AI in Logistics and Supply Chain Management

January 2021 · SSRN Electronic Journal
DOI:10.2139/ssrn.3862541

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Abstract Artificial Intelligence (AI) applications are pervading logistics and supply chain management. The widespread availability of data, combined with sustained improvements in computing power, provide new opportunities to improve supply chain decision-making. Data may originate from digital logistics applications, or the connectivity of assets through Internet of Things technologies. AI can also facilitate the automation of well-defined workflows. Yet, while AI may appropriate certain tasks, we believe it will not make the job of the logistics planner obsolete. AI empowers and augments human capabilities. This chapter explores and demystifies the opportunities of AI for logistics and supply chain management.

1 Introduction: Digital Logistics

Artificial intelligence (AI) refers to the ability of a computer or computer-controlled robot to perform tasks commonly associated with human beings. The *intelligence* in the term implies that the task being performed by a machine, script, or algorithm would require the use of intelligence, were a human to do it.

Although AI has been around since the late fifties, it has only become a mainstream concept since the last decade. AI now powers our smartphones, our TV recommendations, and even our photo libraries. Also in business, AI has transformed from an obscure term to a buzzword. In a 2021 survey by Accenture, 77% of

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executives state that their IT architecture is becoming critical to the overall success of the organization.[1] In the healthcare sector—transformed in 2020 by the COVID pandemic—the confidence in AI is even stronger. Reportedly, 98% of healthcare executives have developed an AI-strategy plan, among which 44% have already implemented an AI strategy.[2] Other business surveys are similarly strong. McKinsey, for example, notes that nearly 58% of executives surveyed have already embedded at least one AI capability in their company.[3] The message from the industry is clear: AI is here to stay, and the companies that learn how to adopt and scale it are poised to enjoy a competitive advantage.

In logistics and supply chain management, analytics and computer support have been around for decades. Supply chain planners, for instance, use software tools that process historical data to forecast demand; many enterprise resource planning (ERP) systems automate the decision of when and how much to order; and warehouse and transportation management systems optimize storage and transportation operations. Each of these supply chain support tools can be run as a siloed application, or integrated with other business operations, such as financial accounting or application programming interface (API) software. Cloud-based service offers the additional flexibility to scale up IT infrastructure to accommodate temporary computing needs.

The recent breakthrough in digitizing logistics operations comes from real-time connectivity of assets to the data platform: machines, vehicles, and devices can now be monitored via sensor technologies that capture all sorts of data in real-time. In addition, when sensors become impractical, operators can provide feedback information through mobile and wearable devices. This extensive connectivity is known as the fourth industrial revolution, also referred to by the term *Industry 4.0*.

Such connectivity provides (quasi) real-time visibility over all workflows. A "digital control tower," in analogy to the airport control tower, can provide visual alerts that warn of inventory shortfalls, or process bottlenecks, before they happen. Using simple control algorithms, teams on the front line can course-correct even before potential problems become actual ones. Furthermore, the availability of historical data can give rise to increasingly sophisticated algorithms which add additional intelligence to the control rule: predictive analytics learn from historical data to obtain patterns and correlations not evidently detected by humans. By means of a *digital twin* of its physical operation, real-time analysis and optimization can even prescribe decision-making where users make decisions based on what intelligent agents recommend.

The digital control tower providing real-time information, potentially augmented by predictive diagnostics and analytics, may support logistics and supply chain man-

[1] Accenture: Technology Trends 2021. https://accntu.re/3nN0ABW

[2] 3rd Annual Optum Survey on AI in Healthcare. https://bit.ly/3azuVOU

[3] McKinsey global AI survey. https://mck.co/3auUtN5

agers in their decision-making. As we discuss in this chapter, these 'smart' decisions have the potential to bring about more efficient, more resilient, and even more sustainable supply chains. Observe, however, that these AI tools do not necessarily perform an entire workflow. Instead, each delivers a predictive component to assist someone in making a decision. AI can take over some, but not all, tasks. In fact, in the majority of supply chain AI implementations to date, humans still have the last word. AI does not imply—by itself—autonomous decision-making (Boute and Van Mieghem, 2021).

2 Smart Logistics

Back in 2017, The Economist published an article titled, "The world's most valuable resource is no longer oil, but data" (The Economist, 2017). The use of digital applications as well as the connectivity of assets through, e.g. sensors and digital control towers, generates large amounts of data (possibly in real-time). The question that now arises is how such data can be leveraged to improve the level of *intelligence* store, and share. These data have the potential to make logistics and supply chain control more adaptive and *smarter*.

In traditional data-driven applications, one typically uses one or—at most—a few sources of data, such as historical demands or current inventory levels. As long as the input variables remain 'countable,' one can implement (or even program) if-then instructions to support (or even automate) decision-making. The integration of various digital applications, in contrast, generates a data pool of different sources, collected automatically through sensors (*Internet of Things*) as well as manually through mobile and wearable communication devices (known as the *Internet of People*). When the number of data sources grows rapidly, the ensuing mountain of data makes the explicit enumeration of if-then instructions infeasible.

This is where machine learning comes into the picture. Whereas AI is the umbrella term for all computer rules that mimic human intelligence (including if-then instructions), machine learning is the subset of AI where an algorithm *learns* to mimic human behavior and makes its own decisions. Machine learning algorithms are in essence *prediction machines* that perform a task without using explicit instructions (Agrawal et al., 2018).

A milestone for the mainstream use of machine learning is the victory of the algorithm AlphaGo over the world champion of the Chinese board game Go, Lee Sedol, in March 2016.[4] The ancient game of Go is played on a board with 19 x 19 = 361 positions, each of which can contain a black, white or no stone. It therefore has $3^{361} \approx 10^{172}$ possible states; several orders of magnitude more than chess[5], and

[4] A breathtaking documentary of this victory is available at `https://www.alphagomovie.com/`

the source to reduce the time lag between data generation and deriving insights, and c) a distributed paradigm for sharing information, alerts, and notifications in real-time among ecosystem partners for collaborative and cognitive decision making in the event of disruptions. A Digital Control Tower (DCT), like its analogous counterpart in an airport, can provide visual alerts that warn of disruptive events like inventory shortfalls or congestion and bottlenecks, i.e., potential or actual disruptions (Boute and Udenio, 2021) [12]. The antecedent for such a system is the focal firm's connected, digital supplier ecosystem, since one of the four significant flows of a digital supply chain is information flow (Garay-Rondero et al., 2020) [27]. ...

... Realtime collaborative decision making is contingent upon a) generation, filtering, and aggregation of data across the supply chain in an event-driven process chain (Achir et al., 2022)[1] b) active monitoring and processing of the data near the source to reduce the time lag between data generation and deriving insights, and c) a distributed paradigm for sharing information, alerts, and notifications in real-time among ecosystem partners for collaborative and cognitive decision making in the event of disruptions. A Digital Control Tower (DCT), like its analogous counterpart in an airport, can provide visual alerts that warn of disruptive events like inventory shortfalls or congestion and bottlenecks, i.e., potential or actual disruptions (Boute and Udenio, 2021) [12] . The antecedent for such a system is the focal firm's connected, digital supplier ecosystem, since one of the four significant flows of a digital supply chain is information flow (Garay-Rondero et al., 2020) [27]. ...

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the Internet of Things (IoT) is a global network of smart devices that integrate the physical and digital worlds. While the IoT is reported to be a foundation technology for the emerging Industry 4.0 era, empirical evidence of IoT use in supply chain management is scant. With the fourth industrial revolution, new technologies and business opportunities Arise, enabling previously unknown ... [Show full abstract]

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