et al., 2017). Bar codes, wireless sensors and Radio Frequency Identification (RFID) are all examples of technologies which contribute to the ever-expanding reach of the internet of things (Zhang et al., 2017).

Cloud manufacturing refers to a virtual network in which providers supply manufacturing resources and customers can access their services – such as product design, simulation, and testing – on-demand. The manufacturing resources available become services which are currently; the industrial value creation inside the early industrialized countries is shaped by the improvement in the direction of the fourth stage of industrialization, the so-called Industry 4.0.

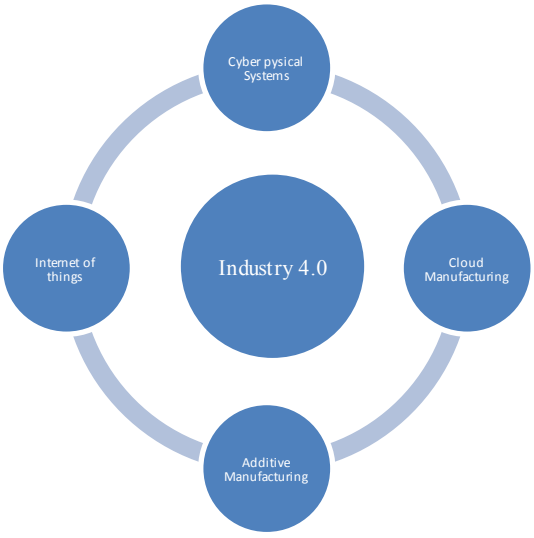

Fig 2: Components of Industry 4.0(adapted from Jabbour et al. 2018)

Additive manufacturing is the manufacturing of product components without the need for specialised tools and construction capabilities; it represents the flexible and connected prototyping of product components on a large scale, facilitating customisation (Holmström et al., 2016). 3D printers are the main resources currently associated with additive manufacturing.

E: Physical Cyber system CPS the basis of the Industry 4.0

This concept describes the vision of intelligent factories which is characterized by complete networking of all parts to produce that is main the real-time control of the production chain through the of information and communication techniques and also by the installation of robots which are more and more numerous in the enterprises.

But most commonly it is described as an "ecosystem of technologies monitoring the status of physical objects, capturing meaningful data, and communicating that information through networks to software applications".

To make use of these data, for example to generate forecasts and enable companies to take fact-based decisions, it is important to consolidate and evaluate these data in an intelligent way (Sauter et al. 2015). Consequently companies must face the challenge to develop smart predictive informatics tools to manage big data. If this challenge will succeed then smart factories producing smart products with the aid of CPS and the IoT, collecting smart data at each step of production, will be enabled to self-organize each required manufacturing

Not only is Industry 4.0 not defined uniformly and thus is not clear-cut, but we are also not talking about a single technological innovation, but rather a combination of various technologies that can only unleash their full potential together.

F. Impact of Industry 4.0 adoption in MSMEs:

Recognizing the continuing competitive pressures, small enterprises are becoming increasingly proactive in improving their business operations, which is a good starting point for introducing new concepts of Industry 4.0. This leads to the implication that the successful implementation of an industrial revolution Industry 4.0 has to take place not only in large enterprises but in particular in SMEs. It is a key means to enhanced productivity.

The Ministry of Micro, Small & Medium Enterprises is implementing a "Digital MSME" Scheme for promotion of Information & Communication Technology (ICT) in MSME Sector and motivate MSMEs to adopt ICT tools and applications in their business processes. The scheme is revolving around Cloud Computing which is emerging as a cost effective and viable alternative in comparison to in-house IT infrastructure installed by MSMEs. In cloud computing, MSMEs use the internet to access common as well as tailor-made IT infrastructure

including Applications/Services which can greatly help MSMEs in almost every facet of their business. ICT applications have become essential for any enterprise that has to sustain or grow in a global environment.

A great challenge for the future lies in the transfer of Industry 4.0 concepts and technologies to micro, small, and medium sized enterprises. Industry 4.0 adoption can be achieved through the use of many technologies. However, these technologies are not well mastered by MSMEs. As the range of technological options increases MSMEs will have to take advantage of developments towards networked production. Other-wise their international competitiveness could be threatened**.** Despite the enormous economic potential of Industry 4.0 SMEs in industry remain relatively cautious about it.

