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A Systematic Literature Review on Adoption of Industry 4.0 in Supply Chain

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Abstract: ***Industry 4.0 was propelled in 2011 in Germany, after then this topic gain attraction from all over the world. This latest technology is pushing the existing market to a new stage and this paper looks at Industry 4.0 (I-4.0) implementation in the supply chain also known as supply chain 4.0. Supply Chain 4.0 (SC-4.0) is re-establishment of supply chain by taking inbound logistics from supplier to manufactured it and then provide outbound logistics through distribution channel to customer by using Industry 4.0 (I-4.0). In this article, researcher analysed the collected literature on I-4.0 implementations in the Supply Chain (SC). The literature selected for this analysis was broadly categorized into two ways: 'aspect-based' and 'research-based methodology'. The research based methodology are classified into five categorized on the basis of method used and they are literature survey, case study, conceptual framework, theoretical study and survey. The aspect based approach also classified into four category and they are adoption of Supply Chain 4.0, logistics, inventory management and supply chain performance. This article used literature review method to analyse a total of 36 articles related to SC-4.0. Previous papers research only in particular industry but this paper shows risk and benefits of application of I-4.0 in various type of SC industry. This paper aims to close a divide between conceptual study and practical implementation of I-4.0 technologies in SC, thoroughly reviewing chosen articles and providing potential learning opportunities.***

Keywords: Industry 4.0, Technology, Supply Chain, Supply Chain 4.0, Literature review, Supply Chain Performance, Risk, Benefits.

I. INTRODUCTION

According to Fatorachian and Kazemi (2020), Industry 4.0 interconnect the machine, peoples, device and organizations with internet and CPS that they communicate each other for better results [10]. Deng et. al. (2017) explain the definition of I-4.0 involves the paradigm transition from centralized management to decentralized enhanced regulation, the goal being to establish a highly scalable and customized product and digital manufacturing style [7]. According to Frank et. al. (2019), I-4.0 was seen as a modern manufacturing process in which many emerging developments combine to include digital solutions. This is, still, a lack of awareness of how organizations are applying such innovations [11]. Szozda (2017) stated that the first major technology of I-4.0 is IoT, which gather, store and share the information through internet connection [29]. Bag et. al. (2018) shows the seven facet of I-4.0 are digitalization, mobility, transparency, modularization, socialization, autonomizaton and network collaboration [3]. According to Frederico et. al. (2019), there are so many I-4.0 applications, but this study target on supply chain using I-4.0 which is also called as SC-4.0 [13].

There are various applications of Industry 4.0 like medical purpose, health care industry, agriculture industries and supply chain and so on. But this research centred on application of I-4.0 in the SC that is called SC-4.0. SC-4.0 is re-establishment of supply chain by taking inbound logistics from supplier to manufacture it and then provides outbound logistics through distribution channel (like retailers, wholesaler, and ecommerce platform) to customer by using I-4.0. Makris et al. (2019) stated that the important technologies used in supply chain 4.0 are 3D printing, cloud technology and BDA [22]. According to Frederico et. al. (2019), IoT is another important technology for supply chain 4.0 and it improves design, process and SCP [13]. Frederico et. al. (2019) also explain the 4 construct that shapes the supply chain 4.0 are Process performance requirement, Technology levers, Managerial and capability supporter, and Strategic outcomes [13]. Aćimović and Stajić (2019) describe that SC-4.0 reduce supply chain cost nearly 30%, reduced lost sales up to 65-75%, reduced inventory up to 35-70% and also increase agility of supply chain [1].

This paper show advantages and potential of I-4.0 in SC and also shows how SC4.0 changes the traditional supply chain. Due to increasing customers demands, supply chain faces new challenges day by day. These challenges are mitigated by technologies of SC-4.0. But there are also some barriers which restricts the adoption of SC-4.0. Due to this problem most of the industries are not ready to implement this new technology. The paper also shows the barriers that restrict the adoption of I-4.0 in various SC industries. The first goal of this thesis is to review current chosen literature on SC-4.0. Second goal of the thesis is to encourage potential research opportunities by finding knowledge gaps from the literature review and offering useful perspectives for academics and practitioners.

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Based on these research priorities the thesis was formulated answering research concerns.

