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Toward Smart Logistics: Hybrization of Intelligence Techniques of Machine Learning and Multi-Criteria Decision-Making in Logistics 5.0

Mona Mohamed [1,*]

[1] Higher Technological Institute, 10th of Ramadan City 44629, Egypt; mona.fouad@hti.edu.eg.

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Abstract

With cutting-edge technology and data-driven insights, intelligent logistics has become a game-changing supply chain management strategy, helping maximize productivity and streamline processes. The main ideas of smart logistics are outlined in this study. It includes several factors that companies must consider while assessing and implementing intelligent logistics solutions. Real-time visibility, supply chain collaboration, inventory management, robotics and automation, supply chain integration, predictive analytics, scalability and flexibility, security and data privacy, and return on investment are some requirements. Using these criteria, organizations may use intelligent logistics to optimize inventory levels, boost customer happiness, save costs, simplify procedures, and enhance supply chain efficiency. In a dynamic and connected world, intelligent logistics solutions help businesses make data-driven choices, react fast to market needs, and adjust to changing business situations. We applied machine learning algorithms to analyze the supply chain dataset. We used two machine learning algorithms: a decision tree and a random forest. We compute the accuracy, precision, recall, and f1 score. The decision tree has the highest accuracy, with 91%. Then, we used the multi-criteria decision-making (MCDM) methodology to analyze the criteria of intelligent logistics. The AHP method is used to compute the weights of criteria..

Keywords: Multi-criteria Decision Making, Smart, Logistics, Machine Learning, Supply Chain.

1 | Introduction

For every enterprise, logistics are crucial. Owing to logistics' obligation to move and preserve commodities as passing through the supply chain (SC). Additionally [1, 2] where logistics are furnishing high-quality services at affordable or acceptable costs whilst elevating customer loyalty.

The important role of logistics in all economic activities has been emphasized in [3] by Christopher as avital and crucial aspect. Others as Shapiro and Heskett [4] stated that few facets of human activity are independent of the movement of products from the point of origin to the place of consumption. According to Uckelmann in [5]the well-known logistical imperative lies in getting the right product at the right time, in the right place,

Corresponding Author: mona.fouad@hti.edu.eg
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and in the right condition. Also, the scholar emphasized that the environment of logistic markets is characterized by dynamics and complexity. From the point of view of [6] deploying modern information and communication technologies (MICT) facilitate communication through exchanging information among business chain. Subsequently, recent technological developments and innovations have had a tremendous impact on logistics by transforming traditional logistics into digitized logistics[7]. Alluding to tenets of interconnection, digitization, and automation by [8], the fourth industrial revolution (Ind 4.0) encompasses the set of technologies that should be utilized to increase the competitiveness of industrial enterprises. For example, Wang [9] disclosed the notion of logistical 4.0 (Log 4.0), which blends Ind 4.0 technologies as Industrial Internet of Things (IIoT), Internet of Things (IoT), Big Data Analytical (BDA), Robots, Additive Manufacturing (AM), Cloud Computing (CC), Augmented Reality (AR), Artificial Intelligence (AI)…etc. with a variety of logistical activities to boost automation and smarts. Figure 1 summarized the perspective of [9] to showcase the positive aspects of Log 4.0 in business environment.

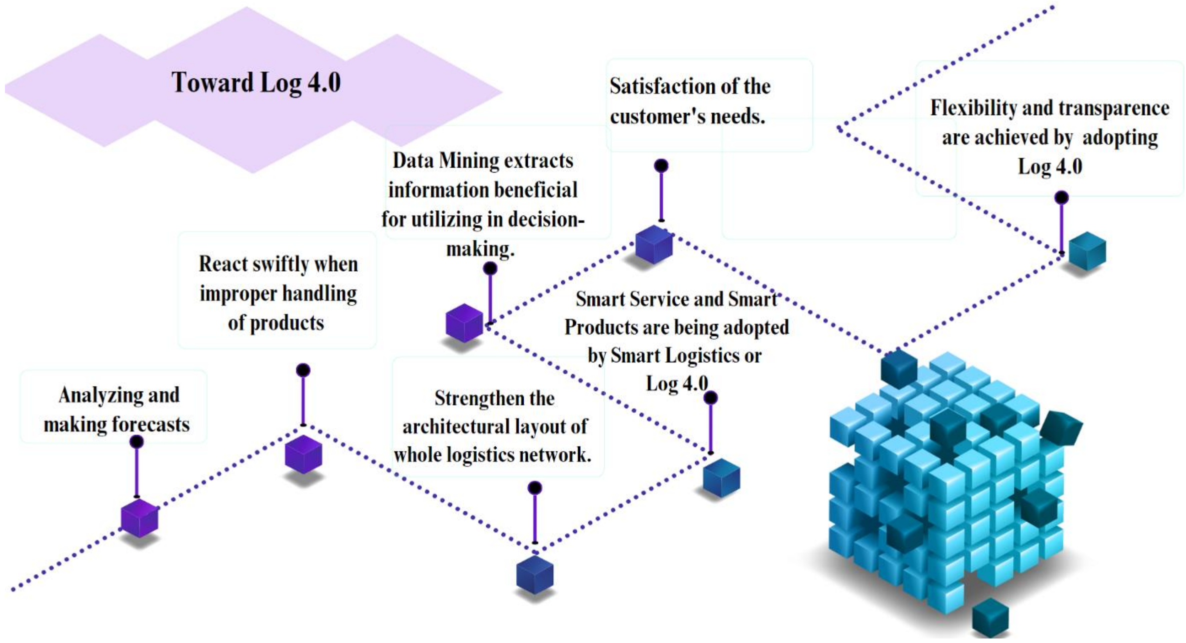

Figure 1. Beneficial of deployment Logistic 4.0 in the business environment.

Notwithstanding the significant role that Ind 4.0 technologies occupy in logistics to be Log 4.0 or smart logistics, the study[10] stated that principal goal of Ind 4.0's is to shift the industrial paradigm through technology, while society's and people's needs have received less attention. Similarly [11] showcased how Ind 4.0 uses new technologies to substitute human beings and boost production. As a result of the anxieties that people and society had throughout the industrial transition, Industry 5.0 (Ind 5.0) was created by Michael Rada [11].Others are embracing this notion as [12] to deploy in logistics to shift Log 4.0 into Logistic 5.0 (Log 5.0) and clarified how Log 5.0 execute by enterprises in 2030. Figure 2 represents scholars' point of view in [13] for implementing the next generation of Log 4.0 indeed Log 5.0 in business environment.

