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IMPROVEMENT OF OPERATIONAL EFFICIENCY IN SUPPLY CHAIN MANAGEMENT

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Abstract: *Supply chain efficiency is essential for companies aiming for competitiveness, customer satisfaction, continuous improvement and efficient digitalization. This paper aims to show how algorithms such as the 3D Algorithm can improve space utilization in transport vehicles, examining the impact on reducing logistics costs. The implementation of these advanced optimization algorithms allows the logistics department to achieve higher truck loading rates and more efficient transport routes. The proposed study is based on the functionality of a Current Data System and to integrate new data into the new 3D Algorithm under test. Finally, this paper serves as a working tool for the logistics department and presents the development trend of supply chain efficiency.*
Keywords: *Fill Rate, 3D Algorithm, digitalization, truck-loading optimization, supply chain sustainability*

1. INTRODUCTION

1.1 Current challenges in supply chain operational efficiency

The logistics and transport sector contributes just over a third of global carbon dioxide (CO2) emissions, making it the largest-emitting sector in numerous developed countries. According to researchers from the Massachusetts Institute of Technology Supply Chains Initiative, freight transportation contributes approximately 8 % of global greenhouse gas emissions.[1],[2]

To get on track with the Net Zero Emissions (NZE) by 2050 Scenario, CO2 emissions from the transport sector must fall by more than 3% per year to 2030. The studies indicate that two main objectives of environmental sustainability should be prioritized: decarbonization and dematerialization, as the large number of transports, perhaps sometimes unnecessary due to the low Filling Rate but also the use of useless materials. [3],[4]

Heavy-duty vehicles accounted for about 10% of the global road vehicle fleet in 2020 and deserve attention because they are major polluters. Heavy-duty vehicles are responsible for 78% of global black carbon, or soot, emissions and 86% of nitrogen oxide emissions.[4],[5]

Increasing vehicle load factors can decrease the number of vehicle-kilometers of freight transport. Since empty trips represent a considerable part of the total vehicle kilometers, increasing loading efficiency leads to fewer vehicle kilometers and, consequently, reduces the environmental impact. Therefore, carriers are not sufficiently incentivized to improve their efficiency. Companies prefer inefficient transportation to inefficient time management, which leads to an increasing number (more vehicle-kilometers) and a decrease in the size of shipments, this causes a multitude of challenges in the supply chain that many companies need to understand and need to develop new ways to streamline and optimize transportation.[6]

The supply chain is made up of complex network entities, from upstream to downstream, such as customers, retailers, carriers, manufacturers and suppliers, transportation networks, complex systems, alerts, etc. These aspects being part of the digitalization of the supply chain, which is the most important aspect and the most important challenge that companies must take into account. Without correct efficiency in terms of digitalization and the use of precise calculation algorithms, the optimization chain would operate based on increased costs and low performance indicators KPI's [7],[8].

Companies prioritize economic, social and environmental impact both in internal operations and in interactions with suppliers and carriers. Emerging technologies such as Industry 4.0, optimization algorithms, calculation algorithms, transport performance KPIs, introduce new challenges in the supply chain. Numerous issues persist, including low overall efficiency, high logistics costs, outdated logistics technology, long transportation times, significant cargo damage, and difficulties in ensuring quality, all of which hinder adaptation to current demands [8].

1.2 The importance of optimizing road transport regarding increasing Filling Rate

In recent decades, there has been a trend in increasing the role of logistics in business strategies and the effect of transportation as a large part of logistics process on companies' productivity and profitability [9].

Rising transportation costs caused of rising fuel prices, extended travel distances, and the demand for faster and more punctual deliveries have led companies to use their transportation resources more efficiently, turning to more technologies for optimization, route visualization, to bring performance. Maximizing the Fill Rate in various modes of transport - such as road, rail, sea and air - has become crucial to achieve high resource utilization and cost-effectiveness of transport operations. Besides the importance of increasing efficiency to cut costs, trying to be more sustainable through being efficient is another target that can be achieved from increasing the Fill Rate. Introducing the concept of supply chain and trend towards optimization of supply network, the area of supply chain performance measurement attracted much academic research. Stewart identified four key operational areas that give superior revenue to the supply chain; delivery performance, flexibility, logistics costs, and asset management [9]. A brief description of the following areas that Stewart identified is [9][10]:

i. Delivery performance: it drives customers' satisfaction and is controlled by supply chain management.
ii. Flexibility and receptivity: supply chain flexibility that contains communication to end product, plants, product sourcing, and lead time.
iii. Logistics costs: order management costs, materials usage cost, inventory carrying cost, supply chain finance, planning and management information system cost.
iv. Asset management: supply chain assets consist of accounts receivable, inventories, selected plants, property and equipment [10].

