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Research Article

Smart Supply Chains- A Futuristic Business Scenario

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Abstract

Supply chains have transitioned from simple logistic functions to futuristic supply chains, having traveled the journey from mere coordination of production and dispatch duties to become the essence of business setups. Information and Technology have changed supply chain management's infrastructure and working mindsets. Agility, reliability, and efficiency have become synonymous with supply chain outcomes due to the alignment of Technology and intelligence. In this chapter, concepts of Industry 4.0 and Logistic 4.0 or Smart supply chains are discussed to understand their evolving trends, needs, and relevance in changing global business setups. This research covers the need and steps of automation, operative and strategic aspects, and actual and potential application of automation in supply chains.

Keywords: Smart Supply Chains, Industry 4.0, Logistics 4.0 , Smart Warehouse

1. Introduction

New age industrial setups are making waves with the revolutionary combination of operating and information technologies which have transformed their primary platform and architecture into more functional, flexible, and versatile structures. Current industrial scenarios crave high-performance materials, a tremendous amount of power, and digital innovations which can reduce their energy dependence, curb their cost, and make them more energy-efficient and sustainable. Industry 4.0 is a system where both machine and system interconnect to combine their strengths and blend their roles to become mutually reinforcing and complementary (Ivanov, 2016). Industry 4.0 or the Industrial Internet of things helps companies increase their competencies and efficiencies and help them generate value for business and make them sustainable (Ali et al 2021a). The success mantra of Industry 4.0 is its dependence on an ecosystem or infrastructure of interconnected devices sharing data through a cloud platform. With secure and reliable data on hand and more information, companies can make a more informed decision, whether it may be client-related, process related or operational, or work-related decision. Renowned global corporates are navigating their technological reformations to stay relevant and functional. Barbara Humpton, CEO of Siemens US, stated that their organization is evolving via large-scale technologies: electrification, automation, digitization, artificial intelligence, and the Internet of Things to cope with the global problems of urbanization, digitization, and climate change[1]. Tata Consulting Services (TCS), guided by Natarajan Chandrasekaran, the chairman of Tata Sons, tripled its revenue from $ 6.3 billion to more than $16.5 billion by embracing new technologies, such as artificial intelligence, the Internet of Things, and blockchain[2].

Digital is one of the three or four top items our chief digital officers are thinking about- both for the here and now and for the longer-term future- Natarajan Chandrasekaran, Chairman Tata Sons.

2. Recent Trends in Industry 4.0

Innovative technologies, coding processes, and developer tools are constantly being used to help organizations build their digital footprints and gradually move towards digital transformation. The list of industries moving towards these trends is media and entertainment, technology, finance insurance education, etc., where innovative technologies are employed to improve employee efficiencies and speed up processes to

offer convenient and on-demand services to customers. Conversion of the existing business model to the futuristic business model is achieved by integrating drivers of change while retaining the core competencies (Ali et al. 2021a). These drivers of change could be industry specific. They might be related to processes, programs, infrastructures, or disruptive technologies[3]. Major technological trends or disruptive technologies shaping the future of Industry 4.0 are

- Advanced Robots-machines meant to replace manual efforts for efficiency and versatility
- Additive manufacturing- achieved through business process redesign and streamlining, which empowers machines with internet technologies to communicate and collaborate for non-disruptive production and waste elimination.
- Augmented Reality-the information obtained by superimposing virtual computer-generated information on a real-time physical environment. Displays, tracking and input devices and computers are used to get an augmented and enhanced view of the real-time physical real world.
- Industrial Internet of things- meant to create a platform for exchanging commodities and services through a network of networks embedded with devices like sensors and actuators. These networks of objects collect data to be passed on to a more centralized controller and simultaneously aids in decentralizing information for optimizing real-time responses.
- Big Data and Analytics- technological inception meant to control, forecast, and detect any threat based on large data sets collected from diverse resources.
- Simulations- these are technological enhancements meant to recreate a real scenario for testing and analysis to set optimum settings for actual change.
- Cloud computing connects cyber-physical systems with servers, databases, storage, networking, and other applications for data sharing in a fraction of seconds. Cloud computing is the happening concept as it allows accompanies to economize on infrastructures and investments in technological enhancements.