G. Possibilities to adopt Industry 4.0 in MSMEs:

Nation growth can be attributed to the growth of Information and communications technology (ICT) sector. The sector was predominantly driven by software services; however, most upcoming Indian start-ups in the ICT sector are product-based companies. Although an emerging concept, in this new era, smart devices assume major control over manufacturing and distribution functions in the economy.

With these characteristics, the IIoT aims at coping with current challenges manufacturers are facing, e.g., increasing volatility of markets and complexity as well as shortening innovation cycles. Furthermore, the IIoT is expected to imply more efficient value creation, flexibility, and customization of products and services. Also, ecological and social benefits are predicted, e.g., reduced energy consumption, waste reduction, and adaptive working environments (Kagermann, Wahlster, & Helbig, 2013; Lasi et al., 2014)

The industry 4.0 is a consequence of this progress in order to maximize the sustainable development, but the passage of the industry on the basis of automated systems to the industry sustainable connected called Industry 4.0 requires three essential conditions:

The technological condition: The computer tools and indispensable industrial to migrate from the Industry 3.0 to the Industry 4.0 are already present (at least a large part, they will be mature in 2020). It remains only the industry capacities to invest massively, and the computer and automation experts communicate between themselves in easy way and intelligible. Its realization is dependent on standardization which plays a crucial role.

The cultural condition: Several countries have already got the industrial strategies in the long term, but some actors are not open enough for this change in particular sustainable development. A true ambition of all these actors and especially the politicians is a key to success. They have an important role to play in the reform and the adaptation of the training of engineers, managers and technicians in order to familiarize themselves with the industry 4.0.

The organizational condition: the old companies' organizational architecture based on the organization in silos must be substitute to go to the interdisciplinary organization, which is main the work must be collaborative between technicians, computer scientists and engineers' teams in order to move from tasks achievement to projects management.

H. Obstacles to adopt Industry 4.0 in MSMEs:

SMEs often do not have their own IT department, which means that the managers themselves have to assess the various Industry 4.0 technologies with regard to their technological maturity and business potential. These differences may also be the reason why small and medium- sized enterprises frequently encounter difficulties in selecting the right solution and complain of a lack of user transparency.

The biggest challenges that small and medium-sized enterprises have to meet in this context are the development of an appropriate strategy, a cost–benefit analysis of the relevant technologies and lack of data security and uniform standards.

The reservations of small and medium-sized enterprises with regard to switching to new Industry 4.0 technologies and moving forward with the integration of the various IT systems can also be attributed to the lack of standards and norms, but also to worries about unauthorised access to data.

The integration of the data generated in the value creation process requires the networking of various IT systems both within and beyond the company. In this way functional areas such as procurement, production and sales can exchange their data in real time. It is not easy for small and medium-sized enterprises, due to lack of resources, to assess the technological maturity of the relevant solutions and their business uses.

Management lacks a methodical approach to implementation. MSMEs are weak on investment capacity and operational performance, with high costs and subpar on time delivery compared to large companies. SMEs manly have short-term

strategies, which do not favour long term investments.

The challenge for small and medium-sized enterprises is to create flexible organisational structures and to boost their employees' interdisciplinary thinking. Employees' existing qualifications and experience thus have to be deployed in the introduction of Industry 4.0 and enabled to reflect on production processes and to bring about continuous improvements.

It can be expected that in future small and medium-sized enterprises will (have to) call in external expertise more frequently, whether with regard to decisions on IT investments or the identification of relevant technological trends.

I. Enablers for success on Industry 4.0 transformation in MSMEs:

Businesses must understand the importance of continually measuring and driving the evolution of the i4.0 enterprise. That makes it imperative to implement *critical enablers* for success on i4.0 transformation: new metrics and incentives, new skills, change management, governance, cyber security and more.

Fig 3: Enablers for success on i4.0 transformation in MSMEs

A qualified workforce is indispensable for the development, introduction and utilisation of Industry 4.0

The readiness and ability of the MSMEs to introduce Industry 4.0 also depends on the framework conditions.