According to Eurostat data, in 2020, approximately 20% of road freight kilometers in the European Union (EU) were completed by empty vehicles [11].

A document of the World Economic Forum suggests that digitization in logistics could generate a value of 1.5 trillion dollars by the year 2025. In this sense, digital has a huge opportunity to reduce logistics emissions by up to 10 to 12% by 2025 and contribute to the decarbonization of the global economy [12].

1.3 The need to implement computing algorithms with a 3D Interface

The digitalization of logistics is characterized through six fundamental characteristics: cooperation, connectivity, adaptability, integration, autonomous control and cognitive improvement. The integration of optimization algorithms in supply chain management has a significant impact on the improvement of logistics operations.

A digital operating model is all about implementing digital capabilities along the organizational layers of governance, processes, data and performance management, and information technology. It allows for required levels of integration and standardization of processes. Digitization through connectivity enables vertical integration from supplier to customer as well as horizontal integration among other competitors and other business partners along the supply chain in order to sustain end-to-end visibility [13][14].

Optimizing the distribution of goods in trucks results in increased transparency in the management of goods flows, to facilitate rapid reactions to changing market demands and operational issues such as delays or damage to goods. In this way, load optimization technologies not only improve transport performance, but also support more environmentally friendly and economically efficient logistics. [15] Easy Cargo is a commercial tool used in logistics for planning truck and container loading. It also includes stacked packing rules. It offers useful features such as Excel import, simple stacking rules and 3D visualization [16].

Aim of the Study

The purpose of this study is to show the effectiveness of a 3D Algorithm by comparison with another data system, in order to optimize the use of truck space within the logistics process, in order to reduce transportation costs, and to improve the overall performance of the supply chain through digitalization and data integration.

Significance of the study

The significance of this study lies in its potential to contribute to the importance of digitalization based on computational algorithms that can bring performance to the supply chain within companies. As there is a real evolution of sustainable logistics within companies, the need for digitalization, for the use of applications that can provide essential data to all parties involved is increasingly important.

Regarding the paper, the planning phase involves defining the study's scope and selecting an appropriate method to address the research questions. To gain a detailed view on this topic, the following research questions are addressed:

1. How does implementing the 3D Algorithm improve space utilization and load optimization in transport vehicles?
2. How does the implementation of the 3D algorithm influence the truck fill rate in the logistics chain, compared to the situation before its implementation?

2. METHODOLOGY

2.1 Research context

The methodology of a 3D Algorithm increases the opportunity for optimization in the supply chain, especially in the context of improving truck loading rates, transportation efficiency and cost reduction. The model presented in this study was examined using an automobile manufacturing company operating internationally. The study consists of applying two calculation systems within the company that will show significant differences in the impact of logistics performance on truck Fill Rate, costs and sustainability. The benefits of using a 3D Algorithm application in a company in the automotive industry can be described as follows: better Fill Rate of the trucks and reduction in the number of shipments.

There is general agreement across the academic and practitioner literatures that the application of digital technologies has the potential to improve and automate many aspects of supply chain management, internally within organizations and externally across the supply chain [17]. Some argue that digitalization will enable leaner operations and may support sustainability at many levels [17]. Recent studies highlight the importance of optimizing load levels in reducing CO_2 emissions in road transport. Vehicle loads have a significant impact on duty truck emissions, even under the same traffic conditions [18]. The algorithm analyzed in this paper, developed and used by the partner company, represents such an applicable solution, but insufficiently explored in the current literature

2.2 Data Collection Instrument

The research focuses on automotive manufacturing companies, with a focus on logistics, especially on the transport segment. The choice of this orientation is justified by the strategic importance of logistics in the automotive industry, where processes are complex, supply chain are extensive, and the requirements for efficiency and cost optimization are high. Transport is a critical component in this ecosystem, as it influences direct delivery times, operational costs and the degree of satisfaction of the end customer. In this context, the research focuses on the application of a 3D Algorithm that supports the digitalization and implementation of logistics processes, specifically aiming to improve the loading rates of transport vehicles. Thus, the aim is to optimize space use, reduce emissions and reduce logistics costs, contributing to a more sustainable and high-performing supply chain. The data is collected from within the company, and the case study will represent an example of the 2 systems studied as well as the differences in the operational performance that can bring. Optimizing transportation from one supplier to the plant, from two or more suppliers to one factory or to two factories, companies can minimize fuel consumption, reduce travel time, and decrease total transportation expenses. To correctly understand the logistics process within an automobile manufacturing company, it is necessary to understand each stage of a transport, so each route will be described. One route is characterized and explained in below figures (fig. 1 – fig. 2):