Table -1 -Industry 4.0 related various dimension

SN	Technology	Use in supply chain	Author
1.	Big data analytics- Descriptive and Predictive analytics, real time monitoring and A.I.	Information about manufacturers, suppliers, and customers, define distribution strategies, fine-tune inventory planning, reduction of back holding and back-ordering, tracing actual data, management of volume, velocity and variety of data for smart manufacturing, track, trace, diagnosis and navigation of supply chain activities.	Rossom, 2011; Manyika et al., 2011; Shu and Barton, 2012; Harford, 2014; Huan and Van Mieghem, 2014; Trappy et al., 2017; Tu et al., 2018; Tu et al., 2018a
2.	IIoT-RFID tags, sensors, actuators, controllers	Cost reduction of inventory, elimination of logistics delays, Improved efficiency of CLSC, empowered machine to machine networking, more structured forecasting leading to improved production capability and delivery performance.	Attaran, 2018; Krivida, 2004; Wu et al, 20106; Wamba and Boeck 2008; Thiesse et al., 2009; Tu et al., 2016; Alicke et al., 2016; Tu et al., 2018b
3.	Cloud-Data storage, real time communication	Enable businesses to take advantages for effective planning.	Zhang et al., 2014
4.	Additive manufacturing	Dynamic routing of products, Production of multiple types of production lots, risk assessment, Automated navigation, autonomous vehicles, factory bots	Wang et al., 2016; Klumpp 2018; Tu et al., 2018b
5.	Augmented Reality- information displays	Reduction of operational errors, enhanced ability to make improved decisions, improved customer service,	Lee et al., 2014; Witkowski 2017Zhang et al., 2017
6.	Advanced simulations	Decentralization for innovation in processes, reduction in lead time in product design, economic research and development processes	Brettel et al., 2014; Tan et al., 2015; Kache and Seuring 2017
7.	Autonomous Robots	Carry and arrange goods more efficiently and in less time, offering flexibility, versatility, and collaboration	Liu et al., 2018

3. Logistics 4.0

Logistics 4.0 could be defined as Technological transformation in the logistics sector or the process of developing the logistic operations through innovative technology resulting in better products and services, efficient processes, and reduced cost and time. In simpler terms, Logistics 4.0 is a continuous phenomenon that has empowered the capacities and capabilities of the logistics sector with technology boosters. Different authors have

expressed their views about this phenomenon: According to Galindo (2016) "It is the progress of labor-saving and standardization by the evolution of IoT", while Schliemann (2016) states it to be "machine to machine communication" for optimization of production and Logistics functions without human interference. The digital capacities of logistics setups are strategic for business survival, and rapid adoption of newer technologies is even more vital for staying ahead in the complex business landscape. Companies often hesitate to adopt or innovate, considering the hiccups a change can bring due to lack of awareness, information, or experience, or even complexity of implementing digital technology (Ali et al. 2021b). Nonetheless, digital transformation of logistics setups eventually becomes cost-effective as it helps streamline supply chain processes to increase productivity and efficiency. Embracing digital change enables companies to access analytical data, manage content, build social networking, improve employee and customer experience through integrated communications and collaborations (Ali et al. 2019). Digital supply chains involve networks of managers, tier suppliers, and third-party logistics providers benefiting from holistic and cohesive movements of men and material, unobstructed by potential bottlenecks and breakdowns due to newer visibility ensuring smooth operations. Logistics 4.0 is meant to eliminate waste by outlining unnecessary and inefficient processes, offering optimal materials quantity and movement decisions, and using driverless transportation to intelligent containers, smart warehousing, smart ports, and smart shelves. Ideally, it should also include an end-to-end connect involving every player in the supply chain with usable data that can handle the complexities arising out of ever-evolving business models. However, autonomous vehicles, automated warehouse operations, and robots (Siciliano and Khatib 2016) are common advanced concepts of the value stream that are more prevalent in the current scenario.

