On the Role of Big Data and Artificial Intelligence for the Sustainability of Complex Logistics Networks of Offshore Companies

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Abstract

Corporate logistics network data is a complex system made up of a large number of interacting entities, used to control, implement and plan the transport and distribution of goods and raw materials. They are essential to supply chain management and subsequently to customer satisfaction.

Today, international freight transport is one of the main pillars of world trade. Its importance lies in the diversity of studies and analyses that have been carried out on this type of transport, covering all aspects of international trade - administrative, political, technical and economic - with the aim of developing and modernising this mode of transport.

Developing and modernising this logistics network has therefore become a major objective for players in the global economy, given the rapid pace of technological, IT and scientific development.

However, the use of intelligent and optimisation techniques in logistics networks has always faced constraints in terms of application and decision-making, with the volume of goods transported increasing every year, leading to new challenges for researchers and operators in this area of international trade.

With this in mind, the aim of this literature review is to outline intelligent solutions based on artificial intelligence (AI) and Big Data (BD), in relation to logistics networks, while reviewing the state of the art of recently published studies that offer perspectives with the use of AI for the sustainability of logistics networks of offshore companies.

Key words :

Logistics networks, Offshore companies, Optimization, Decision making, New technologies, Intelligent solutions, Big Data, Artificial intelligence.

1. INTRODUCTION

With the increase in international trade and the proliferation of free trade agreements, the logistics network of offshore companies has become a fundamental lever for development. Modernising this network to keep pace with technological, IT and scientific development has become a major objective. It should be noted that this modernisation has been accompanied by a growth in the exchange and sharing of data between stakeholders, such as forwarding agents, maritime logistics companies, authorities, etc. In fact, these different stakeholders have found themselves under the obsession of profit and market realism, faced with the need to overcome all quarrels, and therefore to exchange information and data instantaneously and directly.

Logistics networks can be internal to a company, meaning that the company itself manages its supply chain, or external, meaning that they are managed by service providers. In both cases, they can cover a wide variety of functions, such as the supply of raw materials, production, storage, transport and distribution of products for sale.

For greater efficiency, the logistics networks of offshore companies need to be flexible, as they often have to cope with changes in demand, costs and transport conditions. They also need to be sustainable, i.e., respectful of the environment and society. This can be achieved by optimising transport routes, choosing sustainable suppliers and using environmentally friendly technologies.

At the same time, there are a number of major difficulties in collecting and processing data in the logistics network of offshore companies. These difficulties are linked, on the one hand, to competition and data security and, on the other, to environmental and meteorological conditions. The BD is therefore of great importance in supporting the logistics networks of offshore companies for better optimisation and efficient use. By using existing data in real time, these routes can be optimised.

To ensure that goods are properly transported, it is first necessary to understand how the logistics networks of offshore companies work, and to be aware of their needs, innovations and challenges in order to adjust them.

In this context, there is a wide range of transport options, mainly due to the different routes available [1].

At an organisational level, BD is used in the logistics network, and more specifically in supply chains, to improve the performance of this sector and to analyse the data collected on passenger and goods movements. Given the huge number of exchanges of goods carried out every day by supply chains, it is vital to analyse and process this data, with the aim of optimising both the time and volumes of goods to be transported, while at the same time making savings.

There is a wealth of information in the literature on the role of the BD in the sustainability of offshore logistics networks. It is constantly expanding. The objective of this article is to review the intelligent technological solutions, based on the use of BD, to the various problems related to supply chains for offshore companies. In particular, we focus on the distribution of the literature according to the proposed solution. The research results contribute to a better understanding of the role of BD in the sustainability of logistics networks for offshore companies.

The rest of the document is organised as follows: Section 2 is a summary devoted to the various concepts of the subject. The remaining sections 3 and 4 are dedicated to an extended discussion of the fundamental principles of intelligent logistics networks. We close this manuscript with a general conclusion and a presentation of perspectives related to the topic.

2. Overview: state of the art of research and methodology

This manuscript covers a body of work published for the most part in specialised international journals with a focus on work published from the year 2017 onwards. In fact, an in-depth review after the year 2020 can be materialised by the work published by C. Archetti, L. Peirano and M.G. Speranzaen in 2021 [2].

