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Technology as a Key Enabler in Logistics Management

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Abstract

With the explosive growth of world trade crossing continental boundaries and the inroads made by ecommerce into virtually every market, the logistics infrastructure has been severely strained. This makes it imperative to strive to streamline logistics processes in an effort to maximize profit while ensuring world-class customer satisfaction. Technology can be leveraged as the key enabler in this process. In recent years, technology has advanced by leaps and bounds and there are many technological concepts that can be easily applied to improve logistics management. These include artificial intelligence, blockchain, autonomous vehicles, drones, and Internet of Things (IoT) to name a few. However, the implementation of these technologies are fraught with challenges due to a combination of factors such as the need for investment, resistance to change and a lack of holistic systems perspective.

Keywords
Technology, logistics, supply chain,

1. Introduction
With the growth of world trade and a flourishing ecommerce market, logistics infrastructure and services world over are becoming more and more strained. This is further compounded by consumer expectations of receiving goods and services as quickly as possible. Alongside the significant improvements in the energy sector with reduced reliance on fossil fuels and increased use of electric vehicles, it is also imperative that the system is optimized to maximize profits while ensuring exemplary customer satisfaction, and meeting the regulatory requirements. It has also been shown (Nunez-Merino et al. 2024) that in order to ensure a competitive advantage, it is imperative to develop capabilities in an organization that seek to provide improved customer value. Technology can be leveraged in different ways to achieve this competitive advantage. It can serve as a key enabler to reap significant benefits in a myriad of sectors. It has made inroads into agriculture, food processing, energy conservation, manufacturing, and supply chain management.

1.1 Objectives
The objective of this manuscript is to explore the different ways in which technology can be leveraged to alleviate some of the pressure being exerted on logistics infrastructure and systems. Some of the advantages and disadvantages of these instruments are also examined.

2. Literature Review
Some of the high-level technological advances that have relevance and significance in logistics management include additive manufacturing, artificial intelligence, autonomous vehicles, blockchains, drones, Internet of Things (IoT), radio frequence identification (RFID). The following sections summarize some of the applications of these technologies along with their challenges.

2.1 Additive Manufacturing

3D printing which uses additive manufacturing principles where the part is generated by adding layers of material. This is in contrast to traditional manufacturing where material is removed (machined) from a block to create the part. 3D printing provides a significant advantage in the area of mass customization of parts with the ability to provide personalized parts such as healthcare applications. 3D printing also helps reduce the time to market since prototypes can be quickly built and analyzed. Another advantage of 3D printing is that due to its low footprint it can be located closer to the customer thus reducing transportation costs. Additive manufacturing also affords the benefit of being able to produce complex shapes or hard to find spare parts that would have been prohibitively expensive to manufacture using traditional methods (Verboeket and Krikke 2019; Knofius et al. 2019).

Additive manufacturing is best suited for low volume and specialized scenarios (Sirichakwal and Donner 2016). This has a significant impact on the after sales logistics since spare parts can now be produced closer to the consumer instead of having to be shipped (Ben-Ner and Siemsen 2017). Due to the ease with which parts can be produced, there could be a shift in purchasing trends for the end consumer impacting impulsive purchases at the retail store (Fawcett and Waller 2014). Due to the time involved in laboriously adding layers, it is not yet comparable to traditional manufacturing in large volumes. There is also the possibility of impact of the pores on mechanical properties. Moreover, the cost of material tends to be high since it requires extensive pre-processing. The range of materials that can be printed is also limited thus constraining its application.

2.2 Artificial Intelligence (AI)

Artificial intelligence has been around for many decades before entering mainstream with the launch of ChatGPT in 2022. Since then, generative artificial intelligence has found applications in a variety of fields such as education, image generation, software development, research summarization, data analysis, and much more. AI-powered robots and vision cameras have been employed to improve order picking accuracy in warehouses. AI-powered data analysis has provided insights into market trends, consumer preferences, sales forecasts, and inventory management. AI also helps determine optimal delivery routes thus shrinking delivery times and reducing fuel consumption. AI-powered predictive analytics have been used to generate sales estimates, workforce requirements, production schedules, and maintenance frequencies.