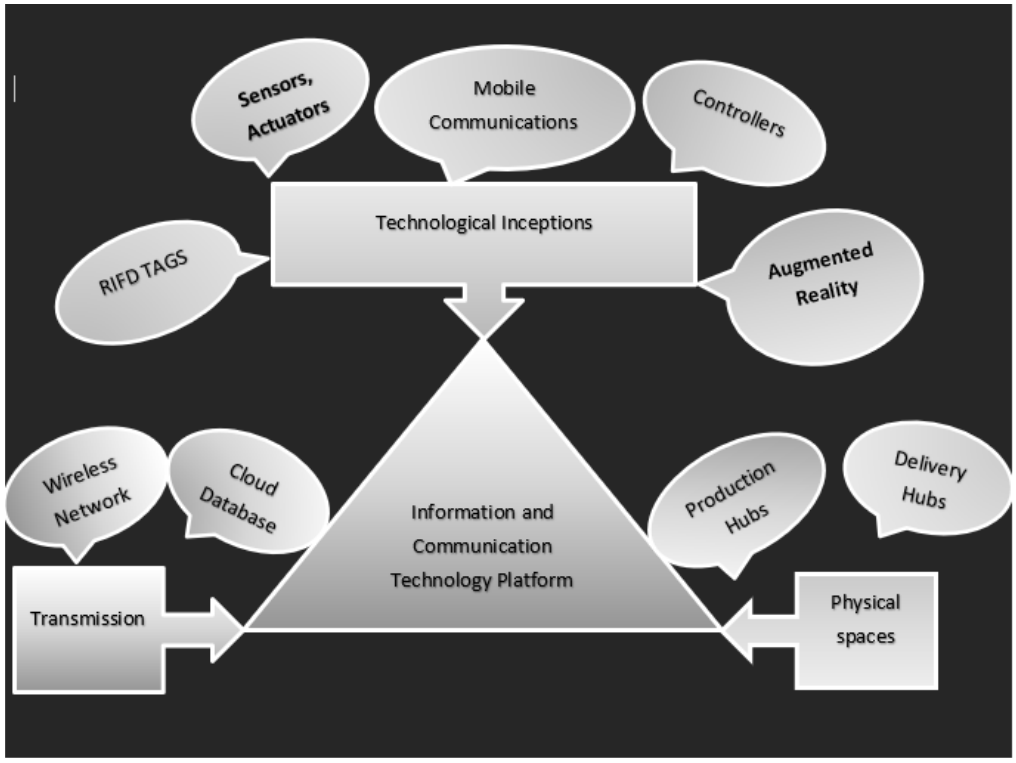

Figure -1- Information and Communications Technology Platform

Why technology is a must in a Logistics?

To achieve successful business operations, a balance must be established between material and information flows, along with a stronghold on finances and market share. Businesses must meet the demands of global customers at their place, time, price, and convenience. These factors cannot play in perfect harmony without continuous supervision and control. The integration of technologies can only handle the complexities added by these factors because businesses must deal with some additional influences, as discussed below.

i) Dispersions of supply chains: Modern logistics have a vast expanse covering multiple logistics activities and logistics facilities in far and well-distributed geographical territories. These geographical dispersions of supply chains require restructuring logistics spaces, supply chain strategies, and technologies that can cater to geographically and culturally different customers, distributors, suppliers, and manufacturers.

ii) Increased demand patterns: Varying macro and micro landscapes of supply chains have brought alterations in demand patterns in different regions. Satellite communications access to internet technologies in remote areas has altered the demand patterns in rural areas and tier 2, 3, or tier 4 cities. Consumers have more income and awareness, and their consumption patterns are changing, which has brought necessary changes in the demand curves. Also, online business portals or e-commerce channels have opened windows of the shopping experience to the most unaware and unreachable customers. Online teaching facilities are available, making people more skilled oriented, and they are opening their business setups from remote places, so there is an increase in sourcing of materials. 'Startups' phase of businesses encourages individuals to attempt entrepreneurship, which adds to the surge in demand for materials[4].

iii) Improved infrastructure: Geographical distribution of supply chains requires alliances with third-party suppliers and manufacturers, which means access to more facilities and a customer base. With world economies more financially sound, offers better national infrastructures, more freight facilities, corridors, business opportunities, investment schemes, improved assets, technologies, and transportation. The economies lure investors to do business schemes, rebates, streamlined tax structures. The above factors suggest that market and industry forces are forcing organizations to discontinue their business prototypes and evolve into new ones by utilizing disruptive technologies such as IoT, additive manufacturing, big data, cloud computing, robots, etc. Simultaneously, businesses share their operations on a global platform which complicate matters in their ways as businesses are burdened with additional challenges, which are discussed below

Challenges in logistics

Nonetheless, the current business atmosphere is fraught with its usual share of challenges with the macro-economic environment bringing its own set of problems of a trade war and cyclic slowdown of growth. Coordination among different units, untrained workforce, hesitation and resistance towards digital change, origin authenticity, and security of data provided by third-party providers are critical concerns4. Supply chain problems /complexities are not only restricted to their structures and formations only, but their technologies and techniques are also not up to the mark.

i) Cost volatility: The wider expanse of business setups is driving the accelerations of distribution

cost leading to thinner profit margins. Online sales coupled with higher rental rates of logistics facilities also add to high supply chain costs. Additionally, supply chains have become more complex and volatile, with product life cycles becoming short and product complexity and customization becoming high. The absence of standards and security concerns and the total cost of deployment have restricted organizations from scaling their growth charts.

ii) Visibility: Forecast accuracy, customer tolerance time, and transactional friction show a downward trend. In contrast, pressure for leaner inventories is on the higher side, with many long lead time parts coming into play.

iii) Supply chain planning: It suffers from outdated forecasting methods, lack of real-time visibility, unpredictable disruptions that are not accounted for. Lack of connectivity among supply chain functions creates inefficiencies leading to higher costs and overutilization of resources.

iv) Value realization: Investments do not bring valuable returns due to competition, complexities of supply chains, rigid regulations, and outdated processes and equipment.

Hence the need for current information and communication technologies is highly favored, which brings a higher degree of integration and enhances value capture and competitiveness. The global logistics market is expected to grow to $27 billion at a CAGR of 7.6% until 2023[5], which indicates that organizations must integrate IoT into their business models to achieve their true potential to excel in the competition.