1) *RQ1:* What is the latest state-of-the-art literature on I-4.0 implementation in SC?
2) *RQ2:* What are potential future developments for the implementation of Industry 4.0 in SC?

This thesis sought to review current research on I-4.0 implementations in SC to address these questions. Within this paper the reviewer discusses SC-4.0 literature and segregates the literature chosen based on I-4.0 implementations of SC.

II. LITERATURE REVIEW

We have taken a systematic research in this report to study the literature on the implementation of I-4.0 in the SC. The research papers were found out through keywords like SC-4.0, application of I-4.0 in SC, digital SC and smart SC and they are from 2016 onwards. The open-source website was used to gather research papers using principles of including and rejection. I found out the research papers only by considering International journal and deleting white paper, books, website, thesis etc.

Finally, we omitted those publications which were not explicitly applicable to our analysis by reviewing the title and abstract of selected research papers. The methodology for article selection is given below

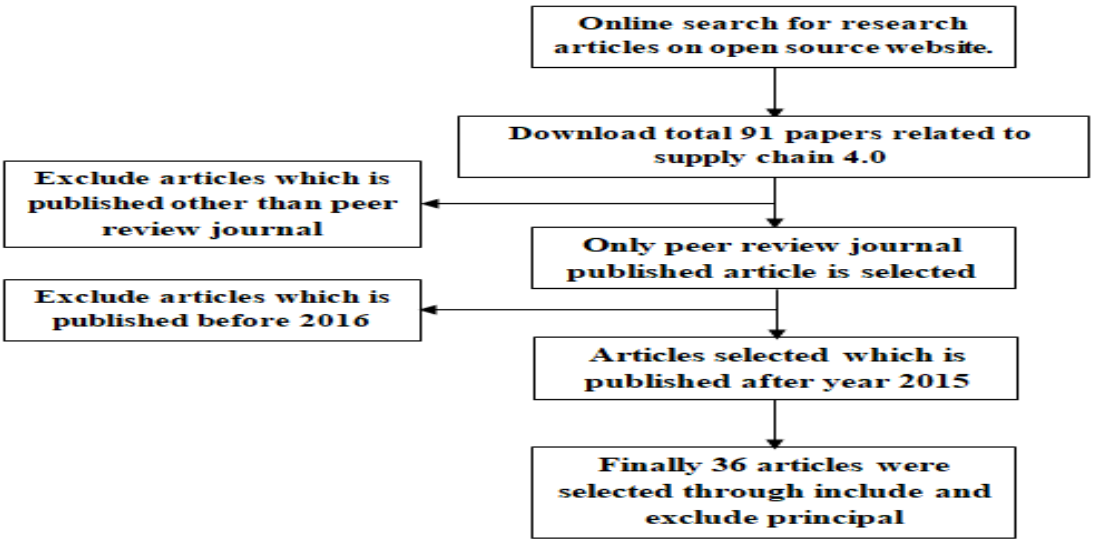


Fig.1. Papers selection methodology

A. Distribution of Article Based on Country of Publication

The research papers found for this analysis are in the period from 2016-2020. This topic is new in research as I-4.0 is propelled in 2011 in Germany. Germany is conducting more research among chosen papers than any other countries as shown in figure below. Germany, UK and India are the countries that research more on this topic. Besides these countries, there are other countries also conducting research on this subject but they have very few articles. The table shows articles based on country of publications.