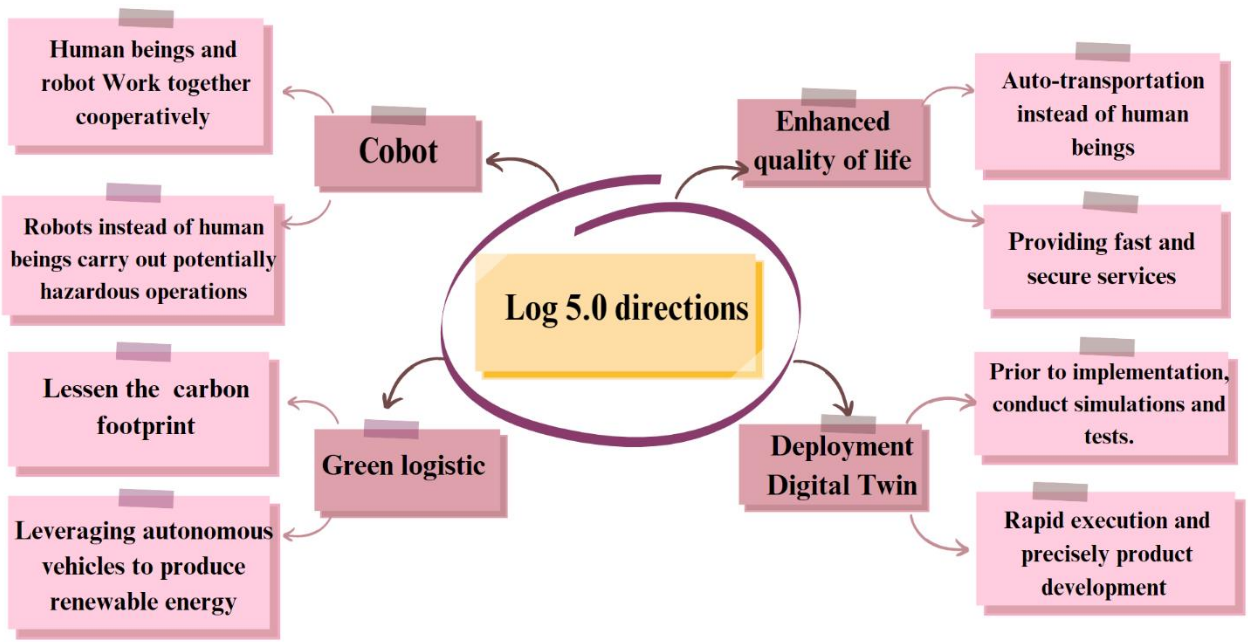

Figure 2. Directions of Logistics 5.0 in a business environment.

According to our conducted survey on earlier studies, smart logistics or Log 5.0 suffer from some issues. The key concern in IIoT networks as an important connectivity factor in Log 5.0 is security difficulties and attacks. For example, the study of [14] critiques the scholars in [15] through their interest about the importance of smart logistics in scheduling, tracking efficiency and optimization, human-machine interaction, controlling assets, and automated manufacturing but neither fully addresses IIoT-scale data management or comprehensive cyber-security protection. Others as [16] revealed the importance of Log 5.0 technologies for guaranty good connectivity while enormous quantities of data generated as a result of this connectedness.

These issues are released through [17] which encouraged the deployment of novel techniques of AI such Machine Learning (ML) techniques and its sub-techniques as Deep Learning algorithms (DLAs).Similarly [6] adopted the notion of executing ML/DLAs in Smart Logistics for industrial businesses. Due to the capability of ML based on [18] aided by DL in exploring several layers or new knowledges from unpredictable or non-stationary information processing.

Herein, this study attempts to get benefit from previous studies about deploying ML/DLAs in smart logistics especially Log 5.0 as success tools in era of Log 5.0. Therefore, we introduce in this study Systematic Literature Review (SLR) about implementing DLAs in Log 5.0 to illustrate how Log 5.0 exploit DLAs for analyzing and extracting information, and predicting incoming events based historical events.

We applied the machine learning algorithms and multi-criteria decision-making (MCDM) methodology in this study. The machine learning algorithms are used to analyse the supply chain dataset; then, the MCDM method ranks the criteria of intelligent logistics. We used two machine learning methods, decision tree and random forest, and the AHP method as an MCDM method.

2 | Research Map and Methodology

This section unveils the study's map and its methodology for SLR through the following steps according to Figure 3.

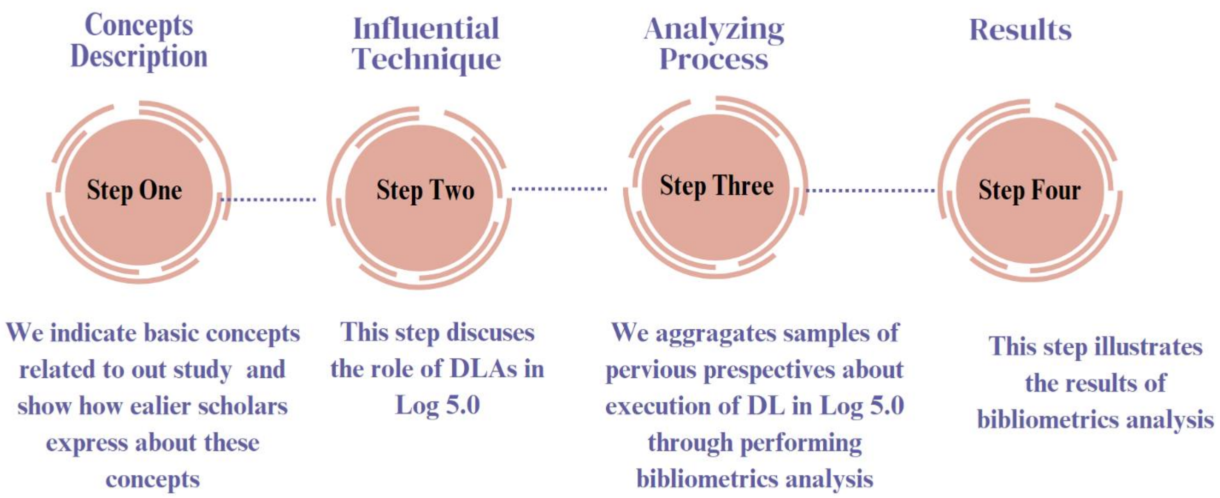

Figure 3. Steps of systematic literature review.