1. Direct flow: Loading point(s)-Supplier(s)-Weekly frequencies (Number Vehicles/week-Delivery-factory

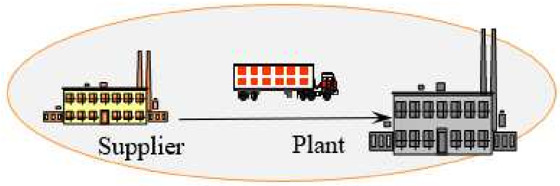

Fig. 1. Direct flow

2. Milk run flow: several suppliers in the proximity from which goods can be collected to be delivered to a factory, or to multiclient factories.

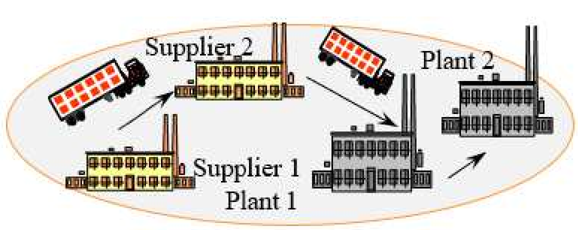

Fig. 2. Milk run flow

The architecture of the 3D Algorithm consists of input data that also includes needs, master data, parameters and output data which results in type of 3D Visualization. The algorithm contributes to effectiveness of the various components of the transport process, starting from reading input data and user specified parameters, to building stacks and prioritizing packages.

Once the 3D algorithm architecture is defined, detailing its functional steps is important to understand the optimization process in depth:

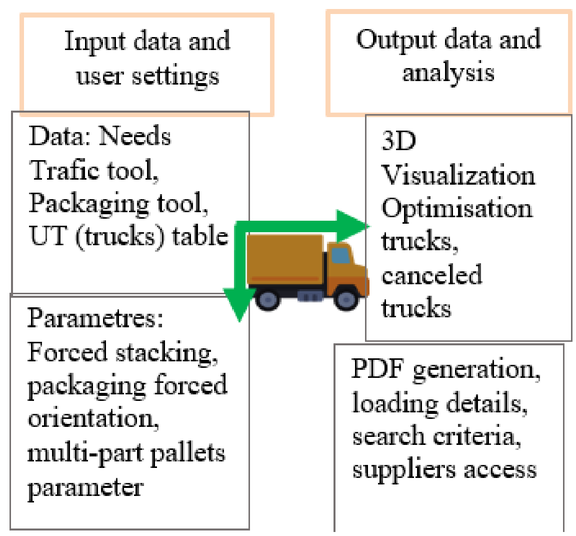

Fig. 3. 3D Algorithm Architecture

i. Reading the input data and the user parameters:

- Needs and available trucks files
- Master data: Trucks Table, transport documentation, logical/physical, axle load calculation, packaging database, axle data, information used to calculate the load on the two axles of the truck. This allows us to generate informative indicators at the end of the calculation.

ii. Pre-processing of available trucks file and Trucks Table:

- Trucks Table: the tool will use these dimensions (and weights) for the truck's creation.

iii. Pre-processing the needs file

- Checks related to the packaging codes (and the packaging nature)

iv. Palletization: cardboard/boxes/metal/ pallets

- The part's documentation
- Checks: pallet height, pallet density.

v. Stacks construction

- Respect the user parameters (density, forced stacking and forced orientation, max. weight on the carton), respect the truck height, apply the handling height from the packaging database.
- Packaging order inside the stack: decreasing area (largest packaging is at the bottom), decreasing weight (heaviest packaging is at the bottom), decreasing height, increasing part.

vi. Processes package by package/stack by stack. Packaging/stacks prioritization

- The packaging corresponds to the stop points of the destination truck.

vii. Multi-client flows

- It is necessary to indicate to 3D Algorithm the linear meters allocated for each factory as part of a multi-client circuit
- Linear meters allocated to each plant to be documented in the sheet: this data will be received by 3D Algorithm
- When calculating a factory, 3D Algorithm saves memory the space used for multi-client plants.