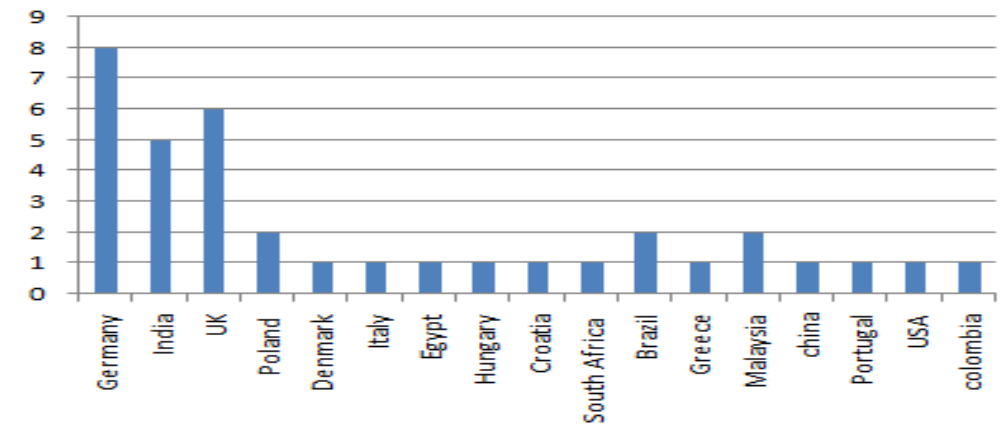


Fig.2. Article based on country of publication

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B. Distribution of Article Based on Year of Publication

For this study, a total of 36 papers were selected relating to supply chain 4.0 origins from different countries and the year of publication start from 2016. A total of 15 papers released during the year 2018 are more than others and then it decreases. The sudden rise in the number of publications suggests researchers became more interested in SC-4.0 during this period. Print publication grew from 2016 to 2018 and then decreased even in year 2020, but the year 2020 is not done yet, so may be in further more work can be performed. The table shows articles based on year of publications.

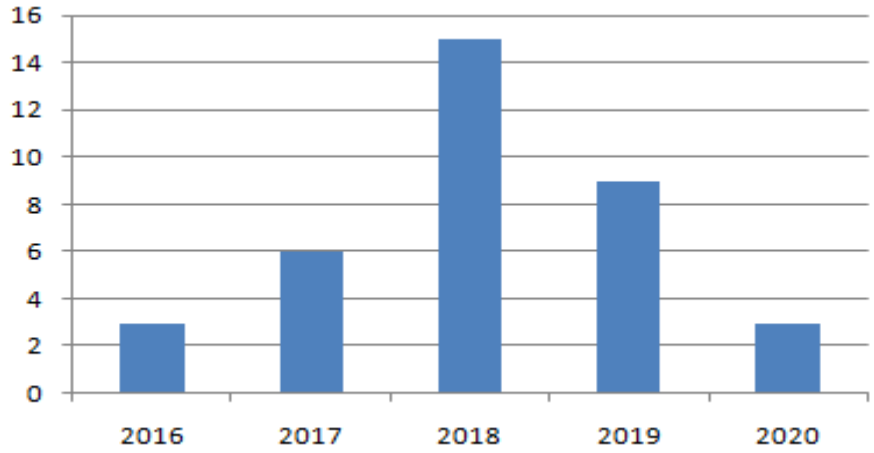


Fig.3. Article based on year of publication

C. Distribution of Article Based on Industrial Area of Research

A total of 36 research papers are chosen in this report, focusing supply chain 4.0 or I-4.0 application in supply chain. Such papers demonstrate I-4.0 implementations at various supply chain firms. Among 36 papers, 13 research paper show Industry 4.0's implementations are mostly in SC management firms, 9 research paper shows I-4.0's implementations in Manufacturing company and 5 papers show application of I-4.0 in logistics company. By analyzing the literature selected, I note that researchers have published their paper on supply chain management journal in large part then process safety and environment process, International Federation of Automatic Control (IFAC) and so on.