The financial environment, the availability of skilled workers, extensive and high-performance broadband access, state support and legal framework conditions are all key factors here. The development and introduction of Industry 4.0 technologies may require substantial investment. A use case for the retrofitting of manufacturing equipment as a specific opportunity for sustainable manufacturing in Industry 4.0.

The main research question to be addressed is

- What are Industry 4.0 requirements and suitable concepts for SMEs?
- How can promising Industry 4.0 concepts be adapted to the needs of SMEs?
- What are suitable Industry 4.0 implementation strategies and organization models for smart SMEs?

Industry 4.0 is still visionary but a realistic concept which includes Internet of Things, Industrial Internet, Smart Manufacturing and Cloud based Manufacturing (Saurabh Vaidya et al. 2018). Currently available Smart Manufacturing (SM) and Industry 4.0 maturity models, and analyze their fit recognizing the specific requirements of Small and Medium-sized Enterprises (SMEs) was reported by Sameer Mittal et al., (2018). They identified characteristic for SMEs and identify research gaps needed to be addressed to successfully support manufacturing SMEs in their progress towards Industry 4.0. The results shows that only a limited number of the SM and Industry 4.0 roadmaps, maturity models, frameworks and readiness assessments that are available today reflect the specific requirements and challenges of SMEs. It provides insights that help towards developing a realistic SM (Industry 4.0) maturity model for SMEs that reflects their industrial realities more accurately. It ultimately lower the entry barrier, and reduce the risk of the transition process towards SM and Industry 4.0 and support the critical change in culture.

Several key factors influence the industrial production such as the instability of the market, the short duration of the life of the product, the individualization of the product and globalization was reported by Mohammed Bakkari and Abdellah Khatory (2018). The work intended to emphasize the importance of the strategic vision of the industrial countries to the Horizon 2030, and the relationship between the industry 4.0 and sustainable development in order to ensure the sustainability of resources and its benefit for future generations. In addition, it focused on the main conditions to migrate from the Industry 3.0 to the Industry 4.0 based on the Internet of Objects (IoT) and the cyber physical system(CPS).

MSMEs have a significant contribution on overall economy and importance was stated by Pillai Lalitha Srinivasan and Kailas Kadu (2018). The world is now witnessing the fourth industrial revolution in the form of Industry 4.0. However significant numbers of manufacturing enterprises in India are still in Industry 2.0 stage with respect to

technology. They concluded that, it is necessary to develop and adopt an appropriate strategy wherein India could reap the benefits of demographic dividend along with Industry 4.0.

The Industrial Internet of Things (IIoT) poses several implications on manufacturers in terms of economic, ecological, and social aspects referring to the Triple Bottom Line (TBL) of sustainable value creation was reported by Daniel Kiel et al., (2017). The comprehensive and structured picture of IIoT-related economic, ecological, and social benefits and challenges are presented. For this purpose, the authors employ an exploratory multiple case study approach based on semi-structured expert interviews in 46 manufacturing companies from three leading German industries. They have justified that sustainable industrial value creation, the IIoT requires an extension of the established TBL by three further dimensions, i.e., technical integration, data and information, and public context.

Tortorella and Fettermann (2017) have reported that adoption of Industry 4.0 technologies has been deemed as a strategy to increase product quality and make manufacturing processes more efficient. However, the way that these technologies are integrated into existing production systems and which processes they can support is still under investigation. Thus, the work examines the relationship between lean production (LP) practices and the implementation of Industry 4.0 in Brazilian manufacturing companies. To achieve that a survey carried out with 110 companies of different sizes and sectors, at different stages of LP implementation. Data collected were analysed by means of multivariate analysis. The findings indicate that LP practices are positively associated with Industry 4.0 technologies and their concurrent implementation leads to larger performance improvements.