Roadmap to Futuristic Supply Chains or Smart Supply Chains:

Future trends point at a gradient shift in supply chains, reflecting their move from traditional formats to digital format offering abundant and reliable information, cohesion in all verticals, and more productive outcomes. This shift is evident in globally distributed organizational interactions among partners about the individual business activity of buying, manufacturing, selling, etc., to making big business decisions. Supply chain trends are leaning towards automation where a continuously learning, thinking, and ever evolving ecosystem is helping in significant supply chain functions like storage, material handling, packaging etc. (Sanders 2016; Davenport and Bean 2018). Automation brings visibility or transparency in the supply chain and helps achieve Operational

Optimization or availability of the right product at the right time, place, quantity, condition, and cost (Iansiti and Lakhani 2017; Kranz 2017).

Below are the discussions of various phases of automation

Initial phase of automation: Idea of Machine for Man: An ideal digital supply chain begins with the prediction of disruption of existing supply chains being strong enough to encourage management to look for alternative operating models and structures, leading to new revenue streams, new customers, or new distribution channels. Disruption of the supply chain is necessary and must be achieved by inviting ideas and applications and soliciting the expertise of new people from outside for a renewed outlook. Relevant ideas and applications which can address the performance gaps and create value must be shortlisted.

Second phase of automation-Design of Machines and Network: Ideation of vision must be followed by its activation by formulating digitally customized operating models. Designing and building digital capabilities for supply chains requires exploring alternate business routes, replacing manual labor with robots for assembly, processing faster deliveries, and better customer satisfaction. Aligning vision with model design with a clear focus on building capabilities, systems, structures, and processes unique to the industry and business context is a must to convert supply chains into predictive and self-adjusting supply chains. Digital supply chain models should consider digital technologies like IoT, Predictive analysis, API (Application Program Interface) for having end-to-end visibility in digital flow. To better align digital vision with operating models, companies must prioritize business areas for experimenting with new ideas.

Third Phase of automation- Actualization of Machines Network: Real-time data and accurate time information are essential for this phase, where the execution of ideas takes place with machines' help. Advanced clouds solutions are sought to simplify complex networks, from using sensors for information, advanced technological enhancements like the LAM-Local Application model, RFID-radio frequency Identification, Bar codes, and IOT-Internet of things. The machine networks must be programmed to control the internal work environment, analyze physical data for performance measurement, filter relevant data for processing, align with a centralized system and uniform standards and protocols. Machine networks must be multifunctional, accessible, and applicable to customized applications.

Figure 2: Actualization of Machines Network

"The machines are telling us, work with them in the virtual world, and then turn around and drive improvements, new business models, and new ways of meeting customers' needs in the real world" . Barbara Humpton, CEO of Siemens US[2]

Smart Supply chains are designed on digital platforms empowering industrial machines with digital technologies and open pathways for collaborations and communications between machine-machine, machine-network, and network-network. Digital platforms with embedded devices must integrate digital applications with intra and inter-organizational business processes. Simplification of data on a given scenario can be done using the machine learning approach. A variety of skill sets are required to handle Technology, decentralized business structures, prioritizing primary activities, developing supervision models, converting to cloud solutions, and highlighting the elimination of distribution channels as essential factors in converting supply into smart supply chains. Smart supply chains can easily be said to take advantage of the digital enhancements to filter the data related to an unfavorable physical and industrial environment, manufacturing, and suppl complications to get optimum results. The vision of smart supply chains is digital competence based on the information and decision on-demand and delivery projections and production efficiencies.

Mistakes to avoid: Digitalization of supply chains is still a distant dream for many companies as challenges of scattered infrastructure, disparate systems, not so prominent visibility, and excess of data prohibit them from realizing their goal. However, others have mastered the game and started getting better results. The result-oriented approach requires mistakes to be avoided for optimum results, which are discussed briefly below.

I. Data management: to avoid the complexity and chaos created by an excess of data, companies must filter and channel the data according to their specific business goals. Success strategy should be specific data for specific enterprises and a specific value chain to capture critical business insights. Companies are spending a fortune to capture and streamline data but eventually, end up unnecessary pooling data and spending money

to store and manage that data. Risk management should be appropriate for the reliability of data too.

II. Cost Capture-for financial stability

III. Continuous evaluation and evolution of Technology for staying ahead and relevant

IV. Compatibility, adaptation, and transfer of Technology for the transparent and complete flow of the chain

Popular applications in logistics 4.0: The main aim of logistics 4.0 is to identify suitable technologies for digital transformation to derive reliable, flexible, and quality outcomes. From optimizing material flow to detecting disturbances and relevant patterns, efficient production planning and stock management, intelligent material distribution, shorter transport routes, timesaving, and transparent logistic flows. These applications must include networking decentralization and should be oriented to specific service and offer clarity about the real-time capability. These applications should use advanced robotics and artificial intelligence, hi-tech sensors, cloud computing, the Internet of Things, data capture and analytics, digital fabrication (including 3D printing), software-as-a-service and other new marketing models, mobile devices (Khan et al 2022) . Some popular applications are Smart Enterprise Resource Planning System, Smart Warehouse management system, Smart Transportation Management System.