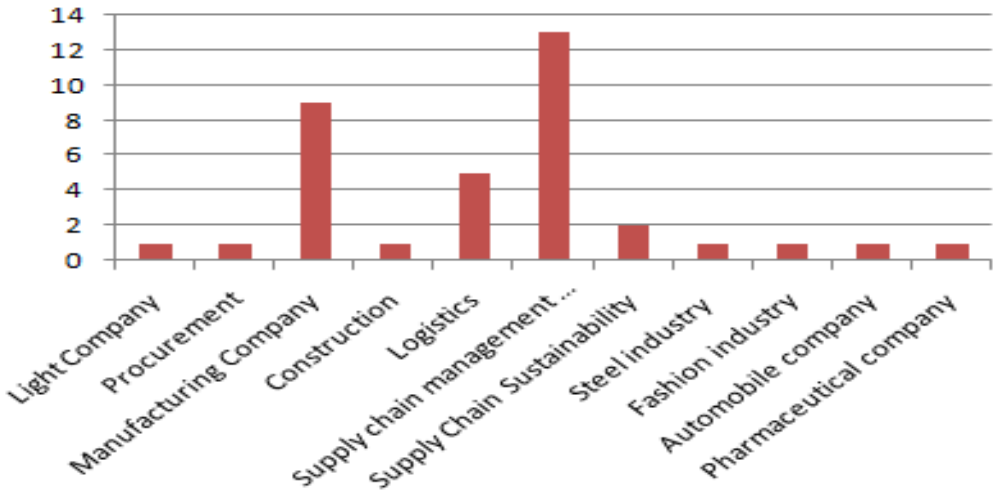


Fig.4. Industry used for research

The literature selected for this analysis was broadly categorized into two ways: 'aspect-based' and 'research-based methodology'. These research based methodology are classified into five categorized on the basis of method used and they are literature survey, case study, conceptual framework, theoretical study and survey. The aspect based approach also classified into four category and they are adoption of SC-4.0, logistics, inventory management and SC performance.

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III.POTENTIAL AREA OF RESEARCH ON APPLICATION OF INDUSTRY 4.0 IN SUPPLY CHAIN

Within this paper we concentrate on evaluating papers related to I-4.0 implementation in the SC. As mentioned above, it is broadly divided into two categories, namely aspect-based and research-based methodology. In this section, four category of aspect based literature survey are reviewed.

A. Adoption of Supply Chain 4.0

In the most part, modern supply chains integrate marketing, product creation, production, and delivery systems so that the commodity meets the ultimate customer [22]. SC-4.0 has the ability to challenge conventional supply chain transformations [31]. This presents the phrase "Supply Chain 4.0" to highlight relationships between I-4.0 and SC [13]. Globally, businesses are moving slowly towards implementing such enabling technology in this dynamic, unpredictable, nuanced and ambiguous world to avoid perishing [3].

There's some dark side of industry 4.0 that affect supply chain 4.0 adoption and service. The priority order of defined problem dimensions is given as: challenges of management, technical barrier, and political challenges, moral and ethical issues [21]. The five major obstacles in SC are customer service, cost reduction, preparation and managing the threats, the partnership between manufacturers and collaborators and talent [25].

Therefore it is clear that Supply Chain 4.0 has already started in theoretical studies, but it is still a dream to be applied in actual Supply Chain 4.0 [12].

B. Logistics

One of the main aspects of SC management is logistics; the key goal of logistics is to efficiently and accurately control the movement of goods, resources and knowledge at the Right time and amount for the right gear at the right spot [9]. Logistics should be improved asset and stock management, inventory management, intelligent handling and distribution of transport, energy and materials and Cyber Safety and Defense [19]. The connection between strategic business processes and logistics contributing to successful supply chain efficiency [9]. Enterprises are focused on generating value for consumers, who are becoming increasingly conscious and demanding in terms of growing consumer expectations related to lead time delivery times, product quality and reliability [33].

Evidence shows that smart supply chains make use of networking and technological advances to build a scalable, efficient and clear network [12].

C. Inventory Management

The supply chain 4.0 allows valuable resources such as inventory visibility to grow improve and potentiate in real time [23]. Five metrics to assess the condition of a single process: inventory, lead time, delivery date compliance, efficiency and process costs [28]. Additive manufacturing technology in SC tends to increase production efficiency, shorter lead times, increasing commodity individualization and reducing inventories [18]. The production period could be shortened by buying larger quantities of raw materials, while at the same time reducing purchasing and shipping charge, storage costs may rise, however, due to the rising level of inventories [31]. In the case of warehousing, smart Shelving and pallets should be the foundation of new material management [33]. SC has divided into seven dimensions: manufacturers, manufacturing, inventory and distribution, consumers, information technology , human resources, and measuring efficiency [2]. Supply chain 4.0 increased inventory rates as it would use more just-in-time procurement [2].

D. Supply Chain Performance

I-4.0 is the pattern of the industry's future growth, which will have a significant effect on the competitiveness of the entire society, radical improvements in global architecture, manufacturing processes, operations and service systems, enhanced flexibility, higher speed, improved production performance, improved quality with multiple advantages. [7]. Such I-4.0 focused on innovation greatly improves the alignment and communication performance of the entire SC [8]. The evolution of I-4.0 increases pharmaceutical industry profitability [8]. Cloud computing enhances overall efficiency by efficient use of resources, cost-effectiveness; usability, versatility and device scalability [9]. Additive development tends to decrease the amount of SC strata, and providers. I-4.0 and manufacturing additives are increasing competition and flexibility in development [18]. SC-4.0 enhanced sensitivity of the whole SC including architecture, production, and quality and regulating facilities [20].

