Big Data in Logistics

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Abstract:

The logistics sector involves complex operations that require a high level of precision and efficiency. In recent years, the use of big data has revolutionized the logistics industry, providing companies with valuable insights and analytics that can help improve their operations. Logistics companies generate massive amounts of data daily, including shipment tracking, inventory levels, delivery schedules, and customer feedback. In logistics, big data analytics involves leveraging extensive and complex data sets to derive insights, make informed decisions, and enhance transportation processes. The goal is to extract valuable information and patterns from this data to improve operational efficiency, reduce costs, enhance customer service, and enable strategic decisions. The impact of big data on logistics is hard to overestimate. This paper will discuss the role of big data analytics in the logistics sector.

Keywords: big data, big data analytics, big data applications, logistics, supply chain, transportation.

INTRODUCTION

Logistics refers to the comprehensive management of resource acquisition, storage, and transportation, ensuring the timely delivery of the right number of resources to their designated destinations in optimal condition for customers. Logistics has never been more complex than it is today. In modern times, a large volume of information is shared between companies involved in a supply chain network. All that information is collectively called big data. Big data is a large volume of unstructured and structured data collected from multiple sources. Undoubtedly, big data has been reshaping numerous business sectors, with logistics analytics standing prominently among them.

Big data refers to data sets whose size or properties exceed the capabilities of traditional databases. It involves vast volumes of structured and unstructured data that can be analyzed for insights. It has become a subject of growing importance. Data surrounds us everywhere. Today humanity generates about 1.7 megabytes of information per second and 2.5 quintillion bytes per day. Data is unlocking

new efficiencies across many different industries and logistics is no exception. Logistics collect data from different sources. The global logistics industry creates over 50 terabytes of data daily from shipments, routes, vehicles, and warehouses [1]. For transportation and logistics, the most common big data sources include computers across the Internet, mobile devices of consumers, RFID tags, GPS devices, IoT sensors, and financial transactions from customers.

Big data is fundamentally reshaping the logistics landscape, moving operations from merely reacting to issues toward a proactive and predictive footing. It helps organizations analyze information about products and services to make informed business decisions. Businesses can use the insights gained from big data analysis to optimize their services to lower costs, speed up delivery, provide in-demand products to customers, and provide a better customer experience [2].

WHAT IS BIG DATA?

Big data applies to data sets of extreme size (e.g. exabytes, zettabytes) which are beyond the capability of the commonly used software tools. It involves situation where very large data sets are big in volume, velocity, veracity, and variability [3]. The data is too big, too fast, or does not fit the regular database architecture. It may require different strategies and tools for profiling, measurement, assessment, and processing. Different components of big data are shown in Figure 1 [4]. The cloud word for big data is shown in Figure 2 [5].

Big Data is essentially classified into three types [6]:

➢ *Structured Data:* This is highly organized and is the easiest to work with. Any data that can be stored, accessed, and processed in the form of fixed format is known as a structured data. It may be stored in tabular format. Due to their nature, it is easy for programs to sort through and collect data. Structured data has quantitative data such as age, contact, address, billing, expenses, credit card numbers, etc. Data that is stored in a relational database management system is an example of structured data.

➢ *Unstructured Data:* This refers to unorganized data such as video files, log files, audio files, and image files. Any data with unknown form or the structure is classified as unstructured data. Almost everything generated by a computer is unstructured data. It takes a lot of time and effort required to make unstructured data readable. Examples of unstructured data include Metadata, Twitter tweets, and other social media posts.

➢ *Semi-structured Data:* This falls somewhere between structured data and unstructured data, i.e., both forms of data are present. Semi-structured data can be inherited such as location, time, email address, or device ID stamp.

The different types of big data are depicted in Figure 3 [7].

The process of examining big data is often referred to big data analytics. It is an emerging field since massive computing capabilities have been made available by e-infrastructures [8]. Big data analytics is the application of advanced analytic techniques to large, heterogeneous data sets that comprise structured, semi-structured, and unstructured data from many sources with sizes ranging from terabytes to zettabytes.

It enables predictive analytics, which involves using historical data to forecast future outcomes. Analytics include statistical models and other methods that are aimed at creating empirical predictions. Data-driven organizations use analytics to guide decisions at all levels. Several techniques have been proposed for analyzing big data. These include the HACE theorem, cloud computing, Hadoop, and MapReduce [9]. Figure 4 shows big data analytics [10].

CHARACTERISTICS OF BIG DATA

Big data is growing rapidly and expanding in all science and engineering, including physical, biological, and medical services. Different companies use different means to maintain their big data. As shown in Figure 5 [11], big data is characterized by 42 Vs. The first five Vs are volume, velocity, variety, veracity, and value .

➢ *Volume*: This refers to the size of the data being generated both inside and outside organizations and is increasing annually. Some regard big data as data over one petabyte in volume.

➢ *Velocity*: This depicts the unprecedented speed at which data are generated by Internet users, mobile users, social media, etc. Data are generated and processed in a fast way to extract useful, relevant information. Big data could be analyzed in real time, and it has movement and velocity.

➢ *Variety*: This refers to the data types since big data may originate from heterogeneous sources and is in different formats (e.g., videos, images, audio, text, logs). BD comprises of structured, semi-structured or unstructured data.

➢ *Veracity*: By this, we mean the truthfulness of data, i.e. weather the data comes from a reputable, trustworthy, authentic, and accountable source. It suggests the inconsistency in the quality of different sources of big data. The data may not be 100% correct.

➢ *Value*: This is the most important aspect of the big data. It is the desired outcome of big data processing. It refers to the process of discovering hidden values from large datasets. It denotes the value derived from the analysis of the existing data. If one cannot extract some business value from the data, there is no use managing and storing it.

On this basis, small data can be regarded as having low volume, low velocity, low variety, low veracity, and low value. Additional five Vs has been added [11]:

➢ *Validity:* This refers to the accuracy and correctness of data. It also indicates how up to date it is.

➢ *Viability:* This identifies the relevancy of data for each use case. Relevancy of data is required to maintain the desired and accurate outcome through analytical and predictive measures.

➢ *Volatility:* Since data are generated and change at a rapid rate, volatility determines how quickly data change.

➢ *Vulnerability:* The vulnerability of data is essential because privacy and security are of utmost importance for personal data.

➢ *Visualization:* Data needs to be presented unambiguously and attractively to the user. Proper visualization of large and complex clinical reports helps in finding valuable insights.

Instead of the 10V's above, some suggest the following 5V's: Venue, Variability, Vocabulary, Vagueness, and Validity) [12].

Industries that benefit from big data include the healthcare, financial, airline, travel, restaurants, automobile, sports, agriculture, and hospitality industries. Big data technologies are playing an essential role in farming: machines are equipped with sensors that measure data in their environment. The analysis of both structured and unstructured data is crucial in the shipping industry to gain insights into customer behavior, improve operational efficiency, and make informed business decisions.

BIG DATA IN LOGISTICS

Big data refers to massive amounts of both structured and unstructured data that are hard to process by traditional methods. Big data in logistics refers to the massive volume of data generated throughout the delivery process. This includes data from GPS trackers, customer orders, driver routes, traffic conditions, vehicle telematics, and even social media. When processed using a logistics management system, this data helps businesses make informed decisions and predict future trends with high accuracy. The use of big data in logistics and supply chain management has transformed the way companies operate in the industry. Big data analytics has revolutionized logistics, and companies now utilize these technologies to create exceptional growth opportunities.

Big data in logistics refers to the collection, processing, and analysis of complex datasets related to logistics management operations. It covers massive datasets from IoT sensors, telematics, and barcodes that are used to improve supply chain visibility and operations. It can help optimize routes, enhance factory processes, and raise performance throughout the entire supply chain. Not only does it provide intelligent insight into improving operational efficiency, it also helps to better satisfy customers' economic and environmental expectations. By using big data, players can optimize operational costs, enhance their operational efficiency, and help customers find the best ways to deliver their products to consumers [13]. Figure 6 shows a representation of big data in logistics [14], while Figure 7 shows its impact on logistics [15].

APPLICATIONS OF BIG DATA IN LOGISTICS

Big data has become an invaluable asset in the logistics and supply chain industry. Applications includes inventory management, warehouse management, risk management, demand forecasting, and route optimization. Figure 8 shows some use cases of big data in logistics [16]. Thus, key applications include the following [2,14,17,18]:

➢ *Routes Optimization:* Safe, reliable, and fuel-efficient routes remain one of the biggest challenges for businesses. Due to cost reduction initiatives and sustainability efforts, many logistics companies are seeking ways to optimize routes. GPS data, road condition data, and weather data can be combined with fleet data to identify the best route for each vehicle at any given time. Navigating complex transportation networks poses great challenges for logistics companies striving for efficiency in deliveries. Big data analytics plays a vital role in route optimization by considering traffic, weather data, GPS information, and historical delivery details. Big Data allows logistics platforms to optimize delivery routes by analyzing real-time traffic data, weather updates, historical delivery trends, and customer availability.

➢ *Warehouse Management:* Warehouses serve as crucial hubs in logistics and supply chain operations, and any delays here can result in substantial losses. Efficient warehouse management and order fulfillment are vital for meeting customer expectations. With big data analytics, companies can eliminate routine tasks for warehouse workers, such as documentation, picking, and packing. In addition to reducing stockouts and overstocks by optimizing inventory management, data analytics can also improve the efficiency of warehouse management. Companies can track the movement and location of stock and combine this information with sales data to identify the best location for each SKU in the warehouse and find opportunities to streamline. Amazon's fulfillment centers exemplify the integration of robotics, big data, and the Internet of Things in creating smart warehouses. A warehouse management system is shown in Figure 9 [19], while Figure 10 shows warehouse automation by Amazon [19].

➢ *Inventory Management:* If a product is out of stock, there is a high likelihood that shoppers will shift their purchase behavior. Data-driven decision-making ensures that businesses maintain optimal inventory levels. A logistics management solution can analyze sales trends and supply chain disruptions, helping companies avoid stockouts or overstocking. Walmart utilizes big

data analytics to monitor product sales and inventory levels, enabling them to proactively restock shelves. Figure 11 shows a typical inventory management [18].

➢ *Risk Management*: Risk management is another area where big data is transforming logistics. It benefits from improved forecasting. By analyzing data on supplier performance, weather patterns, geopolitical events, and other factors that can impact supply chain operations, businesses can identify potential risks and take proactive measures to mitigate them. Big data can help companies identify potential risks in their supply chain, such as disruptions due to weather or political unrest. By anticipating these risks, companies can better prepare and mitigate potential negative impacts. The organization can assess any threats and risks to the business and devise timely strategies to mitigate them. Effective risk management can help to minimize disruptions in supply chains.

➢ *Demand Forecasting:* Accurate forecasts ensure smoother operations and reduce unnecessary transportation and warehousing costs. Big data analytics empowers logistics professionals to make accurate demand forecasts and optimize inventory levels. It fosters accurate demand forecasting by analyzing historical trends, seasonal fluctuations, customer behavior, and market dynamics. Using the wealth of proprietary and third-party data available, companies can track and adapt to shifts in demand in near real-time. Big data analytics allows companies to generate more accurate supply and demand forecasts to inform inventory and shipment planning. In the modern business landscape, big data analytics for transportation and logistics plays a crucial role in handling operational demand. Big data applications facilitate planning for the increasing demand across the supply chain. This also includes adjusting strategies based on annual trends, such as market changes or seasonal needs.

➢ *Last-Mile Logistics:* In today's fast-paced logistics world, last-mile delivery has become the most critical — and costly —stage of the supply chain. It is often the last mile that brings the most trouble to logistics businesses. Last mile delivery costs represent 50% of the total shipping expenses. It represents the final leg where goods are transported from a distribution hub to the customer's doorstep. As technologies evolve, the future of last-mile delivery lies in hyper-personalization, predictive optimization, and autonomous decision-making — all fueled by big data.

➢ *Predictive Maintenance:* Analyzing large amounts of data from equipment sensors, maintenance records, and other sources can help supply chain managers identify patterns and predict when maintenance is needed. This can help reduce downtime, extend the lifespan of equipment, and minimize repair costs. By predicting maintenance needs in advance, the company can schedule maintenance at the most convenient time and avoid costly downtime or repairs. Data about fleet conditions allows companies to conduct maintenance in advance. The result is reduced fuel consumption and fewer delays due to vehicle breakdowns.

➢ *Predictive Analytics:* Big data analytics enables companies to gain valuable insights from historical data and identify improvement opportunities. Predictive analytics techniques help companies anticipate future scenarios, such as demand fluctuations, supply shortages, or transportation disruptions. By using predictive analytics, logistics companies can anticipate demand patterns, and potential supply chain disruptions, and optimize inventory levels. This results in improved responsiveness to customer demands and less risk of stockouts or overstocking.

BENEFITS

The benefits of big data include improved supply chain visibility, enhanced decision-making, increased efficiency, and predictive analytics. By integrating big data analytics into logistics management software, companies can optimize operations and gain a competitive edge. Data analytics capabilities now define market leaders in the logistics industry. A logistics company might

use big data to analyze sensor data from its fleet of trucks to identify patterns indicating when maintenance is needed. Other benefits of big data in logistics include the following [14,20]:

➢ *Automation:* We use big data to automatically gather information from the transportation *vehicles* along their routes, data such as demography, weather, and traffic. The convergence of big data, automation, and the Internet of things paves the way for potentially fully automated logistics. With developments like self-driving vehicles, the whole supply chain processes – from loading to driving to the final delivery – would be able to operate seamlessly through automation.

➢ *Cost Reduction:* A major benefit of big data in logistics lies in cost reduction. Logistics companies face significant operational costs, including fuel expenses, warehousing, and labor. Big data enables businesses to analyze cost patterns and implement strategies that enhance efficiency. With intuitive data visualizations and dashboards, companies can identify patterns and trends, streamlining operational processes.

➢ *Waste Reduction:* Big data is helping companies to understand how much waste their production and distribution processes produce. Companies can use the data to refine processes and change materials that produce excess waste. Combined with good material management practices, waste can be greatly reduced.

➢ *Improved Transparency:* Real-time monitoring of goods' movement and delivery operations assists in increasing internal and external efficiency. Improved transparency also boosts customer satisfaction by offering up-to-date tracking information, thus fostering trust.

➢ *Informed Decision-making:* Another major benefit of big data in the logistics industry is that it fosters informed decision-making and proactive strategies. Logistics companies have changed their approach to decision-making dramatically. When data is collected, processed, and analyzed using advanced technologies like AI, machine learning, and data visualization tools, it turns into actionable intelligence that powers smart decision-making.

➢ *Better Customer Satisfaction:* Customers want to know when they will receive their orders and if a package is expected to arrive later than anticipated. They expect real-time updates on their shipments. Logistics management software with big data capabilities provides accurate tracking, estimated delivery times, and automated notifications. The more informed a customer is, the happier they tend to be. Big data supports customer segmentation, helping tailor communication and delivery schedules according to behavior patterns.

➢ *Sustainability:* Big data analytics can also help businesses to become more sustainable. By analyzing data on energy consumption, carbon emissions, and other environmental impacts, businesses can identify areas where they can reduce their environmental footprint. Data-driven routing reduces carbon emissions by minimizing unnecessary mileage. DHL and other firms use this to calculate and lower their carbon footprint.

Some of the advantages of using big data in logistics are displayed in Figure 12 [19].

CHALLENGES

Big data is not some magic bullet. If you do not manage it well and have a clear game plan, it can actually turn into a huge pain. There are challenges associated with its implementation, including integration, data security, data quality, change resistance, and skill shortage. A major challenges is the sheer volume of data that businesses must collect and process. Other challenges of big data in logistics include the following [2,21-23]:

- ➢ *Data Security:* Privacy and security are significant concerns when it comes to big data. If data is not protected correctly, it can be vulnerable to breaches or unauthorized access, which can lead to identity theft, financial losses, and damage to the company's reputation. Privacy laws also require companies to handle data responsibly, adding legal considerations to ensure compliance. With so much data being collected and stored, businesses must ensure that they are complying with privacy regulations and that they have robust security measures in place to protect the data from cyber attacks and breaches.

- ➢ *Data Quality:* Reliable insights depend on accurate, well-organized data from multiple sources. If the data is outdated, incorrect, or inconsistent, it can lead to poor decision-making, which in turn harms business operations and customer satisfaction. High-quality integrated data allows companies to make better decisions. However, achieving this can be complex and costly for many businesses. Big data analytics can also help businesses to improve quality control in their supply chain. By analyzing data on product defects and returns, businesses can identify areas where quality issues are arising and take corrective action.

- ➢ *Change Resistance:* This creates a major barrier to big data adoption. The challenge goes beyond technical aspects and touches human nature deeply. Employees often resist change because they worry about learning new skills and their limited tolerance levels. Implementing big data analytics requires a significant shift in organizational culture. Companies must invest in change management initiatives to ensure that their staff is aligned with the goals of the big data analytics implementation and is motivated to adopt new technologies and processes.

- ➢ *Collaboration:* As companies grapple with the challenges of collecting and sharing supply chain data, there is a growing awareness among supply chain operators that collaboration is key to solving problems. The need to share data encourages companies to develop compatible database structures and standards. By sharing data with suppliers and other partners, logistics companies can improve communication and collaboration across their supply chain. This leads to more efficient and effective operations overall.

- ➢ *Integration:* Integrating big data analytics into existing logistics and supply chain management systems can be a challenging task. The integration of different data sources can be complex and require significant investment, posing challenges for logistics providers. Companies need to ensure that their systems can handle the volume of data generated by big data analytics and that they can integrate the insights generated into their existing workflows.

- ➢ *Skill Shortage:* Big data analytics requires a specialized skill set that is not readily available in many logistics and supply chain management organizations. The skill set required to effectively implement big data analytics includes expertise in data science, statistics, machine learning, and data visualization. Logistics providers may need to invest in training and development to bridge skill gaps.

- ➢ *Complexity:* The complexity of big data analytics can be overwhelming for many logistics and supply chain management organizations. Big data analytics requires significant expertise in data science and analytics to generate meaningful insights.

- ➢ *Compliance and Regulation:* For any company working with confidential information, data security and compliance should be the top priority. Even the smallest data breach can lead to massive financial consequences and loss of trust from customers. Big data can help businesses to comply with regulations and standards in their industry. By analyzing data on regulatory requirements, businesses can ensure that they are meeting all necessary standards and avoid costly penalties. Companies should make sure that the way they store and process the information complies with the applicable regulations, like GDPR and HIPAA.

CONCLUSION

Companies are progressively recognizing the importance of big data. They are actively using it to become more competitive, sustainable, and customer-focused. Embracing this data-driven approach enables businesses to stay competitive, meet customer expectations, and drive innovation in the dynamic world of supply chain operations. In the cutthroat world of logistics today, companies that are not leaning on big data are going to have a tough time keeping up and will inevitably fall behind their competitors. The era of basing critical logistics decisions on intuition or outdated reports is over.

As technology evolves, logistics operations have become increasingly complex. Logistics is evolving due to big data and we are beginning to process data from the supply chain to make better strategic and tactical decisions to improve revenue, increase savings, and improve customer experience. Big data analytics in logistics helps transportation companies optimize routes and schedules in real-time, improving overall efficiency with smart data-driven decisions. Big data's future in logistics looks promising. The full potential of big data in the logistics industry is yet to be harnessed. More information about big data in logistics can be found in the books in [24-28] and the following related journals:

- ✓ *Journal of Big Data*
- ✓ *Big Data and Cognitive Computing*

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Figure 1. Different components of big data [4].

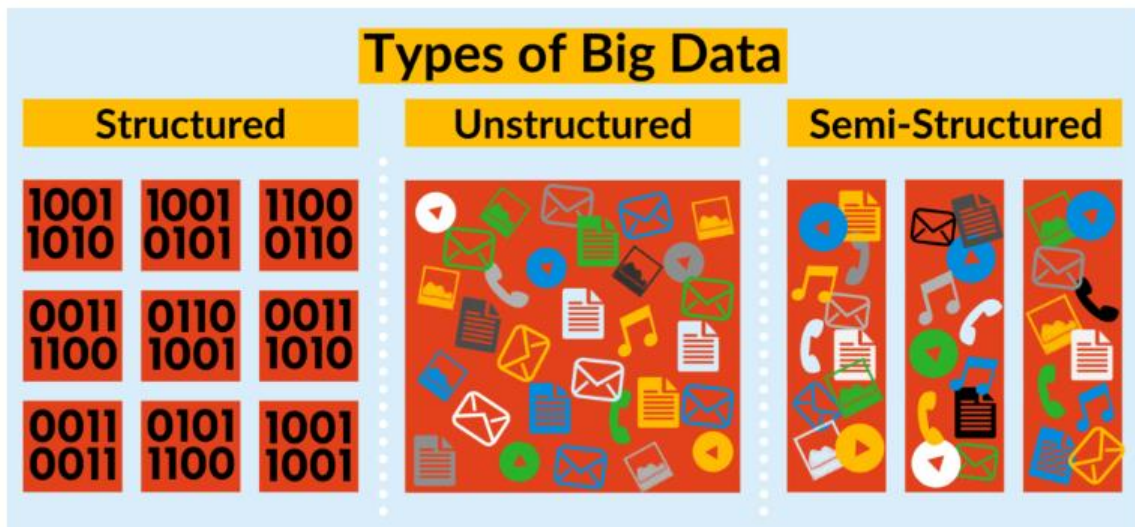
Figure 2. The cloud word for big data [5].

Figure 3. Types of big data [7].

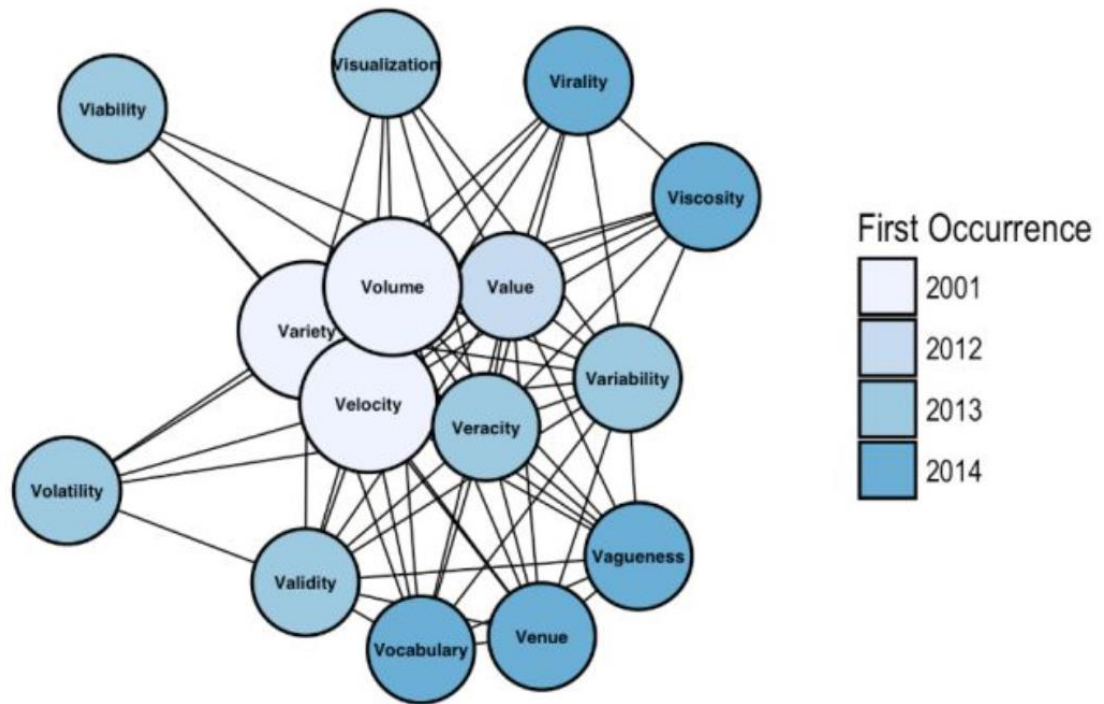**Figure 4. Big data analytics [10].**

Figure 5. The 42 V's of big data [11].

Figure 6. A representation of big data in logistics [14].

Figure 7. The impact of big data on logistics [15].

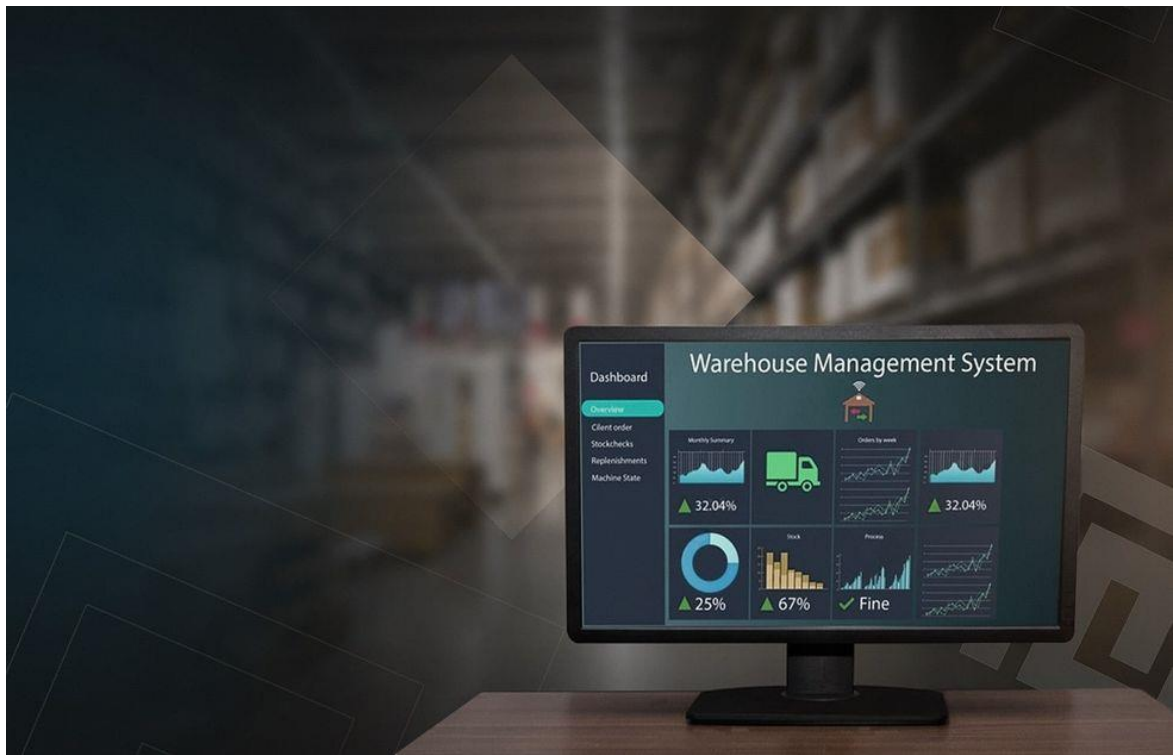**Figure 8. Some use cases of big data in logistics [16].**

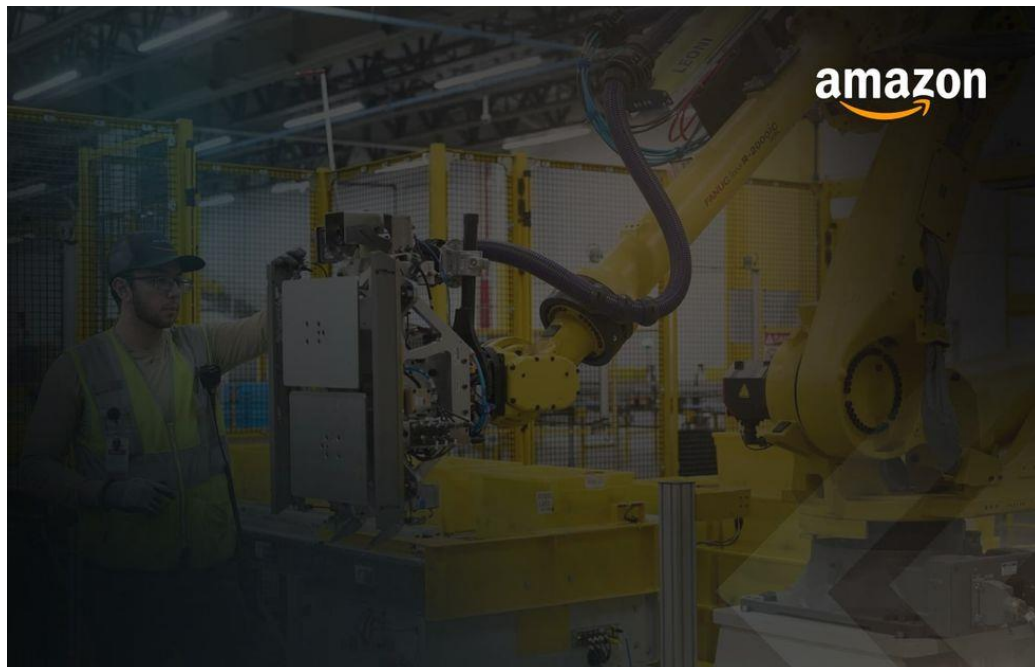**Figure 9. A warehouse management system [19].**

Figure 10. Warehouse automation by Amazon [19].

Figure 11. A typical inventory management [18].

Figure 12. Some of the advantages of using big data in logistics [19].