2.3 Comparison of the Current Data System with 3D Algorithm

The Current Data System uses the factory's needs and creates shipments in the form of ITs, for example (P-102-6212). These scheduled transports contain agreement on the departure and arrival times of suppliers and the loading and delivery ordered from a carrier correspond to several circuits.

P = programmed transport

102 = arrival times correspond to a specific day on the calendar (for example, April 12)

6212= coding a route

The Current Data System is a system that provides planning, but without getting involved in the logistical details of the load. This system takes into account the overlapping rules (another related system of rules for all packaging used) while the 3D Algorithm uses the entire height of the truck, disregarding the overlapping rules. The major difference is that the 3D Algorithm, being a calculation algorithm and not just data received from the plant's needs, uses the total height of the truck and does not respect the standard overlap from the packaging base that both systems use as a reference. In 3D Algorithm, the orientation of a package can be done, with the ability to rotate the packages to further optimize the truck. Packaging overlap rules refer to predefined constraints that dictate how packaging can be positioned relative to one another within a confined space, such as a truck.

Table 1 shows the differences regarding both systems studied:

Table 1

Differences between Current Data System vs 3D Algorithm

Current Data System	3D Algorithm
Algorithm in the form of data	3D visualization/Filling truck optimization
When the system cancels a scheduled truck, it can no longer use it: this can cause overflows for the following trucks	3D Algorithm tries to reactivate a scheduled truck instead of creating an overflow.
No choice of packaging orientation (only one possibility)	3D Algorithm propose the optimum placement from mixing orientation for the same packaging.

Methodological Constraints

The main methodological constraints relate to the generalization of the study findings. The findings may not be directly applicable to factories because the study is based on a single factory from which tests could be performed and data could be collected. Further studies with different routes or more complex examples can be chosen for future research directions.

Similar limitations are also due to the types of data that can be collected from the company.

3. CASE STUDY

3.1 Descriptive data

In the study below, there are two data systems for analyzing truck Fill Rates. The systems are the ones explained above, with differences. The first, based on the less precise algorithm, since it is a system that includes the factory needs according to the volume of parts per supplier and estimates fewer linear meters, while the second, more advanced in terms of functionality, but also in terms of architecture, allowed a more efficient use of the space inside the trucks, thus providing a broader estimate of the number of linear meters. For this study, relevant data were collected, real examples for an automotive company where a study related to the transportation process is being carried out, including the following information for each truck. More specifically, the study refers to two shipments, identical in terms of data, route, transportation data, same supplier, carrier, truck, but expressed differently through 2 different systems.

Truck Type and Technical Characteristics:

- Truck Type: 24-ton truck. (24000 kg)
- Max meters linear per truck: 13,5 ML

Data on Transported Products:

- Variable Dimensions of Products, for example below, it will use the same product for both situations with the following data:

Table 2

Dimensions of the packaging used

Length (mm)	1200
Width (mm)	1000
Height (mm)	975
Packaging material	Metal
Packaging code	SLI-0770

Table 3

Dimensions of the packaging used

Length (mm)	1600
Width (mm)	1200
Height (mm)	930
Packaging material	Metal
Packaging code	SLI-1200

Table 4

Dimensions of the packaging used

Length (mm)	1206
Width (mm)	1010
Height (mm)	193
Packaging material	Plastic Pallet
Packaging code	SLI-2112

The type of packaging BAC-O-4325, BAC-6424, CAR-G*09 resulted from the data below is loaded into europallets, SLI-2112, therefore it dimensions will be taken into account.

Table 5 summarises the study that was carried out on the following Route Romania-Spain with the relevant data:

Table 5

Current Data System

Supplier	Plant	Delivery Scheduled	Linear meters calculated	Weight calculated
1.Pitesti Wiring	Valladolid	04/03/25 00:05	8.61	10100
2.Campulung Wiring	Valladolid	04/03/25 00:05	2.93	1787

According to Curent Data System, 11.54 ML were calculated in the truck from 2 suppliers who deliver parts in the packaging presented below. Table 6 summarises data obtained:

Table 6

Data obtained from Current Data System

Packaging	Number	Weight	Linear meters
SLI-0070	51	9915	8.49
BAC-O-4325 on SLI 2112	10	182	0.10
CAR-G*09	2	4	0.02
SLI-1200	11	1787	2.93

Users must apply different forced parameters to overcome this algorithm. The first system provided concrete and precise data in numbers regarding the linear size and weight of trucks, without including a 3D visualization of the load.