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IV. METHODOLOGIES USED IN RESEARCH

In this paper, there are five methods discussed which are based on type of study. These methods are literature review, case study, conceptual framework, survey and theoretical study. For this analysis I select 36 research papers which are classified into 5 methods already listed above. 20 per cent of articles carry out their research by case studies, 22% papers used literature review method, 20% papers related to conceptual framework method, 22% papers related to Survey method and remaining 16% paper conduct theoretical study.

A. Case Study

A case study is a research approach requiring very close, extensively depth and thorough analysis of a specific event. Bar et. al. (2018) recognizes eight reasons for optimizing SC processes in line with I-4.0 standards and growing customer satisfactions. Degree of customization, business data management and Consumer Freedom are the important benefits of I-4.0 [4]. Glas et. al. (2016) identified 6 hypotheses about procurement with Industry 4.0 from 7 companies. Procurement 4.0 shall endorse the strategy of I-4.0 companies with guidelines for the application of I-4.0 innovations on SC. Procurement 4.0 aims at bringing Manufacturing 4.0 into the SC [16]. Luthra & Mangla (2018) identified 18 barriers related to I-4.0 in SC sustainability. The aspect of 'Organizational barriers' is identified as the biggest risk followed by 'Technological risk', 'Vital risk' and ' Liability and legal risk' [21]. According to Makris et. al. (2019) Businesses had continuing and strong potential emphasis on Big Data, minimal attention on cloud computing and 3D printing was not yet having an impact on the companies being investigated. Industry 4.0's three main technologies are big data, cloud computing, and 3D printing, both of which are revolutionary developments that may impact the daily activity of the supply chains of major multinational businesses working in multiple industries [22]. Muller and Voigt (2018) identified 7 challenges and potential by conducting survey from different companies [24]. Tjahjono et. al. (2017) shows the application of I-4.0 technologies on 4 SC levers. Industry 4.0 reveals 71.43 per cent of chances within the procurement category, the rest being risks or challenges [31]. Yadav et. al. (2020) find out 22 challenges in automotive supply chain and also shows that lack of political, technological and human capital constrains sustainable growth [35].

B. Literature Review Study

There are total 8 papers which conduct study by literature review method. Aćimović & Stajić (2019) shoes that the most important advantages of supply chain 4.0 are improved versatility, product quality, reliability and profitability. It will require retail customization so that corporations can fulfill customer demands, generating value by continually adding new goods and services to the market [1]. Agrawal & Narain (2018) explain the benefits of digital supply chain it improves decision making, reduce inventory level, shorten delivery times, improve customer satisfaction, and improve supply chain flexibility [2]. According to bag et. al. (2018) the key challenges of supply chain 4.0 are job losses for workers; low employee morale; low Industry 4.0 research; technological risk; and IT risk that impact both consumers and suppliers in the supply chain [3]. Ding (2018) identified some barriers related to supply chain in pharmaceutical industry. Industry 4.0 based technologies greatly enhance the entire PSC's teamwork and communication efficiency [8]. Frazzon et. al. (2019) has introduced a new SC Management (SCM) concept 4.0. Therefore it is obvious that SCM 4.0 has already started in theoretical studies, but it is still a goal to be applied in actual SCM [12]. Ghadge et. al. (2020) explain the model of Industry 4.0 changes industry in many industries, such as the manufacturing, transportation, aerospace, defense and energy sectors [14]. Takhar & Liyanage (2018) explain aspects and benefits of I-4.0 and also explain the risk of SC-4.0. The organizational roles listed as being most impacted by industry 4.0 were IT, production, and purchasing [30]. Zimmermann et. al. (2019) gathers data from 300 supply chain companies connected to I-4.0. The barriers related to SC-4.0 were shown and also describe advantages such as improved efficiency or predictive maintenance is related to these technologies [36].