Smart Enterprise Resource Planning System: Digital logistics transformations start with the move from traditional setups and prebuilt interfaces to highly connected systems that offer real time data for agile and affordable manufacturing. ERP systems must become flexible and compatible with MES for this transition to be successful. ERP or smart ERP system must move from its central location towards an upwards stream of interconnected smart components providing access to real-time data through the modern user interface. Relocation of data based on its priority and significance is encouraged to avoid repetition inconsistencies and bring flexibility to the system. Smart ERP is meant to rationalize the information base to improve risk prediction offer mobility to provide strategic foresight to the business.

Smart Warehouse Management System: Conversion of warehouse management system from the traditional approach towards modern, lean, and technologically enhanced approach is must to

convert these physical infrastructures into profit centers. By reshaping the existing infrastructures and processes, companies are getting improved customer service, accurate inventory estimates, enhanced flexibility, and responsiveness and are cutting down the Labour expenses.

i). Infrastructure of a smart warehouse: Integrated analytics and automation have helped in faster outputs, scaled up operations, fulfilled huge orders, and avoided errors using robots, automated belts, etc. In an ideal automated warehouse, humans are assisted by robots that reduce walking time and manual sorting of products and enable humans to improve their efficiencies by eliminating repetitive tasks.

ii). Working of smart warehouse system: Technological advancements like Augmented reality and IoT allow warehouses to perform the process of picking, sorting, and tagging effectively. Robotic arms are now often used to allow workers to stay hands-free, thus offering onboarding and training costs. Workers receive contextually specific, relevant, real-time data from central systems backed by machine-to-machine communications, preventing manually fed processes. Robots communicate with RFID scanners, which can send a signal to conveyors, which eventually take these signals to the warehouse management system without the loss of any data. An integrated navigation system comprising voice and vision picking provides flexibility and mobility to workers vis see-through displays and easily understood audios. Technologies of Voice Picking eliminates manual and paperwork by using speech recognition instead of scanning barcodes and assisting workers in tracing the products in the warehouse. Another technology of Vision Picking assists the workers and reduces workers' onboarding and training time. It assists workers by choosing the right pick path, displaying pick locations for single and multi-unit order picking, and offering visual guidance about their number and place on trolleys. In a fully integrated connected and digitized warehouse, employees have better access to warehouse activity and data management information, which helps them track the stock and reduce the gap between available and picked products. Sensor detection technology helps optimize the size of the packaging by detecting changes in the size and shapes of products. Big data and predictive analysis predict purchase patterns and the need to reorder products. This is meant to eliminate unnecessary stocking of unwanted inventory, saving money and place. Predictive analysis also suggests best lot combinations be delivered in an area and optimizes route planning, thus avoiding transportation excesses.