As far as our research on scientific works is concerned, the methodology pursued focused on the following keywords: Logistics, Business, Optimisation, Decision Making, Technology, Intelligent Solutions, Big Data, Artificial Intelligence.

This search led to the creation of a bibliographic database which was extended either by searching for the keyword identified in the set of articles found, or by exploring the literature related to the subject in question. With a few exceptions, works that did not address issues related to logistics networks or company logistics in general were rejected.

The frequency of appearance of the keywords is shown in Table 1 below:

Keyword	Frequency
big data	1050
Artificial intelligence	956
Logistics	122
Technology	85
Business	65
Optimization	35
Decision making	27
Intelligence	22

Table 1: Keyword frequency.

It should be noted that the keywords are identified and targeted so that they can be more easily categorised together (for example, the keywords "Big Data" and "Logistics Networks" are reported in "Supply Chain"; "Big Data Analytics" by the abbreviation "BDA"). In this way, the probability of finding articles that do not correspond to the keywords is reduced, and the subjects are more easily identified.

3. Concepts:

3.1. Big Data

Although BD is a buzzword in both academia and industry, its meaning is still shrouded in significant conceptual vagueness. The term is used to describe a wide range of concepts : from the technological ability to store, aggregate and process data, to the cultural change that pervasively invades business and society, both of which are overwhelmed by information overload [3].

To better understand what BD is, we need to distinguish the 3Vs that characterise it: Volume, Speed and Variety.

-Volume refers to the magnitude of data and its voluminous sizes which are described by several terabytes and petabytes ;

- Speed generally refers to the time consumed or required to analyze and process this large and varied amount of data.

-Variety refers to the structural heterogeneity of a data set. Technological advances allow companies to use different types of structured, semi-structured and unstructured data [4].

The DB therefore makes it possible to analyze, measure and arbitrate any type of production, whether human or user feedback : it is therefore used to guide and improve decision-making in order to optimize the desired result.

BD has a wide range of applications, from business management to chemistry, logistics, security and scientific data analysis. The aim of BD is to extract useful information and trends from large data sets that would otherwise be difficult to detect and analyse.

However, processing BD also raises security issues, as it may contain sensitive and personal information, which remains an emerging and growing concern in today's digital world in Morocco. This concern is regulated by the Commission Nationale de contrôle de la Protection des Données à Caractère Personnel (CNDP), established by law 09-08, which ensures compliance with the rules to which public and private bodies must adhere before and during the processing of personal and confidential data [5]. It is therefore important to put in place adequate data security measures to protect the data and the various users.

3.2. Artificial intelligence: AI

AI is a modern approach offering a comprehensive introduction to a dynamic field that is rapidly gaining in popularity and importance [6]. This new trend uses a number of natural language processing techniques, artificial neural networks and Deep Learning. This machine learning technique enables computers to learn from experience and to understand the world in terms of a hierarchy of concepts. Because the computer gathers knowledge from experience, there is no need for a human operator to formally specify all the knowledge the computer needs. This approach is now one of the fundamental components of so-called statistical and neo-connexionist AI [7].

AI therefore offers emerging solutions for business logistics, monitoring transport conditions and forecasting demand, while improving stock management, optimising delivery routes and enabling accurate forecasts of customer demand.

3.3. Supply chain management problem

The literature on supply chain management in relation to AI is made explicit in the work of A. Aror, A. Jain and V. Kumar [8]. These authors review the various applications of AI in supply chain management, including demand forecasting, production planning, inventory management, transport logistics and warehouse management.

The authors also describe the main areas of AI used to manage the supply chain, including machine learning, neural networks, optimisation algorithms, expert systems and natural language management approaches. They clearly demonstrate the benefits of using AI in these areas, including improved operational efficiency, cost savings, data-driven decision-making and risk management.

The article attempts to address the questions of how AI is being used in supply chain and logistics management, what potential benefits might result from its use, and the difficulties and constraints associated with its implementation. The aim is to provide a comprehensive and up-to-date review of the state of the art for AI applications in this area so that researchers, practitioners and policy makers are aware of recent developments and the implications of using AI to manage the supply chain and logistics.

3.4. Solution Approach: The Taboo Search Algorithm

This article focuses on supply chain management issues, including demand forecasting, production planning, inventory management, transport logistics and warehouse management.