C. Conceptual Framework

There are total 7 papers which conduct study by conceptual framework method. Dallasega et. al. (2018) explains that proximity of construction supply chain 4.0 [5]. EIMesmary & Gamal Abd El-Nasser (2019) surveyed the I-4.0 innovation application in logistics and also shows its benefits [9]. Fatorachian & Kazemi (2020) shows I-4.0 is a critical paradigm change in SC management. This I-4.0 and its enabling innovation, including CPSs, IoT and BDA will lay the groundwork for the development of automated and supply chains [10]. Frederico et. al. (2019) displays 4 dimensions that create supply chain shape and also design structure to describe supply chain 4.0. Ivanov stated that the influence of digitization on SC management (SCM) and the influence of SCM on the regulation of ripple effects [13].

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Kozma et. al. (2019) demonstrates I-4.0 has a major effect on the processes of SC management and logistics; they just looked at the German industrial sectors [19]. Schlüter et. al. (2016) submitted a short summary on I4.0 and SC risk management and it was on that basis that a framework was created [28].

D. Theoretical Study

Dalmarco & Barros_2018 said that there are eight I-4.0 innovations in the SC, and demonstrated its advantages as well. Such innovations help boost the different SC efficiency which needs to be mitigated. This paper analyzed I-4.0 introduction into the SC [6]. Deng & Han (2017) stated that I-4.0 will significantly affect the competitiveness of society as a whole; the I-4.0 is not only an opportunity but also a threat for China's manufacturing sector [7]. Muthusami & Srinivsan (2018) claimed that the Industry 4.0 concept and reviewed the barriers and strategies to reduce those barriers as well. They provide a step-by-step approach to demonstrate how current and conventional production processes can be turned into an Industry 4.0 factory [25]. Witkowski (2017) stated that Emerging innovations such as the Internet of Things, Big Data and Industry 4.0 build opportunities to satisfy the demands of customers and to generate growth in logistics and the SC management [33]. Yaakub et. al. (2018) addresses the effect of I-4.0 on SC management and the effects from the organizational perspective on the business transition [34].

E. Survey Method

Frank et. al. (2019) explains that enterprises with an advanced degree of I-4.0 application tend to incorporate most of the front-end innovations rather than a limited subset [11]. Gisbrecht (2018) stated that supply chain 4.0 principles are supposed to boost the efficiency factors such as quality and profitability of the supply chain manufacturing companies [15]. Hauer et. al. (2018) shows the most impacted fields of marketing-oriented PR, public relations and internal communication are being discussed, and ideas are being provided for their potential innovations [17]. Lee et. al. (2019) shows the Malaysian industries will gain benefits when they recognize the major effects of I-4.0. Industries need to consider the I-4.0 effects and government should relate to this study to promote the industries as I-4.0 is introduced [20]. Molano et. al. (2018) reviewed that I-4.0 in Colombia is a area not widely established, so the business and academy will inspire their research and application [23]. Szozda (2017) explain the definition of SC-4.0 and it also compare the traditional SC and SC-4.0 by taking an example of electric tooth brush [29]. Roßmann et. al. (2018) indicates that BDA can boost demand forecasts, reduce the security stocks and enhance supplier performance management. Nevertheless, the supply chain (SC) processes may become more and more automated, resulting in partial elimination of conventional SCM activities [27]. Wang & Ha-Brookshire (2018) research study will enable workers to get the knowledge of I-4.0 and direct the training and knowledge of potential workers [32].

V. RESULTS AND FUTURE DISCUSSION

In this study, 36 papers underlining SC-4.0 or application of I-4.0 in the SC were reviewed. Between 2016 and 2020, these papers were written and selected papers indicate the largest number of papers published in 2018. Such research papers come from various countries but Germany has the largest number of papers on this topic followed by UK and India. For this analysis the literature survey is divided into two groups, one based on methodology, and the other based on aspect based. The methodological approach is again divided into five different forms and these categorized are literature review, case study, conceptual framework, survey and theoretical study. The aspect approach is categorized into four categories and these are adoption ofSC-4.0, logistics, inventory management and SC performance. The SC-4.0 pushes the traditional SC to a new level. Industry 4.0 help to reduce inventory, boost decisiveness, profit and SC efficiency etc.