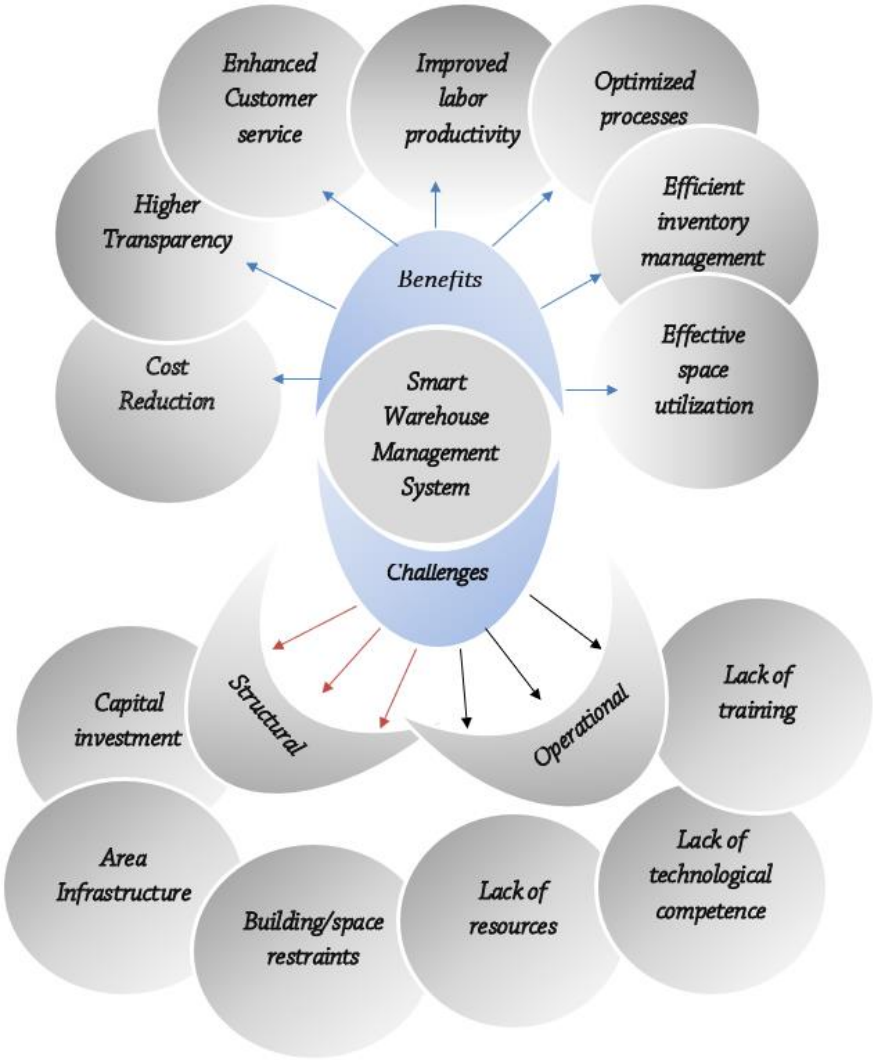

Figure -3- Smart Warehouse Management System

Benefits of WMS:

i). Higher transparency- Technological inceptions bring visibility to the system because of decentralization and data relocation, making the processes more transparent facilitating intra operational collaborations.

ii). Enhanced customer service- Big data and RIFD assist inaccurate predictions of customers' needs, availability of products, time and speedy delivery, and end-to-end tracking processes, giving

an edge to customer service. Predictive analysis ensures fewer delivery failures by selecting the best delivery routes, and automated driverless vehicles and drones are regularly used for speedy deliveries.

iii). Improved labour productivity- Robots have been facilitating human actions for better productivity; IoT removes repetitive tasks, unburdening humans of unnecessary workload, which offers more output with less effort (Ali and Kaur 2022).

iv). Efficient inventory management- Shorter lead times, minimum paperwork, smooth flow of inventory and information, and minimum safety stock are outcomes of smart WMS.

v). Effective space utilization- Lower inventory levels, better space and distribution planning, and accurate information about demand and delivery schedules allow proper use of spaces in the warehouse. The systematic flow of products from receiving area to packaging to the shipping area and that too in lesser time increases productivity and avoid inventory holding cost.

vi). Cost reduction- Cost reduction is a natural outcome of WMS as a lower inventory holding cost less working capital, lesser transactional cost, and more utilization of resources and spaces, which eventually saves cost in loner runs (Ali and Kaur 2022).

Challenges: For WMS to be effective, its alignment and communication with MES (manufacturing execution system) are key. Also, warehouse activities are directly connected with production activities, and their dependence upon ERP complicates the matter. The human factor adds to the ever-increasing list of complications associated with WMS.

i). Structural challenges- Smart technologies do not come cheap they put a big dent in the capital, which poise as a significant hindrance (Ali et al 2021b). Incorporating smart technologies also need to meet some specifications for which companies need to make infrastructural changes that are sometimes difficult to bring. Technological inceptions require a certain level of investment in machinery for which added space is required. Also, smart warehouse functioning requires more data and information and specific software and programming modules that need specific weather conditions like air conditioning or heating continuous electricity supply, which sometimes pose a challenge, especially in remote areas.

ii). Operational challenges- As easier it sounds, converting a warehouse into a smart warehouse does not come without its own set of operational challenges—automation of warehouses a certain level of expertise for handing sophisticated machines and programming modules. The machine modules come in different languages and codes, which require technological competence for decoding and explaining it to others. Lack of technological competence and training could easily hamper the progress towards smart processes. Workers and employees need to be fully and thoroughly trained to handle these complex processes. Lack of funds and resources can be another roadblock for implementing smart in the warehouse systems. However, the industrial revolution is just not scaling up for smart supply chains or smart industrial setups; smart cities are also in the pipeline for a smart digital future. The advantages and complications of the latter are other issues to be explored and discussed.

4. Conclusion

The next industrial revolution is dawning upon us in the form of a digital revolution encompassing major players like big data, analytics, augmented reality, artificial intelligence, cloud computing to give us a fully integrated value creation system. Industry 4.0 is opening new avenues to be explored and new concepts to be implemented to cope with a broad and wide landscape of competition.

References

[1] Alicke, K., Rexhausen, D., and Seyfert, A., Supply Chain 4.0 in consumer goods, McKinsey & Company, Berlin, 2016.