Industrial production is currently undergoing a fundamental transformation, leading towards a digitalized and interconnected industrial production, which is subsumed under the term Industrial Internet (of Things) or Industry 4.0 was reported by Grischa Beier et al., (2016). They discussed the changes that digitalization is expected to bring about in the industrial sector by comparing a highly industrialized (Germany) with a major emerging industrial economy (China). They conducted two empirical surveys asking manufacturing companies from different sectors in Germany and China respectively, how they expect the digitalization of their processes will affect them. Both questionnaires addressed the future of work in production and the future of production itself. An investigation of how the digitalization of industry is likely to affect sustainability aspects of manufacturing companies in two countries with very different industrial structures. They conclude that, this transformation will not only impact the ecological dimension (resource efficiency, renewable energy), but that the technical transformation is likely to be accompanied by social transformations.

Erskin Blunck and Hedwig Werthmann (2017) have analyzed the potential of Industry 4.0 applications to realize a more sustainable manufacturing and to create a circular economy (CE). Case examples show that companies were started to capitalize on the potential of emerging technologies to rearrange production, services, business models or whole organizations in a more sustainable way. This has shown by analyzing the value drivers of Industry 4.0, the potential of rearranging value chains and emerging business models. Overall, smart products and Industry 4.0 technologies could generate significant economic, environmental and social benefits and are able to contribute to strive towards a CE. Software Defined Networking (SDN) is a technology that comes with a proposal of flexibility and agility for the communication networks which fits with the challenges of Industry 4.0 was reported by Theo Lins et al. (2017). They used SDN paradigm to achieve Energy Efficiency as applied to Industry 4.0. Simulation results validated and showed the benefits of using SDN in Industry 4.0.

III. CONCLUSION

The fourth Industrial Revolution is making headway globally and India is no exceptions to it. The government efforts to promote industry 4.0 are largely confined to large and MSMEs in the organized sector, where significant section of MSMEs operate in Unorganized sector. Many manufacturers are still unaware of Industry 4.0. A Significant numbers of manufacturing enterprise in India are still in Industry 2.0 stage with respect to technology. Many MSME are far behind 2.0 as well because of lack of awareness, access to technology and due to shortage of huge funds. The MSME has almost nil access to technology of 4.0. So this study bridges these obvious gaps in the literature. To conclude, the analysis provided substantial evidence to infer that process innovations of SMEs enable them to achieve reductions in energy intensity and thereby improve energy efficiency, productivity and sustainability. The findings of this paper will help decision-makers in the political sphere to anticipate and shape pathways towards a more sustainable future in the industrial sector.

REFERENCES:

[1] BalaSubrahmanya, M.H.(2006),"Labour productivity, energy intensity and economic performance in small enterprises :a study of

brick enterprises cluster in India", Energy Conversion and Management, Vol.47No.6,pp.763-77.

[2] CII. (2011). *Innovation: Changing the MSMEs Landscape.*

[3] Daniel Kiel, Julian Müller, Christian Arnold and Kai-Ingo Voigt" Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0", XXVIII ISPIM Innovation Conference – Composing the Innovation Symphony, Austria, Vienna on 18-21 June 2017.

[4] de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., & Godinho Filho, M. (2018). When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. Technological Forecasting and Social Change, 132, 18-25.

[5] Guilherme Luz Tortorella and Diego De Castro Fettermann" Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies" International Journal of Production Research, 2017.

[6] H. Lasi, P. Fettke, H.-g. Kemper, T. Feld, M. Hoffmann, Industry 4.0. Business & Information Systems Engineering 6 (2014) 239-242.

[7] Hartmann, M., & Halecker, B. (2015) *Management of Innovation in the Industrial Internet of Things*. Proceedings of the 26th International Society for Professional Innovation Management Conference (ISPIM), Budapest: 1-17.

[8] J. Lee, Industry 4.0 in Big Data Environment. German Harting Magazine (2013) 8-10.

[9] J. Schlechtendahl, M. Keinert, F. Kretschmer, A. Lechler, A. Verl, Making existing production systems Industry 4.0-ready. Prod. Eng. Res. Devel. 9 (2015) 143-148.

[10] Jan Holmström and Timothy Gutowski. (2017). Additive Manufacturing in Operations and Supply Chain Management: No Sustainability Benefit or Virtuous Knock-On Opportunities?. Journal of Industrial Ecology.