To answer this problem, we propose the use of optimisation algorithms that combine mathematical concepts and AI, and more specifically the Tabu Search algorithm, which is generally used to solve vehicle routing problems for the distribution of urban goods, the mixed fleet size problem, which is a variant of the vehicle routing problem, called the heterogeneous fleet vehicle routing problem (HFVRP) [9].

The tabu algorithm is a local search technique used to solve complex optimisation problems, including production planning, inventory management and optimisation of transport routes in a chain of complex logistics networks.

The taboo search algorithm is combined with other AI techniques, such as machine learning, to improve the algorithm's performance and adaptability. This iterative technique is based on learning from historical supply chain data, it creates a taboo list to store previously visited solutions and avoid revisiting the same solutions. The algorithm parameters are updated in real time to better adapt to changing supply chain conditions.

Entrance	Output
1-Initial solution: an initial solution of the optimization problem.	1-Initialization: Initialize the current solution with the initial solution. 2-Evaluation: Evaluate the quality of the current solution using the objective function.
2-Objective function: a function that evaluates the quality of a solution.	3-Iterations: Repeat steps 4 to 8 until reaching a stopping criterion (for example, a certain number of iterations or a convergence criterion):
3-Constraints: the constraints of the optimization problem.	4-Generation of neighbors: Generate a neighbor of the current solution by performing a disturbance in the solution (for example, by performing a movement or a modification of the solution). 5-Neighbours evaluation: Evaluate the quality of the neighbors generated using the objective function.
4-Taboo list: a list that stores previously visited solutions.	6-Selection of the best neighbor: Select the best neighbor among the neighbors generated by respecting the constraints and by avoiding the solutions present in the tabu list. 7-Update the current solution: Update the current solution with the best neighbor selected
5-Taboo list: a list that stores previously visited solutions.	8-Updating the tabu list: Update the tabu list by adding the current solution and removing the oldest solutions according to a certain management rule (for example, using a duration or frequency criterion). 9-End of the algorithm: Return the best solution found.

Table 1: General description of the steps of the tabu search algorithm

Optimisation algorithms can be combined with each other to improve the efficiency and effectiveness of the original and/or conventional algorithms. They can also be combined with other control algorithms to achieve better automatic and intelligent control of supply chains.

3.5. Industry 4.0 and the management of complex supply chains

The development of new intelligent solutions will make it possible to consolidate the logistics chains of companies, and more specifically offshore companies, while increasing the efficiency of production and trade, and reducing traffic and production flow bugs, thereby reducing management costs.

Industry 4.0 presents a promising avenue for future research, as well as a challenge for stakeholders in the sector. According to the work of S. Eryilmaz in 2020, Industry 4.0 refers to the ability of machines to mimic human intelligence, and in our context, this emerging technique aims to improve the management of the complex supply chain. Among other things, this includes the use of machine learning algorithms for demand forecasting, production planning, transport management and supply chain anomaly detection [10].

In this approach, it should be noted that there are several challenges and issues associated with the use of Industry 4.0 in supply chain management, such as data privacy, security and ethics. The author concludes by highlighting the growing importance of this technique in the management of complex supply chains, while emphasising the need to address the challenges associated with its use.

3.5.1. Solving approach: Linear programming model

Linear programming (LP) is a method for solving a linear function. Its aim is to determine the optimum of a complex function by taking into account the various constraints and variables of the function. This method is often used in the petroleum, agri-food, heavy industry and manufacturing sectors, as well as in services, banking, insurance and supply chain management.

According to Sona Kandé, who conducted her thesis entitled "Study and resolution of planning problems in multi-level logistics networks", in collaboration with FuturMaster, the developer of APS (Advanced Planning System) software that uses linear programming to calculate solutions for distribution planning problems. The type of network studied has been encountered in recent years by several of FuturMaster's customers, particularly in the distribution of dairy products and beverages, and in cases that can reach very large sizes. It was therefore decided to develop a specific mixed linear program for this type of network and to include a fast heuristic in the software, making it possible to obtain solutions when the solver is unable to find optimal solutions in acceptable times. Even for cases within the solver's reach, some users do not understand the construction of the result and prefer a heuristic whose logic can be explained [11].