[2] Ali, S. S., and Rajbir Kaur. Exploring the Impact of Technology 4.0 Driven Practice on Warehousing Performance: A Hybrid Approach" Mathematics 10, no. 8: 1252, 2022. https://doi.org/10.3390/math10081252

[3] Ali, S. S., Kaur, R. and Sh. Khan Evaluating sustainability initiatives in warehouse for measuring sustainability performance: An emerging economy perspective, *Annals of Operations Research.* 2021a, https://doi.org/10.1007/s10479-021-04454-w

[4] Ali, S. S., Kaur, R., Gupta, H., Ahmad, Z.; and Elnaggar, G. Determinants of an Organization's Readiness for Drone Technologies Adoption, *IEEE Transactions on Engineering Management*, DOI: 10.1109/TEM.2021.3083138 ,2021b

[5] Ali, S. S., Kaur , Deka, S. , Jaswal,M. , Ahmad , Z. and AlSulami, H. . Feasibility of drone integration as last mile delivery , *Emerald Emerging Markets Case Studies*, 9,3, 1-17, 2019https://doi.org/10.1108/EEMCS-06-2018-0150 .

[6] Attaran, M., RFID: an enabler of supply chain operations, Supply Chain Management: An International Journal, 12(4),249-257, 2007.

[7] B. Cortés, A. Boza, D. Pérez, L. Cuenca, Internet of things applications on supply chain management, Int. J. Comput. Electr. Autom. Control Inf. Eng. 9 (2015) 2204–2209.
[8] B.T. Hazen, J.B. Skipper, J.D. Ezell, C.A. Boone, Big data and predictive analytics for supply chain sustainability: A theory-driven research agenda, Comput. Ind. Eng. 101 592–598, 2016.
[9] Brettel, M., Friederichsen, N., Keller, M., and Rosenberg, M., Ho virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective, International Journal of Information and Communication Engineering, 8(1),37-44, 2014.
[10] Davenport, R.T.H., and Bean, R.,. Big Companies Are Embracing Analytics, but Most Still Don't Have a Data-Driven Culture. Harvard Business Review, 2018.
[11] G. Wang, A. Gunasekaran, E.W.T. Ngai, T. Papadopoulos, Big data analytics in logistics and supply chain management: certain investigations for research and applications, Intern. J. Prod. Econ. 176 98–110, 2016.
[12] Galindo, L. D, The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology. Norwegian University of Science and Technology, 96, 2016.
[13] Gunasekaran, T. Papadopoulos, R. Dubey, S.F. Wamba, S.J. Childe, B. Hazen et al., Big data and predictive analytics for supply chain and organizational performance, J. Bus. Res. 70 ,308–317,2017.
[14] Harford, T. (2014), "Big data: are we making a big mistake?", available at: www.ft.com/intl/cms/s/2/21a6e7d8-b479-11e3- a09a-00144feabdc0.html (accessed 11 October 2019).
[15] Huang, T. and Van Mieghem, J.A., Clickstream data and inventory management: model and empirical analysis, Production and Operations Management,23(3), 333-347, 2014.
[16] Iansiti, M., and Lakhani, K.R. 2017. The Truth about Blockchain." Harvard Business Review 95 (1) 118– 27.
[17] Ivanov, D., Dolgui, A., Sokolov, B., Werner, F., and Ivanova, M., A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0, International Journal of Production Research, 54(2) 386-402, 2016. 14
[18] J. Oyekan, V. Prabhu, A. Tiwari, V. Baskaran, M. Burgess, R. Mcnally, Remote real-time collaboration through synchronous exchange of digitised human– workpiece interactions, Future Gener. Comput. Syst. 67 (2017) 83–93, doi:
[19] Kache, F., and Seuring, S., Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management, International Journal of Operations & Production Management, 37(1),10-36, 2017.
[20] Khan, S.; Singh, R.; Haleem, A.; Dsilva, J.; Ali, S.S. Exploration of Critical Success Factors of Logistics 4.0: A DEMATEL Approach. *Logistics* **,** *6*, 13. 2022, doi: 10.3390/logistics6010013
[21] Klumpp, M., Automation and artificial intelligence in business logistics systems: human reactions and collaboration requirements, International Journal of Logistics Research and Applications, vol. 21 (3), 224-242, 2018.
[22] Kranz, M. 2017. Success with the Internet of Things Requires More Than Chasing the Cool Factor." Havard Business Review.
[23] Krivda, C., RFID after compliance: integration and payback, Business Week, December 20, 2004.
[24] Lee J, Bagheri B, Kao HA (2014) Recent advances and trends of cyber-physical systems and big data analytics in industrial informatics. In Proceedings of International Conference on Industrial Informatics (INDIN), 217–229.
[25] Lee, J., Kao, H-A., and Yang, S., Service innovation and smart analytics for Industry 4.0 and big data environment, product service systems and value creation, Proceedings of the 6th CIRP Conference on Industrial Product- Service Systems, vol. 3, no. 8, pp. 3-8, 2014.