[11] K, Renjish Kumar, V. Dr.Vimala M. 2016. Energy Consumption in India- Recent Trends. Asia Pacific Journal of Research I(XXXVI):140–51. Retrieved (http://apjor.com/downloads/0203201620.pdf).

[12] Kagermann, H., Wahlster, W., & Helbig, J. (2013) *Recommendations for implementing the strategic initiative Industrie 4.0 – Final report of the Industrie 4.0 Working Group*. Frankfurt am Main: Communication Promoters Group of the Industry-Science Research Alliance, acatech.

[13] Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., et al., " Smart Manufacturing: Past Research, Present Findings, and Future Directions," Int. J. Precis. Eng. Manuf.-Green Tech., Vol. 3, No. 1, pp. 111-128, 2016.

[14] Kannan, R., Boie,W., 2003. Energy management practices in SME e case study of a bakery in Germany. Energy Convers. Manag. 44 (6), 945-959.

[15] Kiel, D., Arnold, C., Collisi, M., & Voigt, K.-I. (2016) *The Impact of the Industrial Internet of Things on Established Business Models*. Proceedings of the 25th International Association for Management of Technology (IAMOT) Conference, Orlando: 673-695.

[16] Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014) *Industry 4.0*. Business & Information Systems Engineering 6(4): 239-242.

[17] Lee, J., Kao, H.A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. Procedia CIRP, 16, 3-8.

[18] Mohammed Bakkari and Abdellah Khatory" Industry 4.0: Strategy for More Sustainable Industrial Development in SMEs", Production Engineering, Energy & Sustainable Development 2018.

[19] Pachouri, A. & Sharma, S. (2016). *Barriers to Innovation in Indian small and medium size enterprises*. ADB.

[20] Pillai Lalitha Srinivasan and Kailas Kadu" Growth Prospects for MSMEs in India with Reference to Industry: 4.0", IJMS, ISSN (Online)2231-2528,2018.

[21] Pokharel, 2006, http://www.overseas- campus. info/ seminar _ program /2006 _ Asian_ Alumni_ Workshop/Asian_Alumni_Workshop_2006_Bali-Indonesia.pdf

[22] Posch, Alfred, Thomas Brudermann, Nina Braschel, and Magdalena Gabriel. 2015. " Strategic Energy Management in Energy-Intensive Enterprises: A Quantitative Analysis of Relevant Factors in the Austrian Paper and Pulp Industry." Journal of Cleaner Production 90:291–99.

[23] Rainer Drath, Alexander Horch, "Industry 4.0: hit gold hype?", IEEE Industrial Electronics Magazine, June 2014

[24] Sameer Mittal, Muztoba Ahmad Khan, David Romero and Thorsten Wuest" A Critical Review of Smart Manufacturing & Industry 4.0 Maturity Models: Implications for Small and Medium-sized Enterprises (SMEs)"2018.

[25] Sauter, R.D., Bode, M.D. & Kittelberger, D., 2015. *How Industry 4.0 Is Changing How We Manage Value Creation* .

[26] Saurabh Vaidya, Prashant Ambad, Santosh Bhosle " Industry 4.0 – A Glimpse" 2nd International Conference on Materials Manufacturing and Design Engineering2018.

[27] Stock, T. & Seliger, G., 2016. Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP*, 40, pp.536–541. Availableat: http://www.sciencedirect.com/science/article/pii/S221282711600144X.

[28] Theo Lins and Ricardo Augusto Rabelo Oliveira" Energy Efficiency in Industry 4.0 using SDN", IEEE 2017.

[29] Wuest,T., & Thoben, K. D. (2011, September). Information Management for Manufacturing SMEs. In *IFIP International Conference on Advances in Production Management Systems* (pp. 488-495). Springer, Berlin, Heidelberg.

[30] Wu, D., Liu, S, Zhang, L., Terpenny, J., Gao, R., Kurfess, T. & Guzzo, J. (2017). A Fog Computing-based Framework for Process Monitoring and Prognosis in Cyber-Manufacturing. *Journal of Manufacturing Systems, 43*(1), 25-34.