This module has the advantage of being very powerful and versatile, but it also has a few drawbacks. In particular, if some of the data in the problem is incompatible and this renders the problem inoperative, the solution will fail and it will be difficult to find the data in question. As a result, the user wastes time running calculations with no result and no possibility of identifying the cause of the blockage. The proposed heuristic approach should avoid this difficulty.

If an incompatibility is detected during the algorithm, a warning message may be triggered, and the data may have to be corrected locally, but the calculation must not be blocked under any circumstances.

To solve the problems associated with Industry 4.0 and the management of complex supply chains, we propose this algorithm based on linear programming to optimise supply chain management :

1- Mathematical modeling:
   - → Model the supply chain as a network of connected nodes using IoT , each node represents an element (Raw material, production flow, etc.).
   - → Define all the decision variables, such as production quantities, containers to be transported, storage level, etc.
   - → Define the various constraints such as production quantities, transport load, minimum stock level, etc.
   - → Define objective function, such as minimizing supply chain costs.

2- Modeling with linear programming:
   - → Expose the mathematical model as a linear programming problem, this formulate aims to minimize the linear function under linear constraints. The linear programming will therefore have the following form:

Minimize: $Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$

Under the constraints:

$a_{11} x_1 + a_{12} x_2 + \ldots + a_{1n} x_n >= b_1$

$a_{21} x_1 + a_{22} x_2 + \ldots + a_{2n} x_n >= b_2$

...

$a_{m1} x_1 + a_{m2} x_2 + \ldots + a_{min} x_n >= b_m$

$x1 , x2_{, \ldots ,} {}_{xn} > = 0$

We emphasize that the coefficients of the objective function and the constraints " c_i ; $a_{i,j}$ " will be determined by mathematical modelling.

3- Solution: Solve this linear programming problem using mathematical programming software in the form of an autonomous computer program, a solver based on so-called metaheuristic optimisation algorithms, such as those belonging to the evolutionary algorithm family. The optimal solution will maximise production and consequently trade, and minimise traffic and bugs in production flows, thereby reducing management costs.

4- Analysing and exploiting the results: The aim of analysing the results obtained is to obtain a model that avoids inefficiencies and minimises unexpected risks, thereby improving the management of the entire supply chain.

The variables in this algorithm can be modified to suit the specific needs of each business, but it provides a solid basis for modelling and optimising complex supply chains.

4.1. Intelligent transport system and mobility

Over the last few years, the transport and mobility sector has undergone a number of real revolutions, and must now be approached in a systemic way, taking into account urban, technological and human dynamics. In this new context, the existing relationship between man, machine and his immediate environment (maritime, road and air infrastructures) is being reinvented with the concept of intelligent transport systems (ITS).

This evolution towards the so-called autonomous intelligent vehicle has now reached an intermediate stage with the remotely connected vehicle [12], the result of a marriage between the mechanical engineering industry and digital technologies (connectivity systems). The electric vehicle is also part of these new mobility paradigms.

A vehicle is connected when it incorporates wireless connectivity systems enabling it to collect information which it can then use [13].

4.1.1. Resolution approach

The maritime transport of goods is moving towards increasingly serviced vehicles (relating to a focus on service, with invoicing based on usage and no longer on the product), for which the characteristics of the product itself will become secondary. In fact, we are talking about a ship that is equipped to be connected to the outside world, and that receives or sends information using emerging technological solutions based on :

→ **Mobile applications: such as the** Geco air application ;

→ **Bluetooth:** for two-way data exchange at very short distances;

→ **GNSS:** geolocation and navigation by a satellite system;

→ **Cloud:** storage space managed by a remote server.

5. Directions for future research

The problems of the sustainability of logistics networks in relation to information systems, AI and BD are complex in nature: they are operational problems that are little studied, with the literature focusing mainly on functional problems and economic issues. Researchers interested in this subject should explore ways of solving problems that involve intelligent systems combined with different operating modes. In addition, integration can be extended by considering issues related to security, traceability, connectivity of tools, supply chain management, quantities of products to be produced and other physical and logistical issues not strictly related to logistics.

5.1. Connected Transport Perspective

In this sense, the growth of research into remotely connected transport is a promising trend that should continue in the future. In a world where decisions based on information processing and data analysis are increasingly important, current and future technologies are enabling researchers to meet the challenge of building and optimising fully interconnected systems, where information sharing in a BD context is the core of the solution.