[26] Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C. and Byers, A.H. (2011), Big Data: The Next Frontier for Innovation, Competition, and Productivity,
[27] McKinsey & Company, New York, NY, available at: www. mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation (accessed 9 November 2019).
[28] Rossom, P., Big data analytics, TDWI Best Practice Report, Fourth Quarter 2011, TDWI, 2011.
[29] Schiemann, J, Logistics 4.0 - How autonomous are self-managed processes? Axit Connecting Logistics, 16, 2016
[30] Shu, J. and Barton, R. (2012), "Managing supply chain execution: monitoring timeliness and correctness via individualized trace data", Production and Operations Management,21(4), 715-729.
[31] iciliano, B., and Khatib, O. Editors. 2016. Springer handbook of robotics, 2nd Ed. Heidelberg, Germany: Springer.
[32] Tan, K.H., Zhan, Y., Ji, G., Ye, F., and Chang, C.,(2015). Harvesting Big Data to enhance supply chain innovation capabilities: an analytic infrastructure based on deduction graph, International Journal of Production Economics, vol. 165, pp. 223-233.
[33] Thiesse, F., Floerkemeier, C., Harrison, M., Michahelles, F., and Roduner, C., Technology, standards, and real-world deployments of the EPC network, IEEE Internet Computing, vol. 13, no. 2, pp. 36-43, 2009.
[34] Trappey, A. J. C., Trappey, C. V., Fan, C-Y., Hsu, A. P. T., Li, X-K., and Lee, I. J. Y., IoT Patent Roadmap for Smart Logistic Service Provision in the Context of Industry 4.0, Journal of the Chinese Institute of Engineers, 40(7), 593-602, 2017.
[35] Tu, M., An exploratory study of Internet of Things (IoT) adoption intention in logistics and supply chain management: A mixed research approach, The International Journal of Logistics Management, 29(1),131-151, 2018.
[36] Tu, M., Lim, M. K., and Yang, M-F., IoT-based production logistics and supply chain system – Part 1: Modeling IoT- based manufacturing supply chain, Industrial Management & Data Systems, 118(1), 65-95, 2018a.
[37] Tu, M., Lim, M. K., and Yang, M-F., IoT-based production logistics and supply chain system – Part 2: IoT-based cyber-physical system: a framework and evaluation, Industrial Management & Data Systems,118(1), 96-125, 2018b.
[38] Wamba, F.S., Akter, S., Edwards, A., Chopin, G., and Gnanzou, D., (2015). How 'big data' can make big impact: findings from a systematic review and a longitudinal case study, International Journal of Production Economics, 165, 234-246.
[39] Wamba, F.S., and Boeck, H., Enhancing information flow in a retail supply chain using RFID and the EPC network: a proof-of-concept approach, Journal of Theoretical and Applied Electronic Commerce Research, 3(1),92-105, 2008.
[40] Wang S, Wan J, Zhang D, Li D, Zhang. Towards smart factory for industry 40: A self-organized multi-agent system with big data-based feedback and coordination. Comput Net 101,158–168,2016.
[41] Wang, L., Törngren, M., and Onori, M., Current status and advancement of cyber-physical systems in manufacturing, Journal of Manufacturing Systems, 37(2), 517-527, 2015.
[42] Wang, S., Wan, J., Li, D., and Zhang, C., Implementing smart factory of Industries 4.0: An outlook, International Journal of Distributed Sensor Network, 2016.

[43] Witkowski, K., Internet of Things, big data, Industry 4.0 – Innovative solutions in logistics and supply chain management, Proceedings of the 7th International Conference on Engineering, Project, and Production Management, 182,763-769, 2017.

[44] Wu, L., Yue, X., Jin, A., and Yen, D.C., Smart supply chain management: a review and implications for future research, The International Journal of Logistics Management, 27(2), 395-417, 2016.

[45] Zhang Y, Qian C, Lv J, Liu Y (2017) Agent and cyber-physical system based self adaptive intelligent shopfloor. IEEE Trans Indust Inf 13(2):737–744

Webliography

1. https://www.strategy-business.com/article/The-catalytic-co-investor-How-Siemens-US-keeps-RD-alive accessed on Feb21'2021
2. https://www.strategy-business.com/article/Simplicity-Synergy-and-Scale accessed on Jan2'2021
3. https://assets.kpmg/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf accessed on March1'2021
4. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/getting%20the%20most%20out%20of%20industry%204%200/mckinsey_industry_40_2016.ashx accessed on Jan2'2021
5. https://www.logistics.dhl/global-en/home/insights-and-innovation/thoughtleadership/trend-reports/internet-of-things-in-logistics.html accessed on March22'2021