The SC-4.0 has benefits over traditional supply chain as it improves decision making by taking information from different source [29]. I-4.0 and additive manufacturing improve market and production efficiency [18].SC-4.0 help to reduced delivery time, increase customer bonding, increase supply chain flexibility and cost [2]. Many specific advantages can be found from use of I-4.0 in supply chain. The biggest important advantages include improved versatility, standards of quality, performance and profitability [31]. Digitalization leads to supply chain quicker, more versatile, more highly technical, more reliable and more effective [34]. Industry 4.0 innovations are correlated with a range of advantages, such as improved efficiency or predictive maintenance [36]. With all these benefits, Industry 4.0 innovations still have a poor adoption rate. Supply chain 4.0 has already begun in theoretical studies but in real, Industry 4.0 it is still a target to be application in SC [12].

The reason behind the low rate of application of I-4.0 in SC is the challenges or risk arises due to uncertainty. Some research paper identified these barriers and also identified the major obstacles preventing the adoption of Industry 4.0.

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Ding (2018) shows that the challenges of pharmaceutical supply chain are high investment, low manager support, political risk, less knowledge and workers talent issues etc [8]. Ghadge et. al. (2020) explain the barriers for adoption of Industry 4.0 in supply chain are organizational challenge (Financial constraint, resistant to change, low management support, less digital strategy, less experience and network system risk), legal and ethical challenges (legal risk, collaboration problem and data security), strategic challenges (complex issues, lack of govt. policy, less knowledge, less study on economic benefit) and technological challenges (less digital culture and low information quality) so due to risks of supply chain few criterion of Industry 4.0 were taken in their study [14]. Luthra and Mangla (2018) found out some challenges for adoption of Industry 4.0 in supply chain which is divided into 4 groups. These challenges are Organizational challenge (financial issue, low management support, reluctant behavior for industry, poor digital vision or mission, lack of competency and low understanding of I4.0), Technological challenge (lack of standard, poor data quality, lack of infrastructure and network, lack of integration of technology platform), Strategic challenge (political risk, poor research on adoption of I4.0, unclear benefit of digital investment, lack of digital culture), Legal and ethical issues (legal issue, collaboration problem, security issue, profiling and complexity issue). Organizational challenges are the most critical risks in adoption of Industry 4.0 in sustainable supply chain [21]. Muller and Voigt (2018) found out the challenges of industry 4.0 in supply chain and these challenges are inadequate data quality, risk in IT infrastructure, security risk, lack of standard, breakdown susceptibility, fear of employee's replace and financial constraint [24]. Muthusami and srinivsan (2017) shows the challenges of supply chain management which are Service for customers, SC cost risks, planning management, risk management, organizational management and skillful workers and also shows strategies to mitigate these challenges [25]. According to Schluter and Sprenger (2016), the challenges of steel supply chain are Equipment breakdown, due to low temperature object get freeze, railwaybridge broken due to no longer used, coil basins broken due to no longer used, high temperature causes low tide and water get condense [28]. Yaakub et. al. (2018) studied impact of industry 4.0 in supply chain and they shows that barriers to adopting Industry 4.0 in supply chain are data security issues, less human sight, reliability problem, human employment loss, product cost increased due to technical problem [34]. Zimmermann et al. (2019) shows that the risks in supply chain and these technologies are high cost process, flexibility issues, fragmented system landscape, lack of data, stress of growth, lack of qualification, resource constraint, unlinked dataset, lack of collaboration, insufficient quality, lengthy engineering and security risk [36].

Previous papers research only in particular industry but this paper shows risk and benefits of application of Industry 4.0 in various type of supply chain industry. This paper shows advantages of Industry 4.0 in supply chain and also aware managers before adopting Industry 4.0 in supply chain. The literature research carried out in this review is valuable for the practice of managers in the industry of the supply chain. I hope this report will valuable for understand the tremendous promise of Industry 4.0 technologies.

VI. CONCLUSIONS

The aim of supply chain 4.0 is to increase the efficiency, flexibility and productivity of industry. Supply chain 4.0 helps Companies to make innovative product and assist to solve the challenges arises in company. This paper shows numerous advantages of Industry 4.0 in supply chain through reviewing different research papers and also aware managers before adopting Industry 4.0 in supply chain. The advantages of Industry 4.0 in different supply chain companies are reviewed in this paper, but due to uncertainty some barriers or risk arises which restrict the application of I-4.0 in supply chain. This paper also shows I-4.0 innovations are helping to reduce supply chain risk. The barriers related to supply chain and obstacles that restrict the adoption of I-4.0 in different SC companies are shown in this study through reviewing different research paper. So it's necessary to mitigate the obstacles to adopt I-4.0 in SC.