2.1 | Key Concepts Incorporated into Study

This sub-section considers the first step in the map of our study according to determined SLR as mentioned in above Figure 3. It encompasses the main utilized concepts in our study.

- **Industrial Revolutions**

Alaloul et al. [19] discussed the industrial revolutions (IRs) and its role in the tendencies of digital transformation, automated processes, and growing employing MICT in various domains. For more details for the evolution of IRs 's (see Ref [20]). Relying on the industrial revolutions' history that [21] offered, the IRs persisted until technology and human beings became interconnected [22]. Also, [23], [20] are the strong evidences for applying the technologies of IRs especially, Ind 4.0 and Ind 5.0 in other purposes as energy efficiency and renewable sources to be eco-friendly and then achieve sustainability.

- **Operate Logistics under Industrial Revolutions**

In the era of evolutions especially in industry that resulted IRs, the business environment and decisions are influenced by these revolutions as logistics. The term of logistics expressed in [24] as supplying the appropriate product in an adequate amount at the appropriate location, at the appropriate time, at the appropriate cost, and with the appropriate information. When latest industrial revolutions as Ind 4.0 merged in logistics to be smart logistics [16]. So, the term of smart logistics related to MICT. So, the deployment of Ind 4.0 as part of MICT are boosting logistics in different domains. The function of smart logistics in transportation, warehouse, Circulation and packaging is clarified by [25] (see Figure 4).

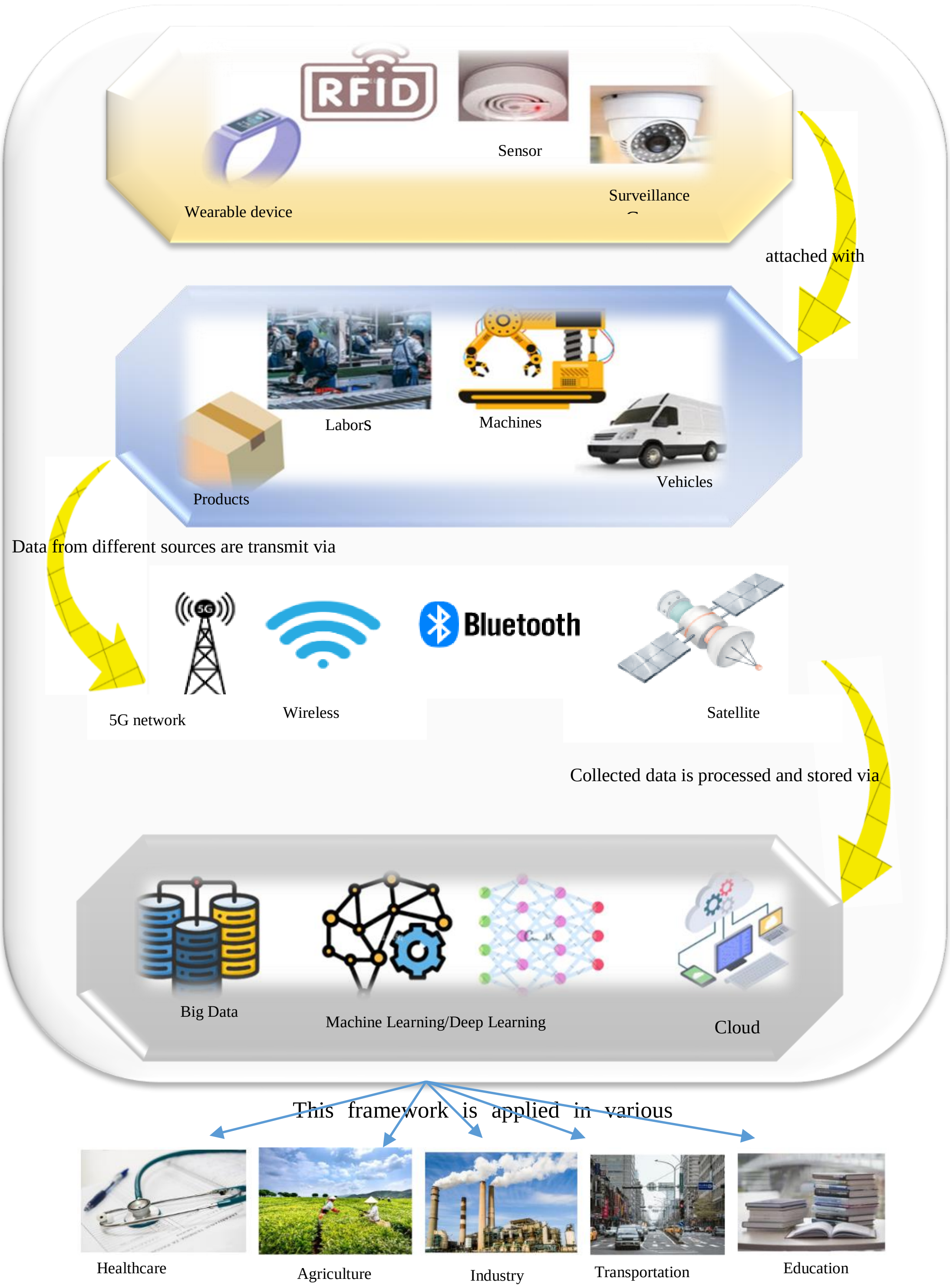

Figure 4. Implementing cutting-edge technologies in smart logistics.

Diverging perspectives prevail regarding. Where [13] disclosed that Ind 4.0. Ind 4.0 is still in its infancy, yet practitioners as well as experts have expressed certain worries about the situation of humans in these cutting-edge technologies. Insist on this perspective [26] considers cite evidence to support the notion that the highly automated environment made possible by Ind4.0 threatens to eliminate humans' worthwhile roles. This matter is discussed by [27] where taking into account the role of logistics operators during the period of prosperity in the context of Industry 4.0 technology. As a result, the still futuristic concept of Ind 5.0 rather than the assumption that robots would take over the industrial environment arose. This study aggregates and expresses the different perspectives for scholars in [27-30], in Figure 5 concerning cutting-edge technologies in revolutions 4.0 and 5.0 to digitize logistics.