Data relevant to the study on 3D Algorithm are illustrated in the Table 7:

Table 7

Data using 3D Algorithm

Suppliers	Plant	Delivery scheduled	Linear meters calculated	Weight calculated
1.Pitesti Wiring	Valladolid	04/03/25 00:05	8 ML	8730
2.Campulung Wiring	Valladolid	04/03/25 00:05	4.8 ML	2916

According to 3D Algorithm, 12.8 ML were calculated in the truck from 2 suppliers. The data obtained were the following:

Table 8

Data obtained from 3D Algorithm

Packaging	Number	Weight	Linear Meters
SLI-0770	45	8730	7.5

BAC-O-4325 / SLI 2112	3	567	0.5
SLI-1200	18	2916	4.8

3.2 Data Analysis

1. 12.8 ml- 11.54 ml =1.26 ml difference between linear meters of cargo that fit in this truck taken as an example on a Romania-Spain route. (1)

2. 1.26 ml ÷ 13.5 ml=0.0933, where 13.5 max ml from a truck. (2)

3. 0.0933×100= 9.33 % percentage of improvement. (3)

The difference from 1.26 meters is due to the improvement according to 3D Algorithm, which optimizes the use of space inside the trucks, thus reducing the number of trucks needed to transport cargo depending on the needs of the Valladolid factory. 3D Algorithm assumes new data, the old system is no longer taken into account. The study contains two different types of calculations.

3.3 Economic impact

To assess the economic impact of the improved truck loading efficiency, €3236 was used as the data collection transport cost per truck and per week, provided by an international carrier.
(3236÷13.5)×1.26=302€ earned/per truck (5)
Thus, the use of 3D Algorithm allows more efficient use of the space in the trucks, contributes to reducing the number of trucks needed and generates an economic gain estimated at approximately 302 euros per week and per truck. To assess the gain per month the following data will be taken into account:
1. Weekly earnings per truck: 302 euros
2. Frequency: 5 trucks per week to earn 302 euros each
3. Number of weeks in a month: 4

302×5=1510 euros per week; (6)

1510×4 weeks= 6040 euros per month (7)

These calculations are based on the assumption that the transport frequency remains constant at one truck per shipment cycle, and that a total of five trucks per week benefit from the estimated economic gain of €302 each.

3D Algorithm is more advanced and included a 3D visualization of the filled trucks, which allowed better estimation of truck capacity utilization. Thus, it allowed to optimize of the available space in the trucks and led to a larger linear measurement, and the difference between the two estimates was 1.26 meters.

In 3D Algorithm, different suppliers are represented by distinct color coding: red represents cargo from the first supplier, Pitesti Wiring, and gray represents cargo from the second supplier, Campulung Wiring.

3.4 Limits of the Study

The study focused on a transport example that starts from two suppliers in Romania and must arrive in Spain.

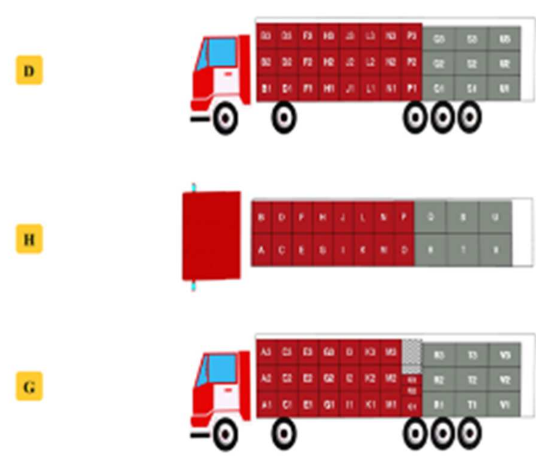

Fig. 4. 3D visualization of the filled trucks analyzed.

Although the same input data was entered into both systems used and these generated differences regarding the packaging used, number of pieces and linear meters, the study does not have wide applicability, similar analyses are needed on more routes and product types. There are too few studies on similar calculation algorithms, although there are many studies based on digitalization and sustainability in the supply chain.