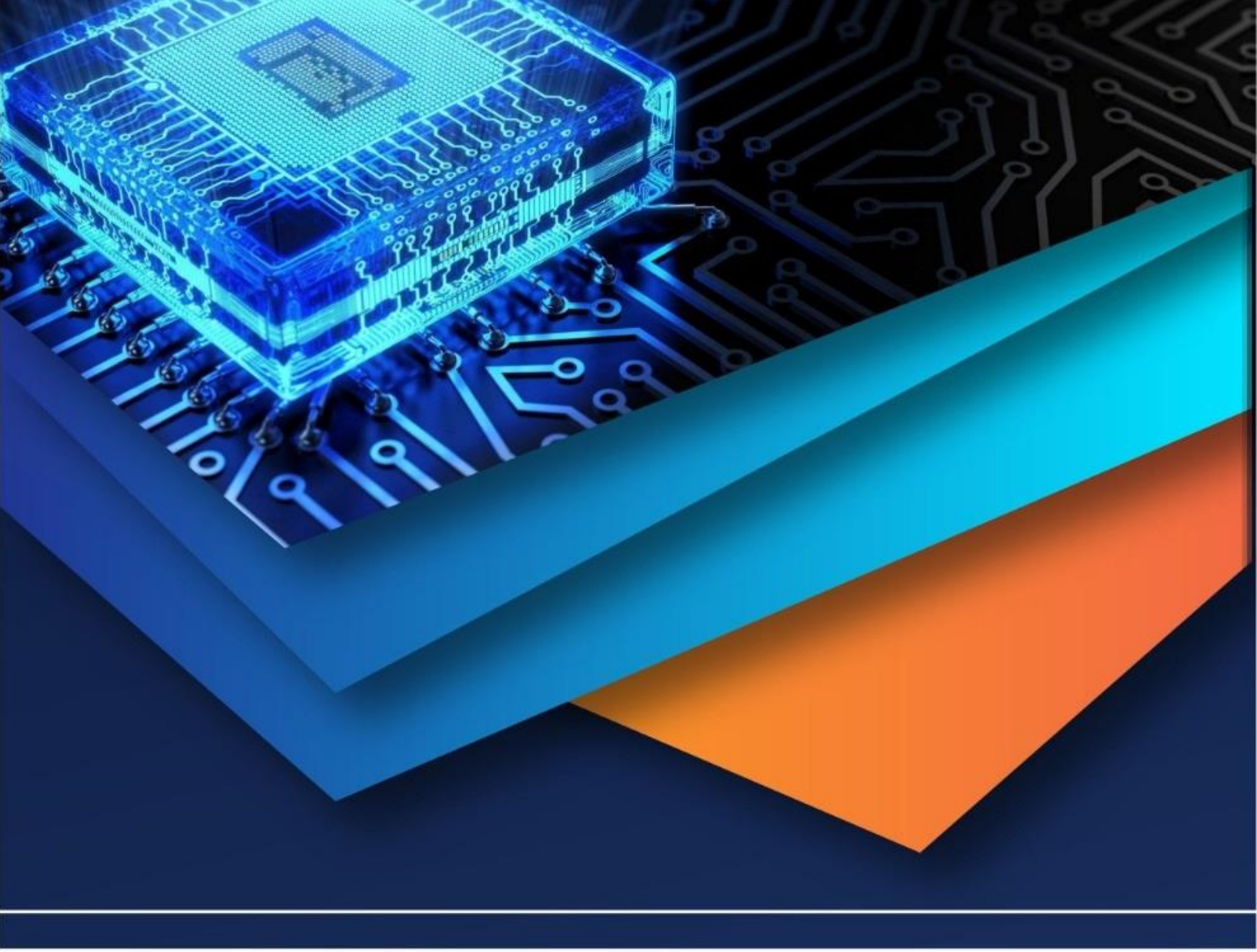
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