5.2. 6G Internet of Things Perspective

Emerging 6G connectivity solutions, such as holography, beamforming, AI-enabled IoT networks, edge computing and backscatter communications to serve smart communities, is an area of research that could present a promising and effective solution to the issues of logistics network sustainability [14].

5.3. Logistic perspective

As Industry 4.0 takes more and more concrete form in production automation, the first cyber-physical systems and cloud network structures designed to streamline logistics operations will remain on the back burner before gaining momentum. Logistic 4.0 can generate huge efficiency gains in the sector.

Anyone talking about Logistic 4.0 must therefore always talk about cybersecurity, which means much more about protecting offshore companies against cyber attacks than about the operational security of logistics itself. It is important to use appropriate technologies to protect offshore companies, crew and the environment by, for example, reliably encrypting data transmitted between land and sea during transportation, regulating access points and access times, or using controllers that, on the one hand, have "computer security by design" and, on the other, can act as a buffer when the connection between land and sea breaks down [15].

5.4. Transport 4.0 perspective

In the age of Industry 4.0, transport needs to be increasingly responsive and resilient. Carriers and freight forwarders must be able to ensure the delivery of any goods anywhere in the world, be able to offer multimodal transport solutions (air, rail, sea or road) at lower cost and in ever shorter timescales, while providing a personalised offer to each client [16].

5.5. Perspective of so-called "intelligent" logistics solutions

This perspective is based mainly on BD, blockchain [17] and Internet of Things techniques. In fact, these tools enable users to trace and control (by barcode or RFID chip) the product and increase their competitiveness, thanks to better visibility and better predictions for efficient planning in complete safety [16].

5.6. Perspective of Digitization of logistics documents

The digitisation and computerised transmission of data to the authorities is encouraged, thereby reducing costs for offshore companies. They also enhance the security and efficiency of the information chain, while reducing its impact on the environment. They also improve stock management, increase the space available in warehouses and improve responsiveness, particularly for perishable products [16].

The use of machine learning and deep learning enables software to be perfected for optimised management of the transport network [16].

5.7. Perspective of visual recognition technologies

3D identification of products makes it possible to check that goods are in good condition throughout the production and transport chain without opening the packages, for example, using a tomographic scan (by 3D X-ray radiology) [16].

6. Conclusion

The sustainability of logistics networks is an increasingly important topic, of interest to large-scale decision-makers, transport operators and industrial companies. Intelligent management of logistics networks for offshore companies has always been a major challenge that encompasses different aspects. Environmental aspects are increasingly taken into account in international policies and research. It should be noted that good management of logistics networks is a lever for development of great importance, including sustainable development, according to the annual reports produced by the United Nations Conference on Trade and Development. This trend towards ecological logistics should be encouraged, as awareness of the importance of environmental features in optimising logistics is paramount. The IMO 2020 regulation is a concrete example of a new trend where large and medium-sized companies are required to invest in sustainability and become serious about supporting environmental sustainability. However, this has been done through voluntary disclosure to meet stakeholder and market expectations. The majority of companies still prioritise profit, with little consideration for environmental aspects. While environmental awareness is widespread in both scientific literature and public opinion, governments and international organisations have only recently begun to take serious action to support environmental sustainability.

The analysis of the research carried out in this literature review has led to the following main conclusions:

- ✓ The issues of data sharing, security and traceability are common to almost all the articles in the bibliography of this literature review, with the exception of the countries of the European Union and North America, where the sharing of information and data is fluid. This explains why the political consensus between countries has a major, central and principal role in the solutions that may be proposed in relation to the subject of intelligent maritime transport.
- ✓ Currently, the most studied problem is the optimisation of the use of connected objects where production and transport chains are partially and totally autonomous. In 2017, the city of Amsterdam welcomed autonomous boats that have several roles (transporting goods and people and cleaning water). The field of optimising this trend is young and holds a lot of potential, especially as real-world applications have been mostly ignored [18].

Finally, it should be noted that, in general, this literature review shows a lack of applications and models of intelligent logistics in relation to BD. On the one hand, the challenge is to have intelligent and emerging models and solutions adapted to our research problem, whose objective is to propose applications, formulations, techniques and solutions capables of tackling real-world instances in the sustainability of logistics networks for offshore companies.

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