4. CONCLUSION

The paper showed through a study the use of an algorithm, which includes 3D visualization of the load, and which allows a significant optimization of space use in trucks. The implementation of the 3D algorithm improved the loading of the cargo in the truck by increasing the number of linear meters because

it used the total height of the truck and did not respect the standard overlap from the packaging base that both systems use as a reference. Truck fill rate is a key indicator in industrial logistics, as it has a direct impact on operational efficiency and transportation costs. In a case study, a factory's supply needs were integrated into a computer system that visualizes cargo requirements in real time. The system uses an algorithm that, based on packaging standards, calculates the required linear meters in the truck for each shipment. In the first step, an algorithm was used that took these standards into account and resulted in a requirement of 11.54 linear meters. Subsequently, an alternative algorithm was applied that does not respect overlapping restrictions and uses the entire available height of the truck, which led to a requirement of 12.80 linear meters. The difference of 1.26 linear meters between the two methods determines if it is necessary a second truck is required for the same cargo volume. Therefore, a better filling rate can prevent the additional costs generated by using an additional vehicle, which implies direct savings in fuel.

Figure 5 offers valuable insights into the difference between the current load optimization system, which does not consider parts packaging, and the 3D Algorithm. The current System Data leads to inefficient use of truck space, resulting in improperly loaded trucks and the need to make multiple shipments per week. As in the image below, if the truck, through the 3D Algorithm, allows the stacking of a single package, taking into account the total height, then it fills a few extra linear meters, which would lead to the elimination of another overloaded truck, which would circulate with very few linear meters.

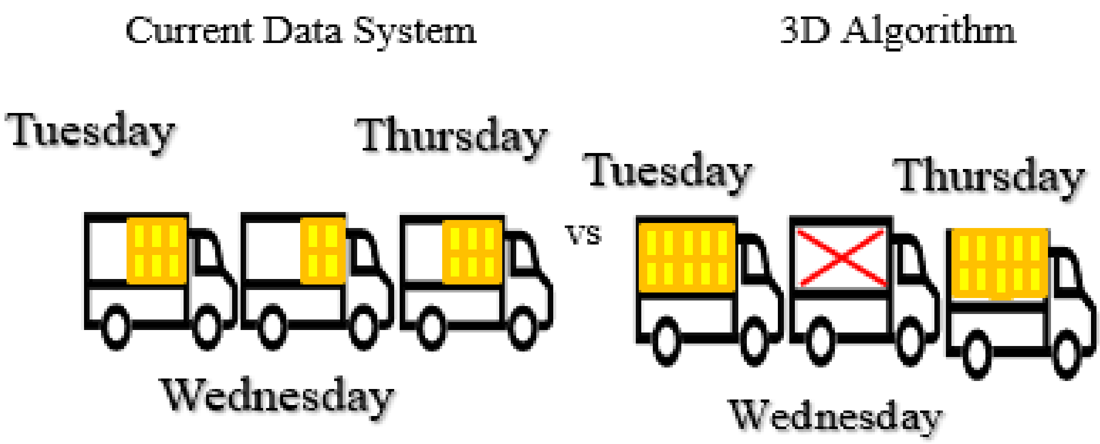

Fig. 5. Current system fixes.

5. FUTURE RESEARCH DIRECTIONS

5.1 Managing multimodal flows

Multimodal transport can also be introduced as a research study because sustainability is a primary requirement and an international issue. CO2 reduction is possible if the number of road transport decreases, which can be mixed with rail routes. So, a research direction with many current studies would be a comparative analysis of CO_2 emissions and fuel consumption before and after the implementation of 3D algorithms, at the level of a supply chain.

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Îmbunătățirea eficienței operaționale în managementul lanțului de arpovizionare

Eficiența lanțului de aprovizionare este esențială pentru companiile care vizează competitivitatea, satisfacția clienților, îmbunătățirea continuă și digitalizarea eficientă. Această lucrare își propune să arate cum algoritmii precum Algoritmul 3D pot îmbunătăți utilizarea spațiului în vehiculele de transport, examinând impactul asupra reducerii costurilor logistice. Implementarea acestor algoritmi avansați de optimizare permite departamentului de logistică să obțină rate de încărcare a camioanelor mai mari și rute de transport mai eficiente.
Studiul propus se bazează pe funcționalitatea unui Sistem de Date Actuale și pe integrarea noilor date în noul Algoritm 3D testat. În cele din urmă, această lucrare servește ca instrument de lucru pentru departamentul de logistică și prezintă tendința de dezvoltare a eficienței lanțului de aprovizionare

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