The swift shifts in the global market, the shifting needs of the consumer, and sustainability considerations all have an impact on today's businesses [16].In this context, [31] reaffirmed that academics as well as experts are exploiting the capabilities of AI techniques for greater efficiency in various logistics contexts. Also, this study focuses on the role of AI, especially DL as victory ingredient in Log 5.0.

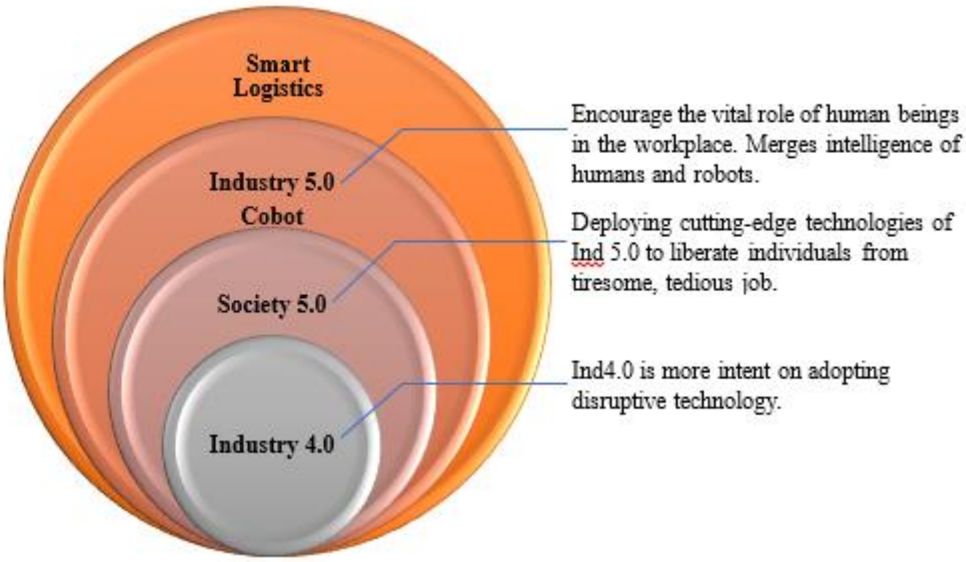

Figure 5. Cutting-edge technologies toward smart logistics.

2.2 | Bibliometrics Analysis

Bibliometrics analysis process is the third Bibliometrics analysis process is the third step in map of SLR. Biblio Whilst this process expressed by [32] as quantitative analysis of the several scholarly step in map of SLR. articles. As Donthu etal. [33] who recommend the procedures for performing comparative bibliometric analysis. Furthermore, we analyze a collection of articles and mapping the science, which might involve co-citation analysis and keyword co-occurrence analysis. This process is performed on ("logistics" OR "smart logistics" OR "logistics 4.0" OR "logistics 5.0") AND "deep learning" to create map based on several bibliographic data from web of science (WoS) database. The following subsections for bibliometrics are the fourth step in SLR (see Figure 3). This study is applied VOS viewer software for conducting bibliometric analysis and mapping. Due to[34] shed light on ability of this software to display big bibliometric maps in an understandable and straightforward mannercomparing to other bibliometric ways.

2.2.1 |Co-Citation Analysis

Herein, VOS viewer has been employed to appraise and visualize interconnection between sources through generating network visualization based on bibliographic co-citations from database of WoS as in Figure 6. Co-citation network based on sources is visualized with 114 items for 7473 sources. These items are clustering into 5 clusters with 144571 Total Length Strength (TLS). Wherein [11] articulated about TLS as the measure that indicates the impact of each source on the articles that are published, is the result of the accumulation of the connections that are connected to each node. Cluster one involves 52 items, cluster two encompasses 24 items where cluster three has 24 items, cluster four has 12 items, finally cluster 5 includes 2 items. Figure 6 exemplified that the International Journal of Production Research 'Int J Prod Res', which generates 602 co-citations and has 21585 of TLS, is the most significant source for ("logistics" OR "smart logistics" OR "logistics 4.0" OR International Journal of Production Economics 'Int J Prod "logistics 5.0") AND "deep learning". As that

Econ', and Journal of Cleaner Production 'J Clean Prod' are occupying the following levels with TLS weights of 14604 and 14508 respectively.

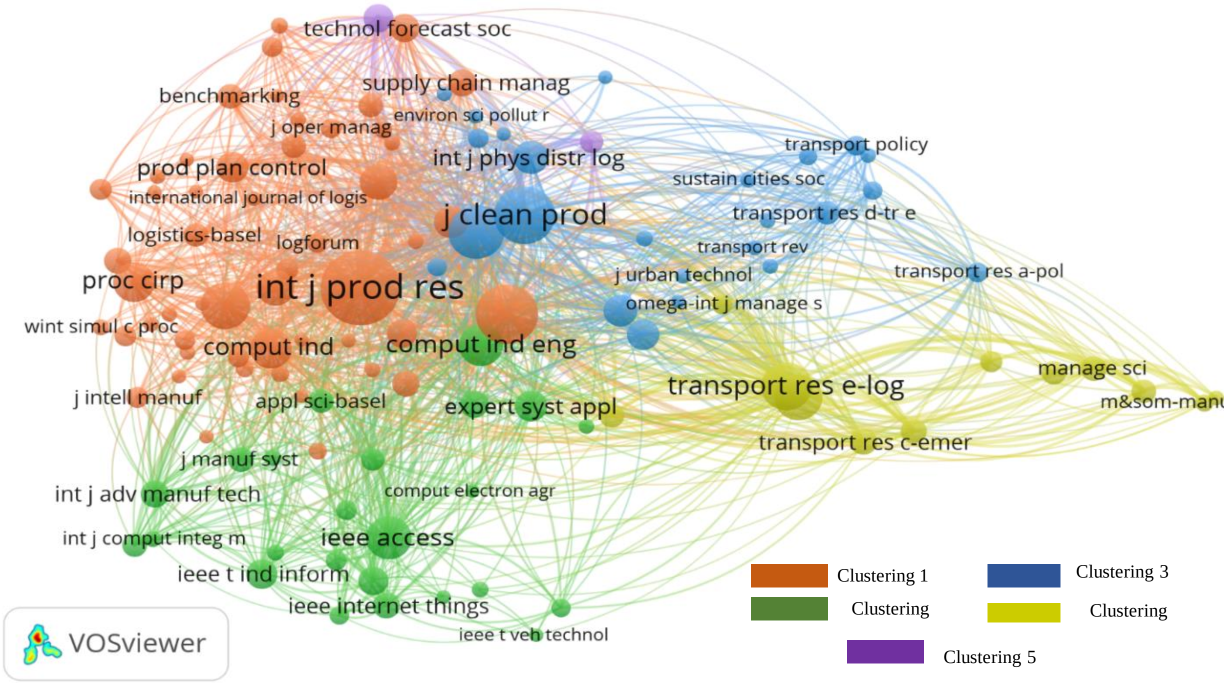

Figure 6. Co-Citation analysis network of deep learning in logistics /smart logistics.

2.2.2 | Co-Occurrences Analysis

The visualized network in Figure 7 is generated from analyzing Co-occurrences for all keyworks related to determined terms (see section 2.3). The purpose of this process according to [11] represents in the scrutiny of keywords' co-occurrences determines how frequently each keyword is used as well as how pairs of keywords interact. The visualized network is divided into seven clusters with 4523 TLS for 1733 keywords. Through analyzing the process for co-occurrence of keywords, TLS yielded through the total number of links that are significant for each term. Whereas industry 4.0 yielded 389 TLS, occurrences 115 and considers most influence while logistics system yielded 8 TLS, occurrences 5 is least influence.

2.3 | Role of AI algorithms in Logistics 5.0 toward smart logistics

This subset considers the second step in the map of our study according to determined SLR. Whereas this step encompasses the earlier works discussed the role of AIA based technologies of Ind 4.0 and Ind 5.0 in Log 5.0 toward smart logistics. For instance [35], The study goes over diverse DL techniques and how it pertain to smart logistics. By covering the most contemporary research concerning this area of study that were released from 2017 to 2021 for DLA-based IoT in smart logistics. The scholars exploit the efficiency of DL in [36] to cope with and manage an excessive amount of data generated from data generated from prevalent in IoT devices. Whereas [37] is concentrated on sensors as an example of an Internet of Things gadget that connects to logistical entities. Convolutional neural network (CNN) implemented by [38] in smart logistics for recognizing face.

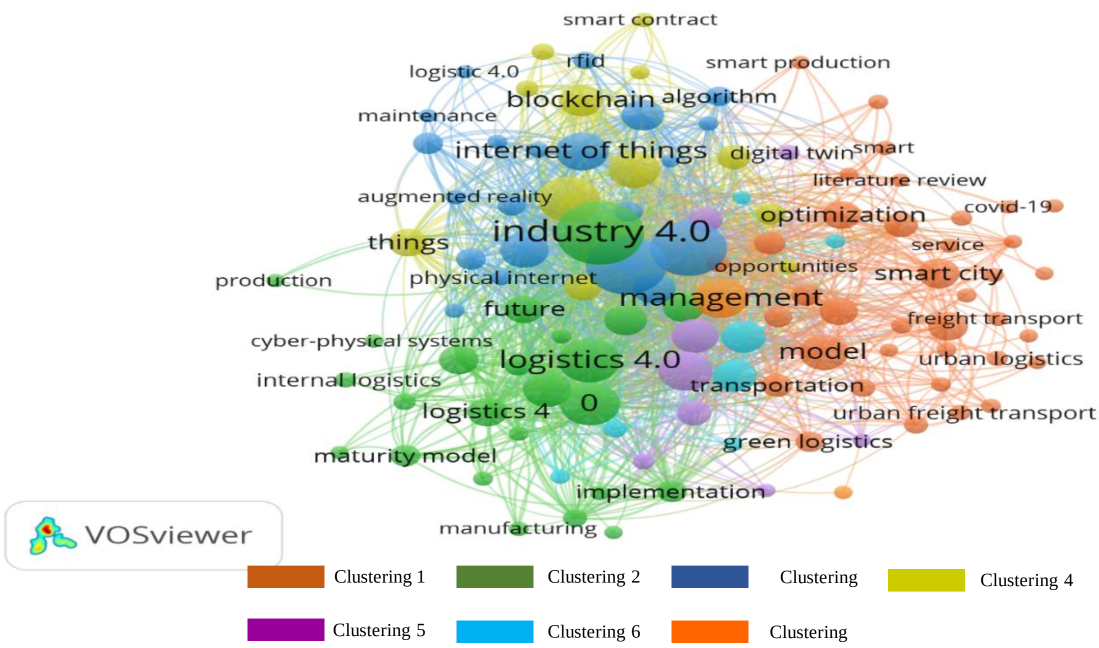

Figure 7. Co-Occurrence analysis network of deep learning in logistics /smart logistics.

Based on surveys conducted for earlier studies, DLAs are volunteering to serve several purposes. As [39] concentrate their research on developing of a machine learning-based model to help smart logistics by detecting anomalous occurrences in the massive volume of electronic orders received from omnipresent clients. Similarly [14] utilized deep autoencoders (AE) in anomaly detection where this technique volunteered for incorporating anomaly detection capabilities into the Cellular IoT architecture, allowing for integrated threat detection at IoT devices. Based on perspective of [35] DLAs are gradually replacing conventional ML models in numerous domains and have positive effect in logistics to be smart logistics. Due to [40] where IoT issues in logistics can emphasized that DL boost IoT applications. As [41] intelligent be recompensed for by DL. So, [42] technologies are needed for contemporary transport, and integrating DL tools with IoT might increase efficacy, sustainability, and decrease operating expenses.

This subsection considers the greatest motivation to conduct bibliometrics analysis in the next subsection for earlier studies and research about the role of DLAs in Log 5.0 and smart logistics.

ML methods train computers to manage massive amounts of data more effectively. Occasionally, conventional methods cannot extract or analyze patterns or information from enormous amounts of data. The need for machine learning methods has increased due to the accessible datasets. Machine learning methods are extensively used in various sectors, including the military and the medical field, to extract knowledge and information from data. Numerous research projects by mathematicians and programmers have led to the creation of several machine-learning algorithms. We applied DT and random forest on SC dataset https://kaggle.com/code/devanshchowdhury/mtp-notebook/input. Accordingly, the various statistical methods on dataset are illustrated as listed in Table 1.

The nodes in the tree indicate attribute testing, while the branches that follow provide potential results for the nodes. The predictive model attempts to divide observations into mutually exclusive categories for data mining and machine learning activities. DTs are tools for decision-making that provide a pathway from observations to possible results. We applied a decision tree and random forest then we compute the performance measures for two algorithms as shown in Table 2. We demonstrated that DT has the highest accuracy, precision, recall and f1 score.

Table 1. Some statistical method on the dataset.

	count	mean	std	min	25%	50%	75%
Days for shipping (real)	180519	3.497654	1.623722	0	2	3	5
Days for shipment (scheduled)	180519	2.931847	1.374449	0	2	4	4
Benefit per order	180519	21.97499	104.4335	-4274.98	7	31.52	64.8
Sales per customer	180519	183.1076	120.0437	7.49	104.38	163.99	247.4
Late_delivery_risk	180519	0.548291	0.497664	0	0	1	1
Category Id	180519	31.85145	15.64006	2	18	29	45
Customer Id	180519	6691.379	4162.918	1	3258.5	6457	9779
Customer Zipcode	180519	35921.13	37542.15	603	725	19380	78207
Department Id	180519	5.44346	1.629246	2	4	5	7
Latitude	180519	29.71996	9.813646	-33.9376	18.26543	33.14486	39.27962
…	…	…	…	…	…	…	…
Order Item Profit Ratio	180519	0.120647	0.466796	-2.75	0.08	0.27	0.36
Order Item Quantity	180519	2.127638	1.453451	1	1	1	3
Sales	180519	203.7721	132.2731	9.99	119.98	199.92	299.95
Order Item Total	180519	183.1076	120.0437	7.49	104.38	163.99	247.4
Order Profit Per Order	180519	21.97499	104.4335	-4274.98	7	31.52	64.8
Order Zipcode	180519	55426.13	11840.22	1040	55426.13	55426.13	55426.13
Product Card Id	180519	692.5098	336.4468	19	403	627	1004
Product Category Id	180519	31.85145	15.64006	2	18	29	45
Product Price	180519	141.2326	139.7325	9.99	50	59.99	199.99

The nodes in the tree indicate attribute testing, while the branches that follow provide potential results for the nodes. The predictive model attempts to divide observations into mutually exclusive categories for data mining and machine learning activities. DTs are tools for decision-making that provide a pathway from observations to possible results. We applied decision tree and random forest then we compute the performance measures for two algorithms as shown in Table 2. We show the decision tree has highest accuracy, precision, recall and f1 score.

Table 2. Performance measures of decision tree and random forest algorithms.

	Decision Tree	Random Forest
Accuracy	0.9007035231553291	0.8127908265012187
Precision	0.9007035231553291	0.8127908265012187
Recall	0.9007035231553291	0.8127908265012187
F1 Score	0.9007035231553291	0.8127908265012187

2.4 | Evaluating the Smart Logistics Criteria using the AHP Method

In this part we evaluate the criteria od smart logistics by the AHP method. The AHP method is used to compute the weights of criteria[41–44].

Step 1. Build the pairwise comparison matrix.

$$X_{n*n} = \begin{bmatrix} 1 & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nn} \end{bmatrix} \quad (1)$$

Step 2. Evaluate the criteria by the values between 1 and 9.

Step 3. Normalize the pairwise comparison matrix

$$n_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (2)$$

Step 4. Compute the weight average.

$$w_i = \frac{1}{n}\sum_{j=1}^{n} n_{ij} \quad (3)$$

Step 5. calculate the consistency index.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

Step 6. calculate the consistency ratio.

$$CR = \frac{CI}{RI} \quad (5)$$

2.5 | Results of Evaluating the Smart Logistics Criteria using the AHP Method

We used eleven criteria of smart logistics to evaluate it and select best one.
Step 1. Build the pairwise comparison matrix suing Eq. (1).
Step 2. Evaluate the criteria by the values between 1 and 9.
Step 3. Normalize the pairwise comparison matrix using Eq. (2) as shown in Table 3.
Step 4. Compute the weight average using Eq. (3) as shown in Figure 8.
Step 5. calculate the consistency index using Eq. (4).
Step 6. calculate the consistency ratio using Eq. (5).

Table 3. Normalization pairwise comparison matrix.

	SLC_1	SLC_2	SLC_3	SLC_4	SLC_5	SLC_6	SLC_7	SLC_8	SLC_9	SLC_{10}	SLC_{11}
SLC_1	0.331666	0.428098	0.362	0.289296	0.296344	0.273256	0.145651	0.138789	0.096819	0.120846	0.157895
SLC_2	0.165833	0.214049	0.362	0.231437	0.185215	0.182171	0.218476	0.158617	0.135546	0.075529	0.122807
SLC_3	0.110555	0.07135	0.120667	0.347155	0.333387	0.242894	0.169926	0.079308	0.096819	0.090634	0.140351
SLC_4	0.066333	0.053512	0.020111	0.057859	0.111129	0.121447	0.121376	0.178444	0.116183	0.135952	0.157895
SLC_5	0.041458	0.04281	0.013407	0.019286	0.037043	0.121447	0.169926	0.158617	0.174274	0.075529	0.105263
SLC_6	0.036852	0.035675	0.015083	0.014465	0.009261	0.030362	0.121376	0.178444	0.116183	0.120846	0.052632
SLC_7	0.055278	0.023783	0.017238	0.011572	0.005292	0.006072	0.024275	0.079308	0.058091	0.135952	0.035088
SLC_8	0.047381	0.026756	0.030167	0.006429	0.00463	0.003374	0.006069	0.019827	0.174274	0.120846	0.087719
SLC_9	0.066333	0.030578	0.024133	0.009643	0.004116	0.00506	0.008092	0.002203	0.019364	0.10574	0.035088
SLC_{10}	0.041458	0.04281	0.020111	0.006429	0.007409	0.003795	0.002697	0.002478	0.002766	0.015106	0.087719
SLC_{11}	0.036852	0.030578	0.015083	0.006429	0.006174	0.010121	0.012138	0.003965	0.009682	0.003021	0.017544

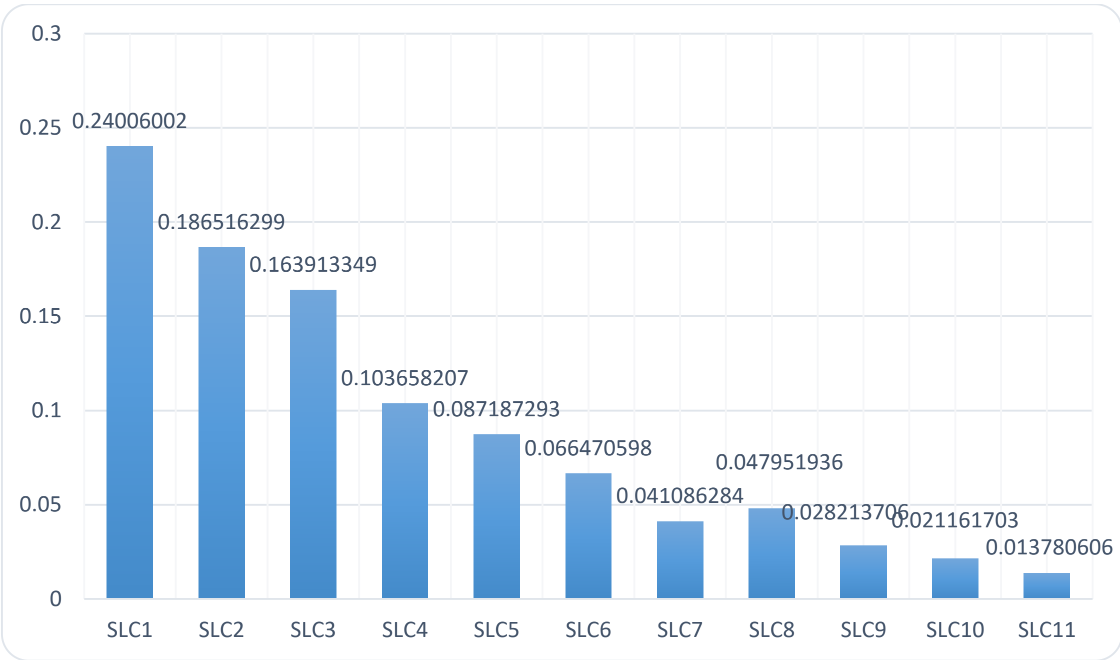

Figure 8. The weights of eleven criteria in smart logistics.

3 | Future scenario for smart logistics 2030 in Egypt

This section pertains to the future vision for the conception of smart logistics especially in Egypt. The authors of [45] emphasized that A critical requirement for sustainable growth has been developed through the emergence of MICT in the logistical services.. The advancement of new technologies and MICT which embodied in this study in Ind 4.0 and Ind 5.0 technologies. These technologies have positive implication on logistics through transforming traditional logistics into Log 5.0 or smart logistics. Thence transportation, education, health, and business and economics (SCM), agriculture, and industry become smart and digitized as a result of digitizing and smart logistics as in Figure 9.

Innovative MICT has been problem solvers for various logistics. Herein, this study conceptualizes the vision of Egypt through merging MICT in logistics services to achieve the goals of sustainability to become smart Egypt.

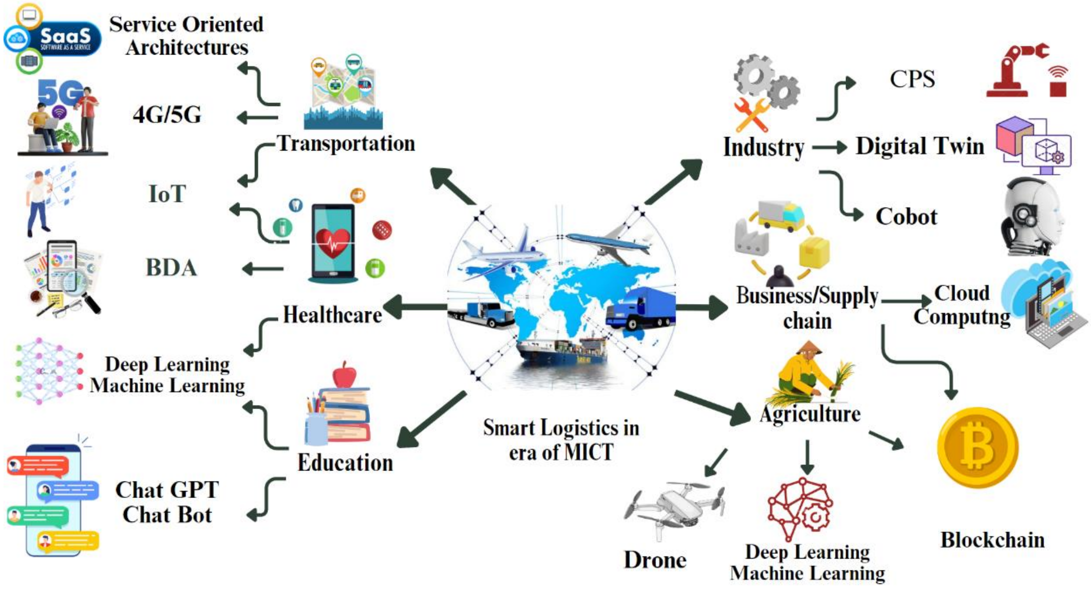

Figure 9. Toward smart logistics services in 2030.

Egypt vision in transportation 2030: Egypt is characterized by a high population, which leads to an increase in vehicles and aggravation of traffic congestion problems. Wherefore, MICT is employed as motivator for bolstering transportation system sustainability through developing smart transportation system (STS) as following:

Through deploying IoT as in Figure 9, the vehicles and traffic lights become smart objects where sensors are attached to it. Consequently, data about the status of traffic and vehicles are collected and transferred via technologies such as V2X and others. This data is monitored and tracked in real time and stored. In STS, Drivers are safe by collecting data simultaneously from the sensors that have been attached to objects. Also, mitigate traffic congestion.as well as volunteering ML and DL as other technologies of MICT for precise forecasts of future travel times which are necessary for drivers and traffic system architects.

Egypt vision in healthcare 2030: Applying smart devices to construct safety and proactive framework for human beings. In Figure 10 sensors are deploying to measure blood sugar and temperature and these measurements transmit by 5G and wireless to store into devices. Whilst MICT technologies analyze collected data by BDA to diagnosis diseases and generate reports which are sent for users. Also, framework considers proactive through alerting users /patient to future health circumstances through predicting diseases based on historical collected data through deploying ML and DL. Similarly, IoT equipment are tracking patient's attitude of health remotely and an alert is issued when the medication is due for him/her.

Egypt vision in education 2030: deploying technology such BCT in education chain is transforming it into education 4.0 or smart education. This technology permits partners in Figure 9 to visualize and monitor transactions which are stored in a distributed ledger (DL). Wherefore education chain characterizes transparency where each partner in chain can realize transactions are stored in blocks. Each partner in the education chain has akin authority though relationships between them are peer-to-peer with high security and trust where no one can easy change or modify in transactions into blocks.

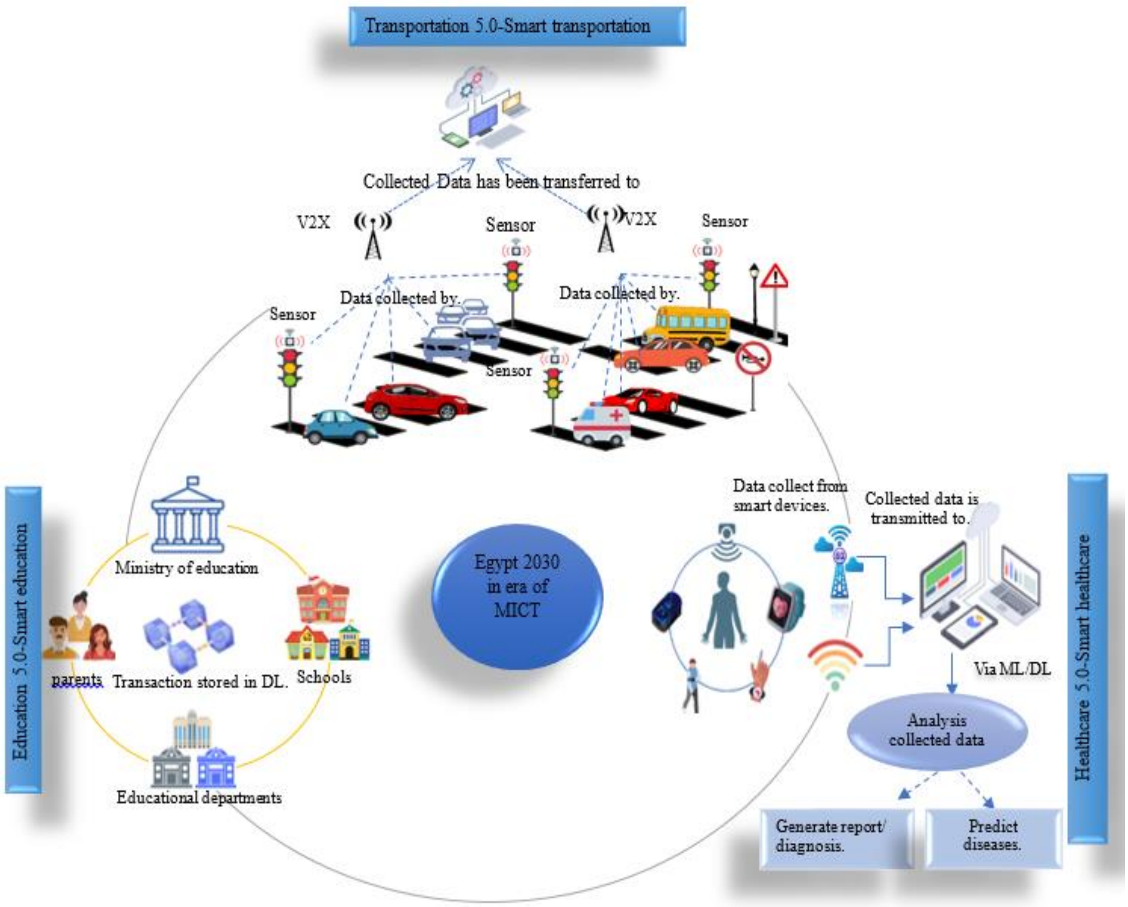

Figure 10. Toward smart Egypt 2030 based on logistics 5.0 / smart logistics.

4 | Conclusions

A paradigm shift in supply chain management is brought about by intelligent logistics, which enables businesses to maximise performance and streamline processes. Organizations may choose and use smart logistics solutions that fit their unique requirements and objectives by considering various factors. Predictive analytics enables data-driven forecasting and decision-making, while real-time visibility offers insights into the flow and placement of commodities. Effective inventory management reduces stockouts and surplus inventory, while automation and robotics technologies optimise workflows and boost productivity. Supply chain cooperation and last-mile delivery optimisation improve customer satisfaction and facilitate smooth operations for all parties involved. Sustainability factors deal with environmental effects, while interoperability and integration ensure that systems work with one another. Thanks to scalability, flexibility, security, and data privacy protections that safeguard critical data, organisations can adjust to changing business needs. Evaluating the return on investment facilitates determining the practical advantages and affordability of innovative logistics technologies.

Organizations may obtain a competitive advantage, boost customer happiness, increase supply chain visibility, and achieve operational excellence by adopting intelligent logistics. Utilizing cutting-edge technology and insights gleaned from data enables companies to streamline operations, save expenses, and react swiftly to changing market conditions. Organizations can spur innovation, seize new opportunities, and adjust to the changing needs of a changing business environment with the help of intelligent logistics. Organizations may attain SC excellence and set themselves up for success in the digital era by using the potential of intelligent logistics. Herein, we utilized SC dataset and DT and RF have been volunteered as ML techniques to analyze used dataset. The result of DT algorithm demonstrated the highest accuracy. Also, MCDM techniques being in AHP techniques to evaluate the criteria of smart logistics through computing criteria's weights where smart logistic criterion1(SLC_1) is the best one with highest weight value in contrast smart logistic criterion 11 (SLC_{11}) is the worst one with least weight value

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Author Contributaion

All authors contributed equally to this work.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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