AI has also been successfully used in reverse logistics which is becoming a vital part of logistics management with the growth of ecommerce. AI tools are being deployed to identify, evaluate and ascertain the quality of goods returned in order to determine the next steps. This includes decisions on whether to refund the customer based on a legitimate return and whether to restock, reuse, or recycle the returned product based on its quality (Mukherjee et al. 2024). Artificial intelligence when combined with human intelligence or authentic intelligence (Cremer and Kasparov 2018) results in augmented intelligence which has the potential for significant benefits far exceeding those afforded by each intelligence in isolation provided the right conditions and circumstances are present. This also ensures equal role for humans and helps assuage some of the fears that artificial intelligence will make some jobs irrelevant consequently rendering the workforce vulnerable.

2.3 Autonomous Vehicles

Autonomous guided vehicles (AGVs) have been employed in warehouses around the world. Autonomous vehicles have also been on the roads in some form or the other for many years now. The Society of Automotive Engineers (SAE) developed a standard for autonomous vehicles (SAE 2021). According to the standard, there are six levels of automation starting with Level 0 which involves no automation and ending in Level 5 which requires complete automation. For example, adaptive cruise control which is prevalent in most newer cars is considered to be Level 1 which provides some driver assistance.

Even though it has not made its foray into the trucking industry, there have been many suggestions on how this could be done in an iterative manner beginning with autonomous trucks. With trucks responsible for getting more than 65% of U.S consumable goods to the market, this is a huge venue for significant cost savings to be accrued. Technology such as lidars, sensors, GPS systems help trucks to be autonomous. Retrofitting existing trucks with these technologies could cost anywhere between $30,000 and $100,000 (Chottani et al. 2019). Platooning is a concept where autonomous trucks would follow a driver-led truck which would be classified as Level 3. Eventually, it is hoped that a group of trucks would go as a convoy on the highways without human interaction reaching Level 5. The drivers would be responsible for dropping off the trucks at truck stops (Chottani et al. 2019).

An important aspect to consider in the case of autonomous trucks is the applicability of classic shipment models. It has been shown (Chen & Lu 2020) that shipment models need to be revised to account for the cost variances between autonomous trucks and ordinary trucks. Since driver availability is not a factor in autonomous trucks, the lead times tend to be shorter and this impacts shipment sizes.

2.4 Blockchain

Blockchain technology was originally proposed by Haber and Stornetta (1991) for timestamping digital documents. The authors proposed two solutions: the linking solution which uses the concept of an immutable linear list, and random witness solution which requires a random number of members of the chain to authenticate the document. Cryptocurrency was introduced in 2008 in the form of bitcoins using the aforementioned blockchain technology. This brought the technology into mainstream and helped garner attention among researchers and practitioners alike. Blockchain is a distributed ledger system with a decentralized network of independent nodes connected through a peer-to-peer system. The basic unit of storage in the blockchain is called a block. Each block contains information about the previous block on the chain and a change in any of the blocks on the network has to be communicated to every other block on the chain thus ensuring transparency and traceability. Moreover, each node maintains a copy of the entire blockchain making the network secure and resilient. There are two different algorithms that can be used to maintain the network. One is called the proof of work algorithm where each node solves a mathematical problem. This is a computationally intensive process but ensures data integrity. The other algorithm is the proof of stake where the blocks are responsible to ensure the authenticity of the data. This approach requires less computation and hence is easier to scale and maintain. However, due to its simplicity, security of the network is quite lax.

Due to the aforementioned advantages afforded by blockchains, this technology has found resonance in logistics and supply chain management (Tijan et al. 2019). One area is to improve visibility of the processes across supply chain partners. Another application is to improve traceability of the product as it makes its way through the supply chain. Blockchain based contracts is another venue that is useful among supply chain partners. Blockchain has been shown to yield significant benefits in the case of low-volume and high-value goods (Berneis et al. 2021).

Despite being heralded as the next big thing due to the benefits afforded by blockchains, there is a general reluctance to adopt this technology due to its complexity (Janjevic et al. 2019). Another issue is scalability and maintenance (Biswas & Gupta, 2019). Since any change to the data in the block requires communication with all nodes in the chain, there is a need for significant computing power. Moreover, the very benefit of transparency could be a disadvantage for companies who are concerned about intellectual property rights and privacy issues (Tijan et al. 2019).

2.5 Drones

Drones have seen numerous applications from thermal image scanning, fire-fighting and real-estate. While holding significant promise in the logistics industry especially for the last mile delivery, this technology has its own challenges:

- *Safety* - Flying drones in densely populated areas can pose a huge risk for the population not to mention the possibility of collision with other flying objects.
- *Regulations* - Federal Aviation Authority (FAA) limits the use of drones in specific areas especially close to airports.
- *Weather* - While drones are becoming more and more resilient to wind and improving in their ability to return back to their "home", adverse weather conditions such as rain, and snow could pose serious challenges.

2.6 Internet of Things (IoT)

Internet of Things refers to a network of devices that communicate through the Internet. These are usually peripheral devices that are not traditionally viewed as computing devices. For example, a GPS sensor embedded in a truck could be relaying real-time information to the company about the exact location of the truck. Other sensors embedded in the trucks could relay information about the health of the trucks which can then be used for preventive maintenance and efficient fleet management. Sensors can also be used for inventory management with real-time information about stock on hand.

2.7 Radio Frequency Identification (RFID)

Radio frequency identification (RFID) has been around for many decades. However, in the recent years, it has gain popularity for the real time tracking ability that can be leveraged to track shipments as they enter or leave warehouses, ports, etc. This technology is based on near frequency and requires low power. Companies like Walmart have begun requiring its suppliers to use RFID tags for their shipments. Another application of RFID allows for geofencing (Oliveira et al 2015) to prevent thefts.

3 Challenges

Despite all the affordances of technology aimed at improving efficiencies and streamlining operations, logistics companies are faced with numerous challenges and barriers (Biswas and Gupta 2019).

3.1 Lack of Uniform Standards and Regulations

Given the pace at which technology has been progressing, oftentimes state and federal agencies are playing catch up in framing regulations to ensure safety and privacy. This begets numerous ad hoc and fragmented approaches which often are neither easily portable or scalable. Moreover, this also means there is no oversight to ensure compliance leaving systems vulnerable to attacks. . Moreover, due to a lack of uniform standards, there is a proliferation of divergent systems that are not conducive to seamless integration.

3.2 Resistance to change

As with any innovation, there is always a resistance to change due to skepticism (Mani and Chouk, 2018) about the efficacy of new technologies. There is also the issue of automation negatively impacting jobs. It is true that some jobs are eliminated as a result of automation and technology. However, this only provides more opportunities for upskilling and engaging in higher-order thinking leading to more innovation and processing improvement.

3.3 High Cost of Investment

Another hurdle is the cost of implementation. There is often significant upfront investment required to effectively implement these technologies. With all the resulting challenges of acceptance and resistance to change, organizations tend to be hesitant to embrace these technologies with full earnest.

3.4 Lack of Holistic Systems Perspective

Due to a lack of understanding of how these technologies interact with existing systems and with each other, implementations tend to be fraught with challenges. Moreover, there tends to be a piecemeal approach to implementation resulting in a myriad of technologies that purport to do different things. This lack of a holistic approach to implementation of technology leads to duplication, inefficiencies, and a lack of interoperability.

4. Conclusion

Technological advances of the 21st century have made it possible to speed up the innovation and improvement processes in many sectors. This growth of technology has also helped in connecting remote suppliers and customers who may be geographically separated by long distances. However, the challenge of moving products across the globe has put a strain on the existing logistics infrastructure and systems. This includes ports, air freights, and road transportation. Technologies such as artificial intelligence, autonomous vehicles, drones, blockchains and RFID can be leveraged to ease some of this burden. However, this is not without challenges which need to be overcome in order to maximize the benefits afforded by technological solutions for efficient logistics management.

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