

Investigating How AI and Data Science Techniques Are Applied in the Freight Transportation Industry, in Particular, the Land Transportation Perspective

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Abstract: The freight transportation industry experienced an increasingly significant role in the global market. In particular, road transportation continued developing over the years with the development of technology. On the other hand, the emergence of Covid-19 facilitated the digitalization speed of road transportation. Hence, this paper identified the application of AI and data science techniques, particularly in the land transportation area within the freight transportation industry. The article first introduced the site's current situation from the sides of development and Covid-19 disease. Then, the author compared data science and AI techniques with traditional approaches. Finally, the present application and future technology trends are identified for the future trend prediction.

Keywords: AI, data science, freight transportation industry, land transportation

1. Introduction

Freight transportation industry, with 9.8% CAGR (Compound Annual Growth Rate) [1], plays a more significant role in the global market. It is formed mainly through logistics management (supply chain management and design) and freight transport (trade goods to other locations for commercial goals) [2]. Freight transportation develops the geographical value of commodities by their displacement in order to satisfy the demands of various places and realise the utility value of commodities [3]. Especially due to the growth of the e-commerce sector, the logistical market produced more than \$24 billion in 2018, a 26 percent increase over 2016's contribution [3]. The transported products could be separated into bulk and non-bulk categories. Non-bulk Freights, the majority of transportation consists of unit load and semi-bulk transportation [2]. Due to its established industrial standard, North America is regarded the leading area on a worldwide scale [4].

According to means of transportation, the freight market may be classified into four categories: railroads, roads, waterways, and airlines [1, 4]. It is important to note that road and rail transportation continued growing over this era, however all other means of transportation are expected to decline in 2020 due to the effect of the new monarchy [1].

Specifically in Organisation for OECD (Economic Co-operation and Development) countries, the number of containers placed between China and Europe surged by about 20 percent from January to

March in 2020, according to statistics from the Department of Commerce of China [4]. In the same year, under the impact of both technology and pandemic, road network also saw remarkable growth [5]. More than 51,000 road transportation businesses (Table 1: enterprise ranking) in the United Kingdom operate more than 399,4 thousand heavy vehicles [2]. The rationale for this is that land transportation is better to other modes in terms of energy consumption, land use, and security assurance [1]. Nonetheless, as demand increases, the logistics of land conveyance grow increasingly problematic. Specifically, the market for road freight transportation has become a near-typical example of total rivalry [6]. To stay successful, businesses need increasingly modern and integrated technological systems [1].

As a consequence, more automated and streamlined processes are integrated into increasingly complete management systems [7]. Enterprises such as Goal Systems are adjusting their product portfolios in accordance with this strategy [8]. As the nation with the world's most rapidly expanding freight transportation business, the United States' success may also be linked to the quick growth among its land transport market (Figure 1) [1]. By the US Transportation department in 2021, 70% of freight transit inside the United States has been done by trucks. As one of the world's most developed marketplaces for road freight, the IoT (Internet of Things) and cloud - based services are prevalent in this industry [7]. Consequently, based on the preceding study, the emphasis of this paper will be on the use and future developments of advanced technology in land and railway transportation.

Table 1: Road transportation enterprises ranking [2].

Ranking	Financial Year Ending	Company	Turnover (Pound)	Return on Turnover	Pre-tax Profit (Pound)
1	2017	Royal Mail	7,658,000	5.4%	411,000
2	2016	DHL	4,035,769	2.9%	116,559
3	2016	XPO Logistics	1,257,210	2.8%	34,903
4	2016	Wincanton	1,118,100	4.0%	45,000
5	2017	DPD Group UK	1,089,382	15.6%	169,860
6	2016	UPS	944,927	6.6%	62,321
7	2016	Kuehne + Nagel	809,640	3.9%	31,386
8	2015	TNT UK	717,699	-3.1%	-22,104
9	2016	Eddie Stobart Logistics	570,200	8.5%	48,200
10	2016	Whistl UK	528,449	1.6%	8,391
11	2016	Hermes Parcelnet	510,369	6.6%	33,727
12	2016	Yodei Distribution	505,713	-11.5%	-58,249
13	2016	Culina Group	420,700	4.6%	19,500
14	2016	Gist	416,678	4.2%	17,707
15	2016	Ceva Logistics	394,484	4.1%	16,147
16	2016	UK Mail Group	366,087	2.1%	7,605

Table 1: (continued).

17	2017	Clipper Logistics Group	340,100	4.7%	16,100
18	2016	Turners (Soham)	313,608	8.7%	27,346
19	2017	Dx Group	291,900	-28.2%	-82,300
20	2016	FedEx Uk	253,035	13.0%	32,939

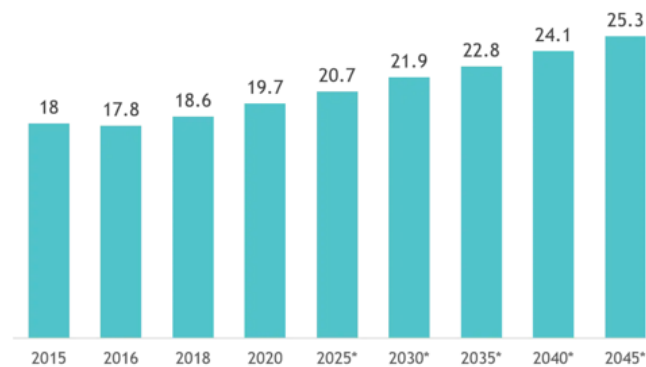


Figure 1: Freight transportation - U.S. railroads' projected demand [1].

2. Current Situation

2.1. Development Tendency

In recent years, as trade volume has increased [9], the sector as a whole has been increasing steadily, accompanied by rising client demands [9]. This is most evident in the need for speedier transit, cheaper transportation costs, and enhanced service efficiency [8]. Such expectations impact the growth of the whole sector in two ways. First, they enhance the complexity of freight transport, necessitating a more adaptable balance between assets, personnel productivity, operational strategies, and profit margins among freight operators [9]. Second, it encourages worldwide rivalry in the sector. Businesses switched the match's emphasis to multinational corporations' control over highly qualified workers and comparatively inexpensive transportation costs [10]. Priority one is to reduce operational losses attributable to human error [9].

2.1.1. Intermodal Transportation

As a result of the aforementioned developments, intermodal transportation has now become a growing market trend [1, 4]. Through globalisation and multi-mode selection, this strategy primarily enhances the firm's safety level, flexibility and transportation capacity [4]. In addition, this strategy gives the organisation with options for larger-volume transportation [1]. Through the business practises of Vertical and Horizontal Integration, the approach enables the organisation to greatly improve its clear-out market and distribution management [1].

2.1.2. Technological Innovation

Conversely, technical innovation allows the development of new conceptual efficiencies [3,4]. Grand View Research [4] provided an illustration of the emergence of information networks boosting on-

time delivery Service creation, a criterion that has become essential in logistics. Simultaneously, the advances in artificial intelligence has significantly enhanced the surroundings [11], safety [8], and operational efficiencies [3] of the freight industry [3]. Thus, it may successfully assist cut costs and increase intermodal transportation success [11].

2.2. Covid-19 Pandemic

SARS-COV-2 is the name given to the development of a microscopic disease due to the impact of the environment on its spread [12]. This infection has brought almost unimaginable global changes. The marine, shipping, supply chain, and people's way of life have completely transformed [13]. Below is a list of the two most major transitions in the industry of freight transformation.

2.2.1.Capacity Loss

Since 2018, the pandemic of 2020 drastically modifies the pattern of transportation capacity increase in several nations [12]. This year, there is a considerable decline in transportation capacity around the world. Some districts promptly paid fees [14] for such ground handlers' belt expropriation. The situation between Europe and North America was perhaps the most dire, with a 52 percent fall in transport capacity, among the global declines in transport capacity [14]. The capacity of Intra-Asia then decreased by 35 percent [14]. In addition, the situation is worsening because of the epidemic in India [13]. Under such conditions, national carriers often sought to decrease epidemic-related harm by implementing this technology [13].

2.2.2.The Surge of Digitization

After investigation, experts from several nations [14] concur that the Worldwide Outbreak of COVID-19 has expedited the automation and digitalization of the freight transportation business. In the realm of maritime transport, the first automated container ship was delivered in 2020 and has already begun testing [14]. Multiple nations have pushed and commended the notion of "Truck Platooning" from the standpoint of road transportation [14]. It refers to the use of the Connection and Automated Support System to link two or more vehicles [13]. This method just requires a human driver to run the Lead Truck [12]. This innovative mode of road freight transport may reduce fuel consumption by 3 to 7 percent [12], and studies indicate that it is beneficial for enhancing drivers' pleasant feelings [14]. In addition, large e-commerce firms, including as Amazon, have already been aggressively boosting the employment of robotics in transportation to alleviate the discomfort created by social distance limits during the epidemic [3].

3. Traditional Approaches VS. Machine Learning/Data Science

As was previously discussed, data analysis and research and technology are gaining an increasing amount of focus in the freight transportation industry's growth. Study on scientific computing has developed dramatically in the freight transportation business [15-17]. The study's findings show that managers might get a deeper understanding of the future status and development of their business by using ML techniques effectively [17]. The parts that follow will examine the definitions of machine learning and data science, their interrelation, their distinctions from other conventional methodologies, and their applications.

3.1. Data Science

Data science is a comprehensive area of study that combines computer science, mathematics, and statistics, as well as domain-specific knowledge, to obtain more insights from data (see Figure 2) [18,

19]. In the era of big data, when the value of data science is becoming more apparent [18], even more firms are attempting to develop and sustain competitive advantages using AI (artificial intelligence) and ML (machine learning) [19]. Figure 3 depicts the link between AI and ML, and ML has been one of the subset of AI that use statistical methods and computer science expertise to increase the performance of computers [20].

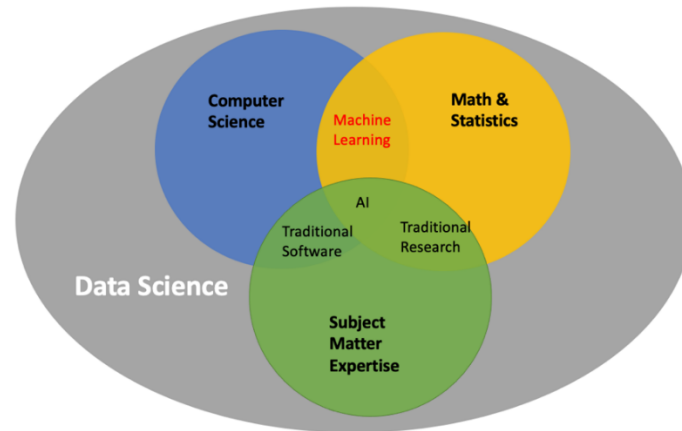


Figure 2: Data Science and ML.

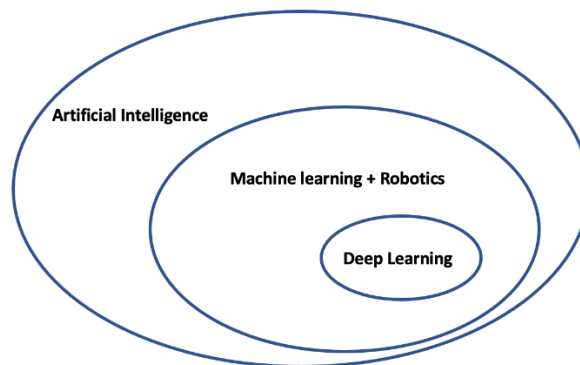


Figure 3: AI and ML.

3.2. Machine Learning

As stated before, machine learning is a subfield of artificial intelligence that use algorithms to teach machines to 'learn' from data and anticipate consequences [21]. According to Bell [22], machine learning is the method used to educate machines to understand from previous experience [23]. This approach may be classified into three categories: supervised, unsupervised, and evolutionary computation [21-23]. The specifics are as follows:

- **Supervised machine learning:** use the tagged trained dataset to forecast the insights, correlations, and patterns of the outcome of a new data set [24]. The two simplest supervised learning techniques are k-nearest peers and regression [24, 25]. ANN (Artificial neural network) is the most common supervised learning approach, and it analyses and processes information by mimicking the neuron in the physical brain [21,24]. However, this strategy requires several data kinds to train the system [21]. Support vector machine is another prominent technique (SVM). It uses the VC theoretical or statistical learning methods [22] to construct non-probabilistic linear programming classifiers to maximise the gap between two categories [25], hence resolving the overfitting issue [21]. In

addition, ensemble learning is created to increase the accuracy and resilience of forecasting [23]. It relies on clustering algorithms to create a composite model that reduces prediction inaccuracy [22]. As ensemble learning techniques, gradient boosting machine, Bayesian networks, and random forest may all be considered [21].

- Unsupervised machine learning: Using unlabeled data from a dataset to identify trends and underlying processes [26]. PCA (Principal component analysis) and clustering are the two most used methods in this field [27]. PCA is the method of conducting a change of basis on data by calculating the components that make up [27], whereas clustering improves accuracy by splitting data points into multiple categories [26].
- Reinforcement machine learning: maximising the cumulative reward via a series of choices made by intelligent agents to maximise the cumulative reward [28].

3.3. Traditional Approach VS Machine Learning

This section contrasts machine learning with conventional modelling techniques, including modeling techniques [29] and OR (operations research) [30]. The link between technique accuracy and data amount is seen in Figure 4 below. The comparison reveals that ML has three primary benefits.

- Machine learning overcomes the prevalent issue of expected deviations in conventional approaches [31]. Since machine learning allows computers to educate them to learn and does not need progressing based on previous premises [32].
- Machine learning techniques are resistant to the multicollinearity issue in resistant to high [32], which would be difficult to manage with conventional methods [31].
- Machine learning might assist in efficiently resolving challenges of enormous scale or great complexity. ML-based optimization offers better quality solutions in less time than the OR technique [30].

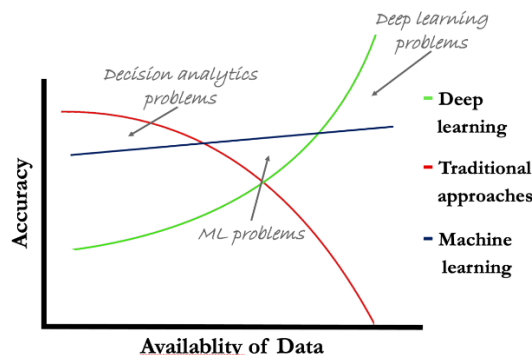


Figure 4: Method accuracy and the data volume.

4. Current Application

This research concludes, based on an assessment of the relevant literature, that machine learning is mostly used in the freight transportation sector for forecasting purposes. From this vantage point, the present predictive assessment of the freight business using ML may be categorised primarily into three categories [33]:

- Value prediction: fuel usage, anticipated vehicle arrival times, container throughput, etc.
- Predicting international freight networks, including freight assets, transport hub condition, etc.
- The possible behaviours of the projected object: best path selection, etc.

Evidently, existing research on ML overall behavior is insufficient, since this form of prediction needs more comprehensive optimization process assistance [33]. In addition, ML may be used for vehicle operating generation using the ANN model [33]. The following table 2 outlines the principal uses of ML-based techniques in land transportation; the remainder of this article will elaborate on the IoT technology and Cobots.

Table 2: Current application [34, 35].

Area	Application	Key Techniques
Internet of Things	Track accuracy; Optimize supply chain	Analysis sensor; Prediction Model
Truck Platooning	Save energy; Save human resource	Connectivity and automatic support system; Prediction model
Process Optimization	Optimize the route selection; Predict requirements and weather condition	Machine learning techniques
Cobots (Canonical Robots)	Improve process efficiency; Corporate with human beings	Deep learning techniques; ANN
RPA (Robotic Process Automation)	Reduce cost; Eliminate humanity operation error; Save operation time	Artificial intelligence; RPA software
Smart Lockers (Pakpobo)	Temperature control, can storage perishable goods; Customize various scenarios	Automatic support system
Prescriptive Analytics	Proceed predictive analytics suggestions; Help to make data-driven decisions	Data analytics software; Prediction model

4.1. IoT (Internet of Things)

The Internet of things is the network of physical objects [36]; it enhances inventory management and supply chain [37]. This method is incorporated into the industry of freight management to accomplish condition monitoring and fleet management [36]. For instance, Fleetroot, a company from the United Arab Emirates, developed an IoT platform to assist businesses in monitoring and managing their vehicles [37]. This platform might offer information on fuel loss and usage and provide vital alarms through integrated vehicle sensors [37]. All of this information will be examined using machine learning techniques and historical data to estimate the fleet's maintenance state [37] and produce the appropriate remedy.

4.2. Cobots (Canonical/Collaborative Robots)

Cobots are robots meant to increase human employees' job productivity and logistical operations by collaborating with them [38]. These cobots can put, pack, and choose items rapidly [39] and may eliminate human mistakes [40]. Canonical Robots, a Spanish firm, manufactures a variety of robots to streamline the shipping procedure [41]. Typically, these cobots have six-axle joints in order to do intricate operations [38]. This technology is used in the warehouses of companies such as Amazon and Alibaba [39].

5. Future

According to the preceding analysis, the future direction of advanced applications inside the freight transportation business should be guided by the following considerations:

1. Comply with the transport and distribution needs of the post-COVID-19 period
2. More study is required on the use of machine learning to behaviour prediction.

The subsequent table (Table 3) enumerated all probable technologies that may be utilised in the future direction. Based on above issue, self-driving vehicles and drone deliveries have been chosen for evaluation below.

Table 3: Future trend [42].

Future Trend	Application	Key Techniques
Cloud Based Transportation System	Use the cloud-based transportation system; Achieve common returns and scalability	Cloud; Software-as-a-Service (SaaS)
Integrated and Frictionless Process	Minimum stoppages and checkpoints; Build mobility hubs for multimodal conveyance; Improve last-mile connections	Mobility-as-a-Service (MaaS); Mobility hubs; Micro-mobility ability
Visibility and Anti-theft CPS	Receive the real-time locations during the process; Prevention of burglary	Tracking technologies; Theft GPS
Self-driving Trucks	AI-enabled trucks could evaluate the current traffic conditions automatically; Trucks could share the knowledge obtained with each other, improve integrity	Self-driving technology; Driverless software; Self-navigating system; Vehicle-to-Vehicle (V2V) communication; 5G technology
Logistical Blockchain	Ensure the accuracy of historical records; Proceed capacity monitoring	Decentralized distributed ledger database; Encryption system construction
Drone Delivery	Contactless delivery ability; Deliver faster	Drone technology
Warehouse Automation	Automate retrieval and storage system; Automatic guided vehicle	Adverb technologies

6. Conclusion

This research assesses the deployment of machine learning techniques inside the freight transportation business, particularly in the land transportation sector. The study is supported by recent state of the globe, and the distinctions between ML and conventional methods are examined. Iot devices and Cobots approaches are presented for the current use, whilst automated driving and drones distribution techniques are shown as future developments. Several possible problems are also discussed, and the blockchain technology is suggested